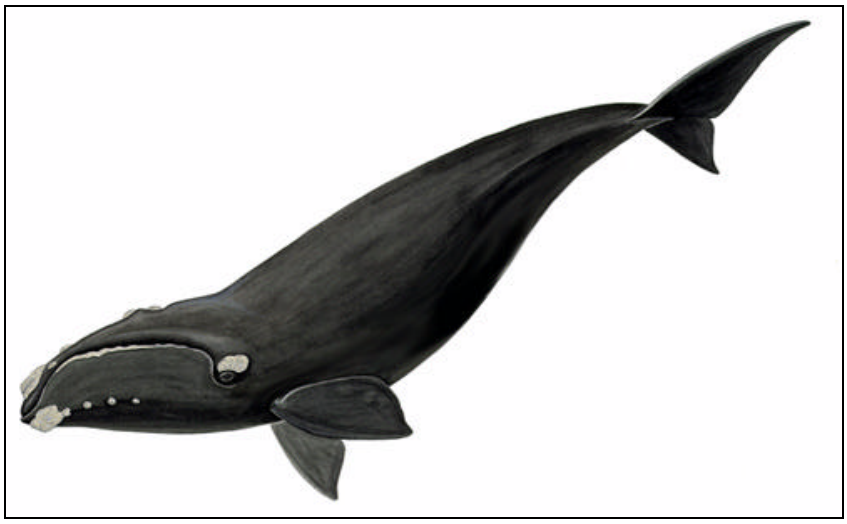

Surveillance, Monitoring and Management of North Atlantic Right Whales in Cape Cod Bay and Adjacent Waters - 2002

Final Report

Center for Coastal Studies
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September 2002

Surveillance of North Atlantic Right Whales in Cape Cod Bay and Adjacent Waters - 2002

Final Report
Chapter One

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September 5, 2002

Acknowledgments

We are most grateful to all of our dedicated colleagues who spent the winter and spring in planes and on boats in Cape Cod Bay to make this work possible. Aerial observers included Jackie Ciano (CCS), Bill Hoffman (DMF), Joanne Jarzobski (CCS), Brian Kelly (DMF), Philip Kibler (CCS) and Peter Borrelli (CCS). Special appreciation is extended to Chandler Lofland, Jack O'Brien and John Ambroult who kept our plane, Skymaster 5382S, flying smoothly all season. We would also like to extend our thanks to Captain James Murray of the USCG, Group Woods Hole, and to Air Station Cape Cod for providing us with a pre- and post-flight call-in service to make sure we landed safely and on hard ground. Special thanks to Marc Costa who kept R/V *Shearwater* shipshape under winter conditions and an extra thank you for additional cruises with the Cornell University team to deploy and recover acoustic monitoring equipment in the Bay.

Oceanographic sampling and photo-identification efforts aboard R/V *Shearwater* were carried out as skillfully as always by Stormy Mayo, Moriah Bessinger and Maria Tucker (CCS intern) under a myriad of weather conditions from snow to brilliant sunshine. They were assisted on the boat by Jackie Ciano (CCS aerial survey team), Bob Cooney (CCS educator), Amy Delorenzo (CCS associate and PhD candidate URI), Phil Kibler (CCS aerial survey team), Ed Lyman (CCS associate), Owen Nichols (CCS aerial survey team), and Jan Young (CCS administrator). Phytoplankton analysis was carried out by Anne Hampton (Castleton State College, Castleton, VT). Many thanks to Peter Borrelli, John Shea, and Jan Young for keeping everything running smoothly on the administrative end of the project. A special thanks to Jennifer Beaudin Ring, and her assistants, Noah and Willem, for proofing sighting data, preparation of the figures for this report and stimulating discussions on Cape Cod Bay right whales. Finally, thank you to the operators of the Cape Cod Canal (US Army Corps of Engineers, New England District) for closing the canal to large vessel traffic on 15 April 2002 for a right whale observed in the canal and for monitoring vessel traffic on 17 May 2002 in response to a right whale that used the canal as a shortcut into Cape Cod Bay.

The vessel and aerial surveys were conducted under a Scientific Permit to Take Marine Mammals No. 633-1483-02 issued by the NMFS to Dr. Charles Mayo. This permit is valid until 31 March 2004. A report of our research activities for 2002 will be submitted to the NMFS permitting office in December 2002. The data collected on this project are archived at CCS, NEAq and URI. This work was supported by a grant from the Massachusetts Division of Marine Fisheries.

Abbreviations used in the text: **ESA** – Endangered Species Act; **DMF** - Massachusetts Division of Marine Fisheries; **CCS** - Center for Coastal Studies; **NEAq** - New England Aquarium; **URI** - University of Rhode Island; **USCG** - United States Coast Guard; **MEP** – Massachusetts Environmental Police, **NM** - nautical mile, **NMFS** - National Marine Fisheries Service; **NEFSC** - Northeast Fisheries Science Center; **NERO** - Northeast Regional Office; **R/V** – research vessel; SAS - Sighting Advisory System, NMFS; **SE** – standard error; **USACE** U.S. Army Corps of Engineers; **WHOI** - Woods Hole Oceanographic Institution.

Cover Illustration: Scott Landry/Whaleco

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Executive Summary

In 2002, from aerial and shipboard efforts in all areas combined, there were 139 sightings of right whales, of which 135 right whales were photographed and analyzed for this report. Of those 135 photographed sightings, 54 were from Cape Cod Bay and state waters along the outer coast of Cape Cod between Chatham and Provincetown (39 from aerial surveys and 15 from vessel cruises), 30 were from aerial surveys of Stellwagen Bank/Wildcat Knoll and 51 were from the Great South Channel.

To date, of the 135 photographed sightings, 48 of 54 (88%) in Cape Cod Bay and adjacent state waters and 21 of 30 (70%) in Stellwagen Bank/Wildcat Knoll have been matched to an individual right whale. The 54 sightings from Cape Cod Bay consisted of at least 24 different right whales. There were 18 right whales identified from aerial and vessel surveys and five additional whales that have yet to be matched, but that do not match any of the 18 animals plus one right whale photographed in the Cape Cod Canal on 15 April that was not seen during surveys. The 30 photographed sightings on Stellwagen Bank/Wildcat Knoll represent 29 different right whales of which 21 have been matched to an individual in the catalogue. Of note is one of the identified whales (# 1145), an adult female, which was seen with a calf. This mother calf pair was not recorded during any other surveys or on the calving ground in the southeast US. Our sighting of the calf brings the annual reproduction total for 2002 to 22 calves. Only one whale was seen on more than one occasion (#1424, an entangled right whale) and there remain eight individuals to be matched. There were 51 photographed sightings obtained in the two Great South Channel aerial surveys. Of those, only four whales, two mother calf pairs also seen on the calving, have been matched. The photographic matching process for the remaining sightings is still underway. None of the matches has undergone final confirmation by researchers the New England Aquarium. This will take place in the autumn of 2002. All sightings were reported upon completion of each survey to the National Marine Fisheries Service Sighting Advisory System. These aerial and vessel surveys are the principal source of right whale sightings for the NMFA/SAS in the winter months for waters in the northeast north of latitude 41°N.

Right whales were documented during aerial surveys of the Cape Cod Bay Critical Habitat area, in state waters west of the critical habitat and along the outer coast of Cape Cod between Chatham and Race Point for 37 days from 7 February to 15 March 2002. These visual sightings were augmented with passive acoustic monitoring in Cape Cod Bay. The bottom-mounted hydrophones recorded low levels of right whale calls from 24 December 2001 through April and early May. The results of the combined research efforts document right whale presence in Cape Cod Bay from late December through April into early May consistent with the results of the past four years. These data support the timing of existing management actions regarding gear restrictions.

The presence of right whales in nearby areas outside of the critical habitats of either Cape Cod Bay or the Great South Channel in 2002 and in past years suggests that a re-evaluation of the area protected by ESA Critical Habitat designation is needed and timely to adequately reflect the distribution and movements of right whales. The use of these areas such as the eastern portion of Stellwagen Bank and Wildcat Knoll has only come to light with the expanded survey efforts of the last five years. Since these areas are used for fishing activity and are transected by a major shipping lane between Boston and New York, consideration should be given to changing the boundaries of the neighboring Cape Cod Bay and Great South Channel Critical Habitats to include these areas of seasonal importance to right whales. We recommend that the data collected in the Stellwagen Bank/Wildcat Knoll area over the last five years be assessed using sightings-per-unit-of-effort analysis to determine the density and seasonality of right whale use and that the area be considered as a target for habitat sampling to assess the conditions of the food resource and for passive acoustic monitoring equipment to augment visual sightings.

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Introduction

The Cape Cod Bay ecosystem is one of five known seasonal high-use habitat areas for right whales (*Eubalaena glacialis*) in the western North Atlantic. A Critical Habitat for the North Atlantic right whale in Cape Cod Bay was federally designated in 1994 (Federal Register 59 FR 28793). This was in recognition of the seasonal importance of Cape Cod Bay as a critical area for feeding, socializing, and as a nursery area for cows and calves (Watkins and Schevill 1982, Schevill *et* al. 1986, Hamilton and Mayo 1990, Kraus and Kenney 1991), including a number of cows that are rarely seen in the other three northern habitat areas (Knowlton *et al*. 1992, Brown 1994). Cape Cod Bay has a long history as an important habitat area for right whales. Photographic identifications date from 1959 (Hamilton *et al*, 1997) to the present, and whaling records provide evidence of right whales in this area in the late fall, winter and spring from at least the early 1600s (Allen 1916).

Since the 1980s, right whales are known to occur in Cape Cod Bay, Massachusetts, and adjacent waters* in all months of the year, with the peak of occurrence from February through April (Schevill *et al.* 1986, Winn *et al.* 1986, Hamilton and Mayo 1990, Payne *et al.* 1990, Brown 1994). The number of right whales documented and the survey effort has shown annual variation. For the period of 1978 through 1986, using photographed sightings of right whales collected from whale watch boats and research cruises, the total number of individually identified right whales in Cape Cod Bay ranged from a single animal in 1978 to 47 individuals in 1986 (Hamilton and Mayo 1990). Expanded surveillance and monitoring efforts in the winter and spring over the last five years have demonstrated that Cape Cod Bay is an important feeding and socializing area from December to May for at least 85 to 95 individuals annually, almost a third of the known cataloged population (Brown and Marx 1998, 1999, 2000, Brown, Marx and Nichols 2001).

Range-wide concerns

Despite international protection from commercial hunting since 1935, the North Atlantic right whale, *Eubalaena glacialis,* is the most endangered large whale in the world. No more than 350 remain (CeTAP 1982, Brownell *et al*. 1986, Kraus *et al*. 1988, NMFS 1991, Knowlton *et al*. 1994, IWC 2001). In the United States, the northern right whale is listed as "endangered" under the Endangered Species Act (ESA) of 1972. Scientists and conservationists have long been concerned about the status of the North Atlantic right whale population and its slow rate of growth (about 2.5% per year in the 1980s, Knowlton *et al*. 1994). The reproductive output of this population has not changed in the last two decades, on average researchers have documented 12 calves per year (Knowlton *et al*. 1994 and NEAq unpublished data). Recent analyses showing a decrease in the reproductive rate (fewer calves per mature female), an increase in the calving interval (Kraus *et al*. 2001, Kraus 2002), and a decline in the survival rate (Caswell *et al*. 1999) suggest we should view the present situation with greater concern (Reeves *et al.* 2001).

The apparent failure of this population to recover has also been attributed to anthropogenic factors including mortality from collisions with ships and entanglements in fixed fishing gear (Kraus 1990, Kenney and Kraus 1993, Knowlton and Kraus 2001). There have been 50 right whale deaths documented between 1970 and 2001 (Knowlton and Kraus 2001, NEAq unpublished data). Of those 50, 18 (36%) right whale fatalities were due to ship strikes, and five (10%) were the result of entanglement in fixed fishing gear, 13 were of natural causes (26%) and 14 (28%) of unknown cause (Knowlton and Kraus 2001, NEAq unpublished data). Ship collisions kill more right whales than any other documented causes of mortality and one half of the ship collision mortalities have been recorded in the 1990s, but entanglements can result in long-term deterioration and may be

* Adjacent waters includes the federal waters of the Cape Cod Bay Critical Habitat and those waters over- and adjacent to-Stellwagen Bank in Massachusetts Bay (e.g. Stellwagen Basin), as well as waters east of Cape Cod.

responsible for more deaths than previously thought (Kraus and Knowlton 2001), and are now thought to be equally responsible for right whale deaths as ship collisions (Kraus 2002). In addition many animals disappear from the population (n=84 through 2000), not all deaths are seen on the beach (Knowlton and Kraus 2001). Caswell *et al*. (1999) estimate that if human related mortality is not reduced this population could become extinct in less than 200 years and upon further analysis suggested that the preventing the death of only two female right whales per year would increase the population to replacement level (Fujiwara and Caswell 2001).

Right whales in Cape Cod Bay and adjacent waters

While the use of the Cape Cod Bay ecosystem by right whales has occurred for hundreds of years, human activities have only impacted the area relatively recently. Right whales are slow moving (particularly when accompanied by a calf) and very difficult to see for vessel-based observers when the whales are feeding at or just below the surface. They do not always appear to avoid approaching vessels, especially when socializing or feeding near the surface. There is a moderate level of commercial shipping in the area; Cape Cod Canal is one of three entrances into the Port of Boston. There are about 550 transits annually by inbound and outbound vessels through the canal and along the western portion of the Bay (Kite-Powell and Hoagland 2002). The habits of the whales and the moderate level of ship traffic in the region make the right whale vulnerable to collisions with vessels in Massachusetts waters. Knowlton and Kraus (2001) documented two right whales that have likely been killed by collisions with ships near this area, one in 1986 (found off Provincetown), the second in 1996 (found near Wellfleet). A third right whale was found dead in Cape Cod Bay in April 1999. A necropsy was performed and the cause of death was blunt trauma, likely the result of a collision with a ship (Brown and Marx 1999). In all three cases, the location of the collision between vessel and whale is not known.

Right whales are at risk of entanglement in fixed fishing gear in the area however there have been attempts to reduce that risk with management actions taken by the Commonwealth of Massachusetts. Some fishing activity is either prohibited (gill nets) or use of modified gear is required in the Cape Cod Bay Critical Habitat area. These modifications include sinking ground line between lobster pots, at least two pots per vertical line, and a 500lb break away link at the buoy (322 CMR 12.05 Critical Habitat gear restrictions during January 1 to May 15). The modified gear is marked with twin orange flags on the buoy stick. Most of the fixed fishing gear in the Cape Cod Critical Habitat area is located in the northern margins along tracklines one, two and three (Figure 1a) in depths greater than 30 fathoms. There is fixed fishing gear set to the west of the western margin of the Critical Habitat in State waters that is not subject to the above gear restrictions because it is outside the critical habitat area, but that gear is scheduled to be modified as described above starting in January 2003. A few right whales have been reported west of the critical habitat area in the past (see Figures 8 and 9).

Over the last twenty years, 72% of the cataloged population of right whales has been photo-documented in Cape Cod and Massachusetts Bays at some time during their lives (CCS and NEAq, unpublished data). These photographic data have been collected during by various means. Recent survey efforts include twice-weekly aerial surveillance flights and weekly vessel-based habitat studies annually from January to mid-May from 1998 to 2001 (Brown and Marx 1998, 1999, 2000, Brown, Marx and Nichols 2001 and this report). Prior to 1998, there were weekly vessel surveys and limited aerial surveys in the winter and spring in 1997 (Hamilton *et al*. 1997, Mayo 1997) and annual studies on foraging of right whales in the winter and spring since 1984 (Mayo and Marx, 1990). Researchers gathered opportunistic sightings from whale watching vessels from April through October from the late 1970s until 1996. The latter platform, which yielded many valuable sightings of right whales (including some rarely seen mothers with calves) in the late spring, summer and fall

(NEAq unpublished data), and reports of entanglements, is no longer available due to a 500-yard exclusion zone around right whales for non-permitted vessels.

In order to gain a better understanding of both the spatial and temporal distribution of individually identified right whales in Cape Cod Bay, an extensive surveillance and monitoring research program was undertaken in the winter and spring of 1998 (Brown and Marx 1998), 1999 (Brown and Marx 1999), 2000 (Brown and Marx 2000), 2001 (Brown, Marx and Nichols) and 2002 (this report). The research directly addresses concerns identified by the Right Whale Conservation Plan submitted by the Commonwealth of Massachusetts to federal courts in 1996, the Northeast Implementation Team; and supported goals in the federal Atlantic Large Whale Take Reduction Plan, the Right Whale Recovery Plan (NMFS 1991), and the ESA. Here we report on the results of the research activities as described below. The objectives of the 2002 surveillance, monitoring and management of northern right whales and the habitat of Cape Cod Bay program were:

I) To document the right whales in the Cape Cod Bay Right Whale Critical Habitat area and adjacent waters from January through mid-May, 2002, using photo-identification techniques to identify individual whales. These data provide information on the age, sex, reproduction, distribution, abundance and patterns of habitat use (residency) of right whales in Cape Cod Bay and help refine long-term, range-wide analyses on presumed mortality, incidence of scarring and demographics. Photographic and sighting data were integrated into the right whale photo-identification catalogue at the New England Aquarium and the sighting database at the University of Rhode Island.

II) To provide sighting data to the National Marine Fisheries Sighting Advisory System. Sighting locations of right whales were reported promptly to NMFS/SAS at the completion of each survey. The goal was to ultimately reduce the probability that right whales will be killed by collisions with large vessels by providing near "real-time" sighting data within Massachusetts waters to port authorities, commercial and military vessels, and other maritime operations. The DMF/CCS program is the principle source of right whale sighting data from January through March.

III) To monitor right whales in the study area for evidence of entanglement. Each right whale encountered was examined visually for any evidence of attached gear. The rescue team was on standby ready for immediate dispatch in the event an entangled whale was reported.

IV) To describe the distribution and abundance of any other marine mammals and shipping activity in Cape Cod Bay and adjacent waters from January through mid-May, 2002.

V) To collect oceanographic information on weekly vessel cruises, from January to mid-May, 2002, designed to develop an understanding of the characteristics of the habitat to which right whales respond. These oceanographic data, combined with data from past habitat studies in Cape Cod Bay by the Center for Coastal Studies, provide additional information on the conditions, which are believed to cue the movements and activities of right whales in Cape Cod Bay and adjacent waters. The results of this work are reported on in the second chapter of this report (Mayo, Bessinger and Brown 2002).

Methods

I) Aerial Surveys

Aerial surveys were conducted from January through mid-May 2002 in the Cape Cod Bay Critical Habitat and adjacent waters (Figures 1a-e, Tables 1a-e). The aerial survey protocol for Cape Cod Bay, as described in Kraus *et al* (1997), was adopted with some modifications. Fifteen tracklines were flown latitudinally (east - west) at 1.5 nautical mile (nm) intervals from the mainland to the Cape Cod Bay shoreline (Figure 1a). An additional trackline, 25 nm in length, paralleled the outer coast of Cape Cod from east of Chatham to the eastern end of trackline one at a distance of about three nm from shore (Figure 1a, trackline number 16). The east-west flight pattern in Cape Cod Bay was chosen for scientific and safety reasons. In these latitudes, winter aerial surveys are hampered by low sun angles in the early and late hours of a survey day and glare is a significant factor in sightability of marine mammals. On east-west tracklines, although glare was a factor in one of the forward quadrants, there was always a section of the survey swath that could be observed without being compromised by glare. It was also safer to have the aerial survey tracklines begin and end near land. A total of 320 nm of 'on-trackline' miles were flown during each completed survey (Table 1a). "On-trackline" miles were those miles flown while surveying due east or due west in Cape Cod Bay and along the outer coast of Cape Cod, but excludes all miles flown between tracklines (cross legs) or while circling.

The surveys were flown under VFR (visual flight rules) conditions up to and including Beaufort sea state four. Surveys were aborted in Beaufort sea state five and/or when visibility decreased below two miles in fog, rain or snow. All aerial surveys originated at Chatham Airport, Chatham, MA. They were conducted in a Cessna 337 Skymaster (5382S), a twin engine, high-wing aircraft with retractable landing gear. The aircraft was equipped with two GPS (global positioning system) navigation systems, full IFR (instrument flight rules) instrumentation, marine VHF radio with external antenna, and wing-tip mounted VHF tracking antennas. Safety equipment included a life raft, four survival suits, signal flares, a medical kit, a waterproof VHF radio, a portable EPIRB, and an aircraft mounted ELT (emergency locator transmitter). All occupants wore aircraft approved PFDs (personal floatation device) during the entire flight.

Surveys were conducted at a standard altitude of 750 feet (229 meters) and a ground speed of approximately 100 knots, using methodology developed by CeTAP (Scott and Gilbert 1982, CeTAP 1982). The survey team consisted of a pilot, data recorder, and two observers positioned on each side of the aircraft in the rear seats. The two rear seat observers scanned the water surface from 0° - 90°, out to at least two nautical miles and reported sightings when they were abeam of the aircraft. In order to maintain a standardized sighting effort, the pilot and data recorder were instructed not to alert the observers to any sightings of marine mammals until after it had been passed by the aircraft and clearly missed by the observers. The turn at the end of each trackline was initiated and completed about 1.5 nm from shore in Cape Cod Bay to maximize the opportunity to observe any whales near shore.

All sightings of marine animals except birds were recorded. Sightings identified as species other than right whales were counted, logged and passed without breaking the trackline and circling in order to maximize flight time available for investigating right whale sightings. Sightings of all vessels in the area were recorded by location and type. At sightings identified as right whales, as well as sightings of large whales, which were not immediately identified by species, the aircraft broke track at right angles to the sighting and circled over the animal to obtain photographs. Photographs were obtained of as many individual right whales within a given aggregation as possible. For each right whale, behavior and interaction with other whales or any nearby vessels or fishing gear was noted. In a few instances, when right whales were spotted from the plane in close

vicinity to R/V *Shearwater*, the vessel was contacted from the plane and photographs were taken from the vessel so that the plane could devote more time to surveying. The right angle distance of each sighting from the flight track was determined from GPS positions.

At the conclusion of photographic effort at each sighting, the aircraft returned to the trackline at the point of departure using the GPS position recorded in the log. These methods conform to research protocols followed by the North Atlantic Right Whale Consortium (CCS, NEAq, URI, and WHOI) and approved by the US NMFS. Trackline and sighting data from the daily logs were entered into the Right Whale Initiative DBase program designed for compatibility with the Right Whale Consortium database. Copies of the daily logs from the aerial surveys are on file at CCS and URI.

II) Vessel Surveys

CCS maintains a 40' (12m) long, twin diesel engine research vessel *Shearwater*. The R/V *Shearwater* has been used successfully for oceanographic sampling and photo-identification in the winter and spring surveillance program in Cape Cod Bay from 1997 through 2002. The R/V *Shearwater* is equipped with oceanographic sampling equipment including a CTD profiler (conductivity, temperature, depth), plankton nets, surface plankton pump, and flow meter as well as photographic equipment and disentanglement gear.

Although the primary objective of these vessel cruises was habitat sampling, some photographs were collected opportunistically of right whales in the vicinity of the boat during sampling and on transits to and from sampling sites. Photographs of right whales obtained during habitat studies were integrated with the photographs collected during aerial surveillance and included in this report in analyses of residency, capture rates, demographics, and life history. The vessel sighting data were included in the report to the NMFS/SAS system. Sighting data from the daily vessel logs were entered into the Right Whale Initiative DBase program as opportunistic surveys.

CCS is the only institution on the U.S. east coast with federal authorization from NMFS to perform disentanglements of large whales, and in 1996 the Center developed a Rapid Response Rescue Program with the US Coast Guard to enable disentanglement of whales at sea. In the event an entangled whale was seen during aerial surveys, CCS was contacted from the aircraft and the vessel dispatched immediately to assess the situation and proceed with disentanglement protocols.

III) Notification of Agencies

Prior to and following an aerial survey, both Group Woods Hole (US Coast Guard) and Air Station Cape Cod at Otis Air National Guard Base were notified of our planned survey, departure time, estimated return and a verbal summary of what was seen. In addition in 2002, Group Woods Hole notified the Pilgrim Nuclear Power Plant of our flights. Following the completion of each aerial survey, the number of right whales seen and the location of these sightings were verbally reported to the NMFS Sighting Advisory System coordinator. The NMFS/SAS office disseminates this information by fax, Navtex, and marine weather radio to the appropriate agencies and mariners. Prior to reporting to the NMFS/SAS, any other whale research vessels operating in Cape Cod Bay and adjacent waters were contacted, additional sightings were added to the report if from an area not already included in the CCS report. A daily summary of the location and number of right whale sightings was faxed to DMF.

IV) Photographic Methods

i) Identification Photographs

During aerial and shipboard surveys, photographs were taken on Kodak Kodachrome 200ASA color slide film, using hand-held 35-mm cameras equipped with 300-mm telephoto lenses and motor drives. From the air, photographers attempted to obtain good perpendicular photographs of the entire rostral callosity pattern and back of every right whale encountered as well as any other scars or markings. From the boat, photographers attempted to collect good oblique photographs of both sides of the head and chin, the body and the flukes. The data recorder on both platforms was responsible for keeping a written record of the roll and frame numbers shot by each photographer in the daily log.

ii) Photo-analysis and Matching

Photographs of right whale callosity patterns are used as a basis for identification and cataloging of individuals, following methods developed by Payne *et al* (1983) and Kraus *et al* (1986). The cataloging of individually identified animals is based on using high quality photographs of distinctive callosity patterns (raised patches of roughened skin on the top and sides of the head), ventral pigmentation, lip ridges, and scars (Kraus *et al* 1986). NEAq has curated the catalogue since 1980 and to the best of their knowledge, all photographs of right whales taken in the North Atlantic since 1935 have been included in NEAq's files. This catalogue allows scientists to enumerate the population, and, from resightings of known individuals, to monitor the animals' reproductive status, births, deaths, scarring, distribution and migrations. Since 1980, a total of 26,275 sightings of 436 individual right whales have been archived, of which 327 are thought to be alive, as of December 2001 (A. Knowlton, NEAq, pers. comm.)

The matching process consists of separating photographs of right whales into individuals and inter-matching between days within the season. To match different sightings of the same whale, composite drawings and photographs of the callosity patterns of individual right whales are compared to a limited subset of the catalogue that includes animals with a similar appearance. For whales that look alike in the first sort, the original photographs of all probable matches are examined for callosity similarities and supplementary features, including scars, pigmentation, lip crenulations, and morphometric ratios. A match between different sightings is considered positive when the callosity pattern and at least one other feature can be independently matched by at least two experienced researchers (Kraus *et al* 1986). Exceptions to this multiple identifying feature requirement include whales that have unusual callosity patterns, large scars or birthmarks, or deformities so unique that matches from clear photographs can be based on only one feature. Preliminary photo-analysis and inter-matching was carried out at CCS, with matches confirmed using original photographs cataloged and archived at NEAq.

iii) Photographic Data Archiving

Upon completion of the matching process, all original slides were returned to CCS and incorporated into the CCS catalogue of identified right whales to update existing files, using the same numbering system as NEAq, in archival quality slide sheets. NEAq archives copies of photographs representing each sighting. Copies of photographs of individuals that are better than existing records, and photographs of newly identified whales, will be included in the NEAq master files as "type specimens" for future reference. The master files are maintained in fireproof safes at NEAq. All catalogue files are available for inspection and on-site use by contributors and collaborators.

V) Data Management, Analysis, and Interpretation

i) Data Management – Aerial surveys

Aerial survey data and sighting data from vessel trips were transcribed from standardized field forms and recorded in computerized DBase files for each of the daily surveys in on-site computers. Copies of the daily logs and computerized data files have been sent to URI for entry into the Right Whale Consortium sighting database. Data were proofed three times, first from printouts generated after data-entry, during processing at URI, and finally when preparing charts of sighting data with GIS.

ii) Data Analysis and Interpretation – aerial surveys and opportunistic sightings

All sightings are incorporated into the right whale catalogue and Consortium database to be integrated with existing data on life histories for each individual identified by CCS. Integration of the sighting data collected during these surveys with previously collected data are used to describe the number, age, sex, and reproductive status of the right whales using the Cape Cod Bay habitat area in 2002. Sighting data from the aircraft are charted to establish patterns of distribution and assess the seasonal and spatial residency patterns of right whales in the critical habitat and adjacent waters. The data on vessel locations are charted and compared with the locations of right whales to assess the level of overlap between right whales and vessels in the area. The exact location of fishing activity was not recorded during the aerial surveys; rather observers record the trackline number and the beginning and end of the fixed gear on that trackline. Following discussions between the researchers and state biologist Dan McKiernan, it was determined that counting and recording of fishing activity on every flight would take away observer effort from obtaining marine mammal sightings and identification photographs of right whales. Since fishing effort is already documented by other agencies, the protocol was changed; the general location of fixed fishing gear along the trackline was recorded on the first flight of the month.

We used the individual identifications of right whales obtained during this study, to examine capture rate, residency and number of days between first and last sighting in Cape Cod Bay. An analysis of the age and sex composition of the winter and spring population was carried out using data from all CCS surveys to assess demographics and habitat use patterns. Right whales, first identified as calves, ranging in age from one to eight years of age were classified as juveniles, individuals age nine or older were classified as adults (based on classifications by Hamilton *et al*. 1996). Whales that were not first sighted as calves were classified as unknown age for the first eight years of their sighting history and as adults thereafter. All females who have calved are classified as adult. Sexes were assigned based on one of three methods: 1) direct observation of the genital area; 2) by association with a calf; 3) by testing biopsy samples with a sex specific DNA marker (Brown *et al* 1994).

Results and Discussion

Aerial Surveys

In 2002, the right whale aerial surveillance team was in position to survey for 135 days from 1 January through 15 May. There were a total of 23 aerial surveys conducted for the season in the Cape Cod Bay Critical Habitat Area (Figures 1-4, Table 2) plus six aerial surveys conducted in adjacent waters including Stellwagen Basin, Stellwagen Bank, Wildcat Knoll and the Great South Channel (Figures 1, 3-4, Table 2) and one flight to support a disentanglement effort for a total of 30 flights.

Our first flight over Cape Cod Bay was conducted on 6 January, no right whales were observed (Figure 2a, Table 2). Five flights later, the first right whale was documented from the aircraft on 7 February (Figure 2a-2c, Table 2). The last day on which we saw right whales in Cape Cod Bay was 15 March, for a minimum residency time from aerial survey efforts of 37 days (7

February to 15 March). This year marked the shortest residency time of right whales in Cape Cod Bay since aerial surveys began in 1998.

Despite the lack of right whales sightings after 15 March, we maintained our survey effort in Cape Cod Bay and nearby waters. On 25 March, one right whale was seen along the outer coast east of Truro. On 2, 11, 17 and 24 April, additional tracklines were flown north of Race Point and east of Truro, resulting in a few more sightings. There were however, more right whales in nearby waters. Two flights on 29 March and 5 April located a total of 25 right whales over the Stellwagen Bank/Wildcat Knoll area (Figures 1c, 1d, 3c, 3d, Tables 1c, 1d, 2 adjacent waters).

On one day (7 March) during the season, additional tracklines were flown the same day as a survey of Cape Cod Bay to cover areas adjacent to the main survey area on Stellwagen Bank (Figures 1b, 3a, Tables 1a, 2 adjacent waters). This was directed to an area from where a dozen right whales had been reported in February from Dave Wiley, Studds-Stellwagen Bank National Marine Sanctuary, but no right whales were seen. On 12 April we flew tracklines south of Nantucket Island to Block Island in response to a report of right whales south of the runway on Nantucket, but no right whales were seen.

Two surveys were conducted in the Great South Channel (Figures 2e, 4, Tables 1e, 2 adjacent waters,). Both flights observed right whales in greater numbers than had been seen in Cape Cod Bay all winter (Table 2 adjacent waters). This last flight on 12 May brought the flight total for the season to a total of 29 days and 105.5 hours in the air to cover about 8725 nautical miles of on-trackline survey effort (Table 2).

The systematic pre-set tracklines in the Cape Cod Bay Critical Habitat area (Figure 1, Table 1a) were surveyed on average in approximately 3.6 hours for those surveys that were not aborted due to an increase in wind speed, sea state (above Beaufort 4) or decrease in sighting conditions (to visibility less than two nm). Completed surveys ranged in duration from about three to five hours depending on the number of right whales encountered and the amount of circling required to obtain photographs.

The DMF provided two state biologists to fill one of the observer positions on some of the flights during the season. These biologists have flown in previous years of this program and have been trained in aerial observation techniques for marine mammals, aerial photography techniques for right whales and data collection. Annual participation maintains those skills. In addition CCS naturalist Joanne Jarzobski started training as an aerial observer. The following table provides the number of flights and accumulated hours during the season in 2002.

State biologist	Number of flights	Hours flown
B. Hoffman	2	10.3
B. Kelly	1	3.5
CCS		
J. Jarzobski	2	6.3
Total	5	19.8

Vessel Surveys

In 2002, the right whale habitat sampling team was in position in Cape Cod Bay for 135 days from 1 January through 15 May. There were a total of 17 vessel days during which oceanographic data were collected in Cape Cod Bay (14) and adjacent waters (3) in 2002 (Table 3). The primary

purpose of these habitat sampling cruises was to collect oceanographic data in the Cape Cod Bay Critical Habitat area weekly to compare concentrations of right whales from aerial surveys with the food resource determined from samples obtain at sea. Please see chapter two of this report for the results and discussion (Mayo, Bessinger and Brown 2002).

The vessel crew located the right whales for the first time during a cruise on 14 February (Table 3). Although they searched for the whale observed from the plane on 7 February, they were unable to locate the animal. The last day right whales were observed from the vessel was on 7 March (Table 3). The photos collected on the vessel have been compared to the ones obtained from the aircraft and were taken through the same matching process as detailed above. The crew on board the vessel did locate right whales north of the critical habitat on 20 April.

In addition there were several cruises in collaboration with Cornell University to deploy bottom mounted autonomous acoustic sensors (acoustic pop-ups) in six locations in Cape Cod Bay (see Appendix IV) and two days spent working with the team from National Geographic to attach a 'Crittercam' to a right whale using suction cups. CRITTERCAM, developed by Greg Marshall, Director/Executive Producer, Remote Imaging, National Geographic, is a small, streamlined, integrated imaging and data-logging system that obtains video footage of the underwater environment of the whale. The goal of this project was to use crittercam to learn about the underwater foraging techniques of right whales, a behavior which is not well known of other than at the surface. It is known from other tagging studies that they generally feed at the depth with the greatest concentration of plankton and that there is a burst and glide fluke stroke pattern when the whales are swimming horizontally through the water (D. Nowacheck, WHOI, unpublished data). A second goal was to learn about what the open mouth of a right whale looks like underwater. This information has potential to inform out work on entanglements of right whales in fishing lines and what modifications might reduce the risk of entanglement. The attempts to attach a crittercam in 2002 were not successful, but a lot was learned about deploying the crittercam that will assist in further attempts next year.

Opportunistic Sightings in the Cape Cod Canal

There were two opportunistic sightings of right whales observed in the Cape Cod Canal this year. These both occurred after right whales were no longer being observed in Cape Cod Bay. The first sighting on 15 April was reported near the middle of the Canal by a cyclist (Mazzolo 2002, Appendix III). The cyclist contacted the USACE Cape Cod Canal Field Office, which dispatched the patrol vessel *Cataumet* to investigate. A member of the vessel's crew identified the animal as a right whale, and the USACE marine traffic controllers closed the Canal to further traffic. The *Cataumet* then proceeded to escort a tug and barge that was already transiting the Canal safely around the whale (Mazzola, 2002). Later in the afternoon, a MEP patrol vessel relieved the *Cataumet*. A DMF biologist aboard the MEP vessel was able to obtain numerous photographs of the animal (D. McKiernan pers. comm.). The whale remained in the Canal for approximately five hours before exiting the eastern entrance into Cape Cod Bay. During that period several large vessels, including a coastal tanker, were held at either end of the Canal. Although most of the vessels were stalled in fog on the western side of the Canal, the recently installed radar tracking system allowed controllers to safely reroute traffic during and following the closure (Mazzola 2002). While the CCS aerial survey team was not operating on this day due to adverse weather conditions, the sighting was well documented by DMF. The photos were of sufficient quality to match to the catalog, and the whale was identified as #3103, the 2001 calf of # 1703 that had been observed in Cape Cod Bay the previous season (Appendix I). CCS did not sight this whale at any other time during the 2002 season. Aerial surveys subsequent to the event on 11, 17 and 24 April did not record any sightings of right whales in the Bay.

The second event occurred on the morning of 17 May, when USACE traffic controllers sighted a whale as it passed the field office at the western end of the Canal. The only traffic recorded at the time was a single large motor yacht, which was directed to maneuver south around the whale. A patrol vessel was dispatched, and the whale was identified as a right whale. No further traffic was rerouted, as the whale transited the Canal rapidly, exiting the eastern end into Cape Cod Bay shortly after it was sighted (B. Mulvey, USACE, pers. comm.). A biologist from the International Wildlife Coalition (R. Asmutis-Silvia, pers comm.) took photographs of the sighting, but a match to an individual in the right whale catalogue was not possible due to poor image quality (A. Knowlton, NEAq pers. comm.).

Sightings and Photo-analysis

In 2002, from all aerial and shipboard efforts in all areas combined, there were a total of 139 right whale sightings, of which 135 were photographed and analyzed for this report (Tables 2 and 3). Of those 135 photographed sightings, 54 were from Cape Cod Bay and along the outer coast of Cape Cod between Chatham and Provincetown (39 from aerial surveys and 15 from vessel cruises), 30 were from aerial surveys of Stellwagen Bank/Wildcat Knoll and 51 were from the Great South Channel.

To date, of those 135 photographed sightings, 48 of 54 (88%) in Cape Cod Bay and adjacent waters and 21 of 30 (70%) in Stellwagen Bank/Wildcat Knoll have been matched to an individual right whale (Tables 2, 3). The 54 Cape Cod Bay sightings were of at least 23 different right whales. There were 18 right whales identified from aerial and vessel surveys. There were five additional whales that have yet to be matched, but that do not match any of the 18 animals. There was one additional right whale photographed in the Cape Cod Canal on 15 April by DMF that was not seen by anyone else. Thus, the minimum for Cape Cod Bay and the outer coast of Cape Cod between Chatham and Provincetown in 2002 as of the date of this report is 24 right whales (Appendix II).

Of the 30 photographed sightings on Stellwagen Bank/Wildcat Knoll, there were 29 individuals identified of which 21 have been matched to an individual in the catalogue; only one whale was seen on more than one occasion (#1424, an entangled right whale, see below and Appendix II). Of the 30 photographed sightings, there remain eight individuals to be matched. The minimum count for this area is 29 individuals including two mother/calf pairs, one pair #1145, was only sighted by DMF surveys.

There were 51 photographed sightings obtained in the two Great South Channel aerial surveys. Of those, only four whales, two mother calf pairs, have been matched (8% of the whales photographed). The photographic matching process for all sightings is still underway. None of the matches has undergone final confirmation at the New England Aquarium; this will take place in the autumn of 2002.

Right Whale Identifications

The photographic matching process is still underway. As of the date of this report, a total of 49 right whales have been identified from all surveys efforts in 2002 (Appendix I and II). There were 18 right whales individually identified in Cape Cod Bay, 21 on Stellwagen Bank/Wildcat Knoll and four in the Great South Channel. Only one right whale was seen in more than one area (#1706, in Cape Cod Bay and Stellwagen). There are, however, still a total of 61 photographed rights whale sightings to be matched to the catalogue, so more inter-area matches may be found.

Of the 18 right whales identified in Cape Cod Bay, the only new whales to the Bay were two yearlings (#s 3139 and 1509y) still with their mothers. These whales had not been seen as calves in the Bay, but their mothers (#s 1039 and 1509 respectively) are regular Cape Cod Bay winter/spring residents. The other three yearlings observed (two with their mothers #s 3102 and 3160) had been seen in 2001 as calves as had the canal whale, #3103, which is now apparently weaned (Appendix I).

There were three right whales who returned to Cape Cod Bay after a one to three year gap in their sighting record for this area (Appendix I): #s 1039 (last seen 1998); 1301 (last seen 2000); and 1509 (last seen 2000), all are adult females. A number of the whales seen in 2002 are regular visitors. There were nine right whales that have been seen from two to three years in a row (Appendix I): #s 1267 (last two years); 1602 (last three years); 1706 (last two years); 2048 (last two years); 2645 (last three years); 2750 (last three years); 3102 (last two years); 3103 (last two years) and 3160 (last two years). Five right whales have been observed every year since 1998 (Appendix I): 1027, 1608, 2145, 2223, and 2425, all are adult females.

There were eight first time residents identified in 2000: 1624, 1630, *1817*, 1971, *2540*, 2608, *2617*, and *2709*. The four italicized whales were seen again in 2001, but none of these whales were seen in 2002. Of the nine first time residents identified in 1999: #s 1716, *1812*, 1981, 2710, 2740, *2750*, *2760*, 2910, *2920*, the four underlined whales were seen again in 2001, the four italicized ones in 2000, only one (2750) was seen in 2002. There were nine first time residents of Cape Cod Bay identified in 1998 (1162, 1270, *1701*, ***1968***, ***2223***, 2240, ***2271***, **2503**, and ***2705***). The five italicized whales were seen again in 1999, the underlined whales were also seen in 2000 and the bold ones in 2001, only two were seen in 2002 (#s 2223 and 2705).

Sightings outside the Cape Cod Bay Critical Habitat

In 2002, there were more individual right whales photographed outside the Cape Cod Bay Critical Habitat on Stellwagen Bank/Wildcat Knoll (n=29) than there was within the boundaries (n=24) between January and mid-May (Figures 3, 7). The Stellwagen Bank/Wildcat Knoll aggregation coincided with the departure of right whales from Cape Cod Bay, but only one whale was seen in both areas, so it did not appear that right whales were leaving Cape Cod Bay for this area. Of this 29 different whales photographed on Stellwagen Bank/Wildcat Knoll, 21 were identified so far and all but three (#s 1145 and her calf, 1960) have been seen in Cape Cod Bay in previous years in the winter and spring.

There were two whales, mother # 2145 with her yearling # 3160, seen just west of the critical habitat in state waters on 1 March (Figure 3a). This same pair was seen the next day on the eastern side of the Bay in the critical habitat.

Each year there are some right whales seen in state waters along the outer coast of the Cape between Chatham and Race Point; usually these whales are also seen in Cape Cod Bay. This year, of the four whales observed along the outer coast (#s 1012, 1306, 1911, 2223), none were observed in the Bay, although all were seen there in previous years.

Seasonality of Right Whales in Cape Cod Bay (by visual and acoustic methods)

The season of occurrence of right whales in Cape Cod Bay in the winter and spring is generally considered to extend from early January through mid-May. In 1998, when right whales were recorded on 4 January, this was the earliest documented sighting of right whales in the wintertime to that date, but there had not been any survey effort prior to January. When two pre-season surveys were flown on 13 December 1999 and 19 December 2000, right whales were

encountered in Cape Cod Bay. On the latter end of the season, sightings of right whales are generally few in number after mid April with sporadic sightings into the turn of May.

In 2002, right whales were first observed in Cape Cod Bay from aerial survey effort on 7 February and were last seen from the plane on 15 March, a residency of only 37 days. The greatest number of right whales was observed during the second two weeks of February and first two weeks of March. There were additional sightings of right whales in the Cape Cod Canal that exited on the eastern side into Cape Cod Bay on 15 April and 17 May. Of note was the absence of surface feeding behavior, most right whales observed were either traveling or socializing.

The acoustic data from autonomous bottom-mounted recorders, referred to as "pop-ups", provided a different picture of seasonality (Appendix IV). These instruments recorded low levels of right whale vocalizations from late December and early January. Call rates increased in early February coinciding with the first observation of right whales from the plane and similarly decreased in late March coincident with the last sightings from the airplane. But sporadic calls were detected at low levels throughout April and May. Despite the observation of socializing right whales from the aircraft, only contact calls, rather than types of calls typically associated with surface social interactions (such as surface slaps from aerial behaviors, or "gunshot" sounds) were recorded on the hydrophones. The acoustic data from the latter part of the season are not yet fully analyzed, but despite the late first sighting and early last sightings from the aircraft, the combined sighting and acoustic data still indicate that, as in past years, the seasonal residency of right whales was from December to May.

In 2000 and 2001, we witnessed a dramatic departure of right whales from Cape Cod Bay. For example in 2000, there were 36 whales seen on 7 April and three on 11 April. In 2001, 16 right whales were seen on 29 April, but only two on 1 May, both of which were outside the critical habitat. In 2002, the departure seemed less dramatic because of the few right whales observed during the season. In past years, there appeared to be a herd-like behavior of departing right whales. This may be a result of collapse in the food resource in the Bay. Mayo *et al*. (2001a) provides some preliminary analysis on the subject that may shed light on the nature of the food resource and provide a means to predict departure.

Year	Date 1st survey	Last survey with right whales	# days of minimum residency	Date 2nd to last survey
1998	04 Jan 1998 (9)*	21 April 1998 (1)*	108 [75]**	19 April 1998 (3)*
1999	13 Dec 1998 (5)	02 May 1999 (1)	140 [86]	01 May 1999 (3)
2000	20 Jan 2000 (1)	11 April 2000 (3)	82 [86]	07 April 2000 (36)
2001	19 Dec 2000 (5)	01 May 2001*** (2)	134 [87]	29 April 2001 (16)
2002	06 Jan 2002 (0)	15 March 2002 (3)	55 [24]	07 March 2002 (2)

* Number in parentheses is the number of right whales photographed from the airplane that survey day.
** Number in square brackets is the minimum number of right whales for the season in CCB.
*** The sightings on 1 May were outside of the critical habitat; 29 April was the last day right whales were seen in the critical habitat in 2001.

Sightings between habitat areas

There were a total of eight records of 14 right whales (including three calves) seen both in the southeast US and Cape Cod Bay (see table below). The mean number of days between sightings

in the two areas was 58 (SE ± 28) for all records and 51 ±18 days for mothers with calves. The number of days between sightings ranged from 36 to 114.

Catalogue Number	Southern sighting (off the coast of Florida)	Northern sighting	Days between sightings
1039 and 3139 (yearling)	9 January	14 February (CCB)	36
1240 and calf	22 February	5 May (GSC)	72
1246 and calf	27 March	5 May (GSC)	39
1310 and calf	9 March	20 April (Stellwagen)	42
1620 and 3102	3 February	15 March (CCB)	40
1911 and 3120 (yearling)	12 December 2001	5 April (Stellwagen) (1911 alone)	114
3160 (yearling) alone	12 December 2001	1 March (CCB)	79
1424 (entangled)	12 February	29 March (Outer coast)	45

In the last five years, a total of 40 right whales (not including calves) were identified in both the southeast US and Cape Cod Bay in the same year. One whale, #2123, was documented in more than one year (1998 and 2001). There were two instances of right whales making the reverse migration from CCB to the southeast in 2000 (Brown and Marx 2000). In the first four years, most of the whales left the southeast in January arriving in Cape Cod Bay in February to early March (Brown and Marx 1998, 1999, 2000, Brown, Marx and Nichols2001). In 2002, right whales were last seen in the SEUS in mid-December to March and arrived in northern waters between February and April. These sightings provide some information on the timing of the migration of right whales through the mid-Atlantic region and the impact on proposed seasonal management plans for the shipping industry. The table below summarizes the maximum transit time over the last five years (calves are not included in the total because their movements are dictated by that of their mothers at this life stage).

Year	Number and sex ratio of transiting whales (male – M; female - F)	Range of days between sightings (days)	Mean number of days between sightings
1998	6 whales; 3 M, 2 F, 1 unknown	30 – 56	46 ± 9
1999	4 whales; 1 M, 3 F	33 – 65	55 ± 15
2000	9 whales; 5 M, 4 F	10 – 86	41 ± 22
2001	17 whales; 4 M, 12 F, 1 unknown	22 – 67	40 ± 9
2002	8 whales; 1 M, 6 F, 1 unknown	36 - 114	58 ±28

Photographs from our aerial survey efforts in the Great South Channel and those of the other aerial survey efforts by researchers at the NEFSC of NMFS through July have not yet been fully analyzed thus it was not possible to document movements of right whales between Cape Cod Bay and nearby waters at this time.

Mother calf pairs

There were no mother calf pairs recorded in Cape Cod Bay. There were four pairs were recorded in nearby areas during our surveys, two pair on Stellwagen (# 1145, 1310) and two pair (#1240, #1246) in the Great South Channel. Right whale # 1145 and calf were not seen during any other survey efforts. The presence of four mother/calf pairs in adjacent waters represents 18% of the known reproduction of right whales in 2002 (SEUS n = 21, DMF surveys n=1, total = 22).

Mother yearling pairs

In Cape Cod Bay in 2002 there were four mothers were sighted with their 2001 calves in close association; #1039 and #3139; #1509 and calf; #2145 and #3160; #1602 and #3102 (Appendix II). These calves were first sighted in January of 2001 off the southeastern U.S.; three of the four mothers were seen alone in late December 2000 or early January 2001 prior to the sighting with a calf (NEAq, unpublished data). The southeastern U.S. observations are consistent with the assumption that most calves are born in this area in January (Kraus *et al.* 1993). Thus it is reasonable to assume calf ages, and thus mother/calf associations, to have been approximately 14-15 months in duration at the time of the 2002 sightings in Cape Cod Bay. Prior to their sighting in Cape Cod Bay, three of these four mother yearling pairs were also observed on the SEUS calving ground, as were six other such pairs (A. Knowlton, New England Aquarium, pers. comm.). Hamilton *et al.* (1995) suggested that weaning in North Atlantic right whales commonly takes place within the first twelve months of life; thus this extended period of association is unusual. Hamilton (*et* al. 1995) describes an extended weaning time of ~17 months; interestingly, the mother documented in that study was #1509 (see above). It is worth noting that Hamilton *et al*. (1995) define a calf as weaned when it is "seen alone for three consecutive sightings spanning at least three days". In reference to the extended weaning period, the authors made no effort to distinguish between mother/calf association and actual nursing behavior; therefore, the reasons for the extended association may not be limited to nutritional dependence. Among mysticetes, nutritional independence for most species is thought to occur within the first year of life (Lockyer, 1984). There is a scarcity of data for actual weaning times for live mysticetes; however, it is reasonable to assume from sightings data that North Atlantic right whale calves typically become nutritionally independent during their first year. For example there is one case of an eight-month weaning time estimated for a right whale calf (#2223) that was orphaned in the fall of 1992 (Hamilton *et al.*, 1995). This animal is still alive and was seen along the outer coast of Cape Cod Bay in 2002 (# 2223 named Calvin, Appendix II).

Studies of terrestrial mammals have yielded a wealth of data on parental care (for a review see Clutton-Brock 1991). From the results of these studies, it is possible to formulate several hypotheses in an attempt to explain the extended mother/calf associations mentioned above. In a long-term study of red deer (*Cervus elaphus*), Clutton-Brock *et al.* (1982) found evidence that older females suckled their calves longer than younger females. Older animals were considered to have lower future reproductive potential, and therefore may have invested more in the care of their existing calves. The known ages of the four mothers seen in Cape Cod Bay in 2002 ranged from 11 to 22 years. Reproductive histories in North Atlantic right whales are known to span a minimum of 29 years, and there is little evidence for reproductive senescence in the species (Hamilton *et al*, 1998). Therefore, it is unlikely that age alone is related to the extended associations. However, if the diminishing reproductive rate documented for the population by Kraus *et al.* (2001) is an indicator of some sort of reproductive failure during the period of their study, then there may indeed be a correlation between future reproductive potential and duration of maternal investment. For a review of possible causes of reproductive failure in North Atlantic right whales, see Reeves *et al.* (2001).

Resource availability may also influence maternal behavior in a variety of ways. Rachlow and Bowyer (1994) noted interannual variation in weaning times of Dall's sheep (*Ovis dalli dalli*) in association with climatic perturbations and the consequent presumed resource availability. In many mammals, maternal care decreases when resources become scarce (Clutton-Brock 1991). Results of a long-term study of bighorn sheep (*Ovis canadensis*) suggested that mothers weaned calves early in order to preserve their own body condition during the absence of sufficient food resources (Festa-Bianchet and Jorgenson 1998). Baboons (*Papio cynocephalus ursinus*) inhabiting a mountain habitat subject to a marked seasonal decline in resource availability have been shown to exhibit increasing

duration of maternal care in contrast to populations in other habitats (Lycett *et al*, 1998). Right whales are known to forage in highly dynamic, patchy environments (Beardsley *et al.*1996). Perturbations in resource availability have been linked to right whale calving rates (Mayo *et al,* 2000; Pershing and Greene 2001), and may also influence the duration of maternal care in right whales.

The above studies on terrestrial mammals focus on the effect of resource availability on maternal condition and consequent investment in the form of nursing. It is also possible that resource availability may influence the duration of maternal care in a more indirect manner. In a review of right whale foraging strategies, Kenney *et al.* (2001) hypothesized that matrilineal learning may play an important role in finding feeding grounds. In what appears to be an anomalous year in terms of resource availability at least in Cape Cod Bay (see Mayo, Bessinger and Brown 2002, Chapter two of this report), it is worth considering the possibility that mothers are extending the duration of parental care to further provide calves with knowledge of feeding areas. Variations in resource availability are likely the result of environmental changes over various spatial and temporal scales (Kenney 2001). Kenney *et al*. (2001) hypothesized that right whales may detect environmental cues such as water mass characteristics. Detection of an anomaly at some time prior to weaning may influence mothers to delay weaning of their calves until a suitable resource patch is found, thus bolstering the calves' probability of survival.

Capture Rates and Residency

Of the 24 right whales identified or captured in Cape Cod Bay, 14 (58 %) were photographically captured on just one day (see below). The greatest number of days on which a whale was captured was 6 (Appendix II). The longest of the Cape Cod Bay sighting histories in 2002 spanned just 18 days. This is a much shorter period of residency than seen in past years. For example in 2001, the two whales with the longest sighting histories for the season were seen over 132 days and 76 days.

Days Photo'd	1	2	3	4	5	6
No. Photo'd (n = 24)	14	6	3	0	0	1

There were 10 right whales captured on more than one day (Appendix II). The number of days between first and last sighting was calculated for all right whales seen more than once that were not seen elsewhere between their first and last sighting in Cape Cod Bay. The number of days between first and last sighting for 10 right whales ranged from 1 to 18 days, with the mean being 6 days
(SE ± 6).

Demographics

The demographic profile of right whales in Cape Cod Bay in 2002 was quite different to previous years (see table below). Of the 19 identified right whales, there were significantly more females (12) than males (2) identified (5 of unknown sex), the first time this has varied from the one to one sex ratio predominant in the population and in Cape Cod Bay in previous years ($P = 0.007$). The catalogued right whale population is made up of 75% adults and 25% juveniles (Hamilton *et al* 1998). The age class of right whales identified in Cape Cod Bay was 53% adults (n = 10) and 47% juveniles (n = 9). This age structure is significantly different from the right whale catalogue ($P = 0.0243$, Hamilton *et al* 1998) and from the age structure observed in Cape Cod Bay since 1998. The demographic structure of the whales seen on Stellwagen Bank/Wildcat Knoll is more typical of what has been seen in Cape Cod Bay in previous years.

Year	Minimum # id'd	Adult/Juvenile	# Unknown age	Males/Females	# Unknown sex
1998	75	58 : 15	2	28 : 38	9
1999	86	55 : 23	8	37 : 35	14
2000	86	64 : 15	7	42 : 36	8
2001	87	57 : 13	17	40 : 30	10
2002 CCB	19	10 : 9	0	2 : 12	5
2002 Stellwagen	21	14 : 3	4	9 : 9	3

The details of the demographic structure of the population broken down by age and sex in bi-weekly intervals are presented in Table 4.

Biopsy Samples

There were no biopsy samples collected in Cape Cod Bay in 2002.

Notification of Agencies

At the completion of each aerial survey, the data on the number of right whales and their location were relayed via cell phone to the NMFS/SAS office in Woods Hole. The verbal data transmission was followed by a fax to the DMF office in Boston showing a table of sightings with a chart of locations. For vessel trips, positions of right whales were relayed via cell phone at the completion of each excursion. The DMF/CCS surveys are the principal source of right whale sighting information for the NMFS/SAS in the winter months.

Other sightings

There were seven other species of cetaceans, one pinniped species and one species of shark sighted while performing these surveys (Tables 2 and 3, Figures 5 and 6). Fin whales, *Balaenoptera physalus*, were the most numerous of the large whales encountered and white-sided dolphins, *Lagenoryhnchus acutus*, were the most numerous toothed whale followed by harbor porpoise, *Phocoena phocoena*.

The sighting database also contains coded entries for vessel traffic observed in the area. Commercial and military vessel traffic were compiled for the season and plotted on a single chart to show their distribution relative to right whale sightings and the critical habitat area (Figure 7).

Human Impacts

Entanglement Report (for further information see the rescue page on www.coastalstudies.org)

One entangled right whale was observed during the CCS flights. The sighting occurred on 29 March along the outer coast of the Cape east of Truro. The whale was identified as # 1424, which was originally seen entangled in the southeast U.S. The history of this entanglement is as follows.

On 15 February 2002 right whale #1424 was observed five miles east of the south end of Amelia Island, Florida. The whale was free swimming and trailing line. Right whale #1424, a male first seen by NEAq in the Bay of Fundy in 1981 and most recently by NEAq on September 17, 2001 was not entangled at that time. In addition to the existing entangling lines extensive (not fresh) scarring was present on the tailstock. The description of the gear on the whale: heavy, green/blue poly or poly blend rope trailing between 150 to 300 feet behind flukes. This line runs forward and enters the left side of the mouth, exits the right side of the mouth and forms a large, loose loop that drapes back approximately 4 feet behind the blowholes before reentering the right side of the mouth.

The bitter end of this line was not seen in existing images. It is possible that it is in the mouth or that it exits the right side of the mouth again and trails. There is no evidence of further body or flipper involvement. There were no further sightings of this whale in the SEUS.

On 29 March 2002, a report was received at 1445 from the CCS Skymaster plane of an entangled right whale, thought to be #1424, 1 mile off of Peaked Hill, east of Cape Cod. R/V *Shearwater* was underway by 1600 and the plane had to refuel. Both crews arrived at the last known location 42° 06'N and 70° 06'W around 1645, but were unable to relocate the whale. Numerous other right whales were also sighted within the area.

The whale was next seen on 17 April 2002. The NMFS-SAS plane spotted #1424 north of Stellwagen Bank in position: 42° 27.8'N/ 70° 24.3'W. The research vessel, *Silver II,* from the Whale Center of New England and the CCS Skymaster plane responded. The CCS disentanglement team from Provincetown arrived on scene by 16:00 aboard *Shearwater*. The CCS team was able to throw a grapple into the trailing line, about 50 feet behind the flukes, and attach a telemetry buoy. Soon after a squall went through the area. Data from the telemetry buoy indicated that it came free of the whale after being attached for about three hours

On 6 May the NMFS-SAS aerial survey team spotted right whale #1424 approximately 55 miles east of Nantucket (41° 18.6'N / 68° 49.8'W). The NOAA R/V *Albatross IV,* located 15 miles north of the sighting and outfitted with a First Response Kit for disentanglement, was alerted; the ship proceeded to the location of the report. Before the *Albatross IV* arrived, the SAS plane lost sight of the whale and at 1430 initiated a search pattern, but soon had to return to land due to low fuel. The crew of the *Albatross IV* relocated the whale about one hour later, however due to its evasive behavior and rough seas they were unable to photograph or attach telemetry equipment.

On 12 May the NMFS-SAS survey plane spotted right whale #1424 for the second time in a week in the Great South Channel. The position of the sighting was 34 NM east of Nantucket (41° 18.8'N / 69° 12.2'W). The NOAA research vessel *Albatross IV* was 22 miles away but could not respond due to an on-board medical emergency.

The last sighting as of this report was on 18 June 19, 2002 by the NMFS-SAS plane at location 42° 14.8'N 68° 42.7'W, approximately 115 nautical miles east of Race Point, Cape Cod.

Vessel interactions

There were no known collisions or close quarter movements reported or observed between vessels and right whales in Cape Cod Bay during the 2002 field season. The two events of right whales in the Cape Cod Canal are described above.

Summary

Cape Cod Bay has a long history of right whale use in the winter and spring dating back to the 1600s (Allen 1916). The distribution of right whales in the northern feeding areas is, in large part, thought to be a direct result of the distribution of their prey (Gaskin 1983). The 2002 field season was remarkable in that there were many fewer right whales seen over a much shorter period of time than has been the norm since 1998. In addition, most of the right whales observed were traveling or socializing, rather than feeding at or near the surface and the demographic composition of the whales sighted were predominantly adult females, also anomalies when compared to the past four years.

Over the last twenty years, it has not unusual to observe shifts in the number and demographic composition of right whales observed in any five known habitat areas. For example, there were no right whales observed in the Great South Channel in 1992,the first year and only year that spring surveys failed to detect right whales in this region (Kenney 2001). This was attributed to a shift in the regional zooplankton community (Kenney 2001). In Canadian waters, right whales were virtually absent from the Roseway Basin Conservation Area in the summer and fall from 1993-1999 while numbers of right whales observed during the same season tripled in the Bay of Fundy (NEAq unpublished data). Prior to 1993, right whales seen in the Bay of Fundy were primarily mothers, calves and juveniles; the area was thought to function as a summer and fall feeding and nursery area (Kraus *et al*. 1988). From 1993 to 1999, the demographic composition of right whales in Fundy included animals of both sexes and all age classes (NEAq unpublished data). There were no oceanographic or zooplankton data obtained for Roseway Basin during the whales presence or absence, so the reason for the whale's disappearance can only be speculated upon based on findings in other habitat areas. It is worth noting that one other planktivore, the sei whale (*Balaenoptera borealis*) was also absent from Roseway Basin and present in greater numbers in the Bay of Fundy during the same time period (NEAq unpublished data). In Cape Cod Bay the hypotheses on the condition of the food resource in the habitat, thought to be the basis for the few numbers of right whales observed, can be examined from the data collected in extensive habitat-sampling program; this will be discussed in detail in Chapter two of this report (Mayo, Bessinger and Brown 2002).

Surveys of areas adjacent to Cape Cod Bay became an increasingly important aspect of the program this year in terms of number of right whales sighted and in identifying other areas of seasonal residency and importance to right whales as a feeding area. More right whales were identified outside of Cape Cod Bay on Stellwagen Bank/Wildcat Knoll than within the boundaries of the Critical Habitat. In addition, one of the mother calf pairs (#1145 and calf) recorded on Stellwagen Bank/Wildcat Knoll was not observed during any other survey efforts. These observations outside of the Critical Habitat occurred near the end of the typical Cape Cod Bay season, but only one whale identified in Cape Cod Bay was also seen in the adjacent waters; it does not appear the right whales seen in the Bay left that area for Stellwagen Bank/Wildcat Knoll.

In 2002, passive acoustic recordings collected on autonomous bottom mounted hydrophones augmented the visual observations from aerial surveys and vessel cruises (Appendix IV). From visual surveys right whales were present from only 37 days between 7 February and 15 March, but the hydrophones recorded right whale calls, albeit at low levels in comparison with 2001, from 24 December through April and May. The next step with the data collected in 2002 and 2001 is to compare actual numbers of right whales from visual sightings with the acoustic census to assess if acoustic monitoring is an effective means of determining presence. With the combined data from aerial surveys and underwater passive acoustic recordings, even in a year with very few right whales observed in the critical habitat, the season of occurrence was as in past years, from mid to late December through April and into early May.

The presence of right whales in nearby areas outside of the critical habitats of either Cape cod bay or the Great South Channel in 2002 and past years suggest that a reevaluation of the area protected by ESA Critical Habitat designation is needed and timely to adequately reflect the distribution and movements of right whales. The use of these areas such as the eastern portion of Stellwagen Bank and Wildcat Knoll have only come to light with the expanded survey efforts of the last five years. Since this area is used for fishing activity and is transected by a major shipping lane between Boston and New York, consideration should be given to changing the boundaries of the neighboring Cape Cod Bay and Great South Channel Critical Habitats to include this area of seasonal importance to right whales. We recommend that the data collected in the Stellwagen Bank/Wildcat

Knoll area be assessed using sightings per unit of effort analysis it determine the density and seasonality of right whale use that the area and that the area be considered as a target for habitat sampling to assess the conditions of the food resource and for passive acoustic monitoring equipment to augment visual sightings.

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Table 1a. Aerial survey tracklines flown over Cape Cod Bay, January to mid-May, 2002. Tracklines begin and end approximately 1.5 nm from land. Cross reference this table by trackline number with chart shown in figure 1a.

Trackline Number	Latitude	Longitude West End	Longitude East End	Trackline Length (nm)
1	42 06.5	70 38.0	70 10.0	21
2	42 05.0	70 37.0	70 14.0	17
3	42 03.5	70 38.0	70 15.0	17
4	42 02.0	70 36.0	70 07.7	21
5	42 00.5	70 34.3	70 06.9	21
6	41 59.0	70 35.2	70 06.6	22
7	41 57.5	70 34.4	70 06.6	21
8	41 56.0	70 31.6	70 06.3	19
9	41 54.5	70 30.8	70 03.1	21
10	41 53.0	70 30.0	70 03.1	20
11	41 51.5	70 30.0	70 02.1	21
12	41 50.0	70 30.0	70 02.1	21
13	41 48.5	70 30.0	70 02.2	21
14	41 47.0	70 29.0	70 04.1	20
15	41 45.5	70 26.0	70 11.0	11
Subtotal trackline miles in Cape Cod Bay				294
16*	41 45.5		69 53.0	26
Total trackline miles, tracks 1-16				320

* Trackline 16 begins at this point, east of Chatham, continues northeast parallel to the outer coast of Cape Cod approximately 3 nautical miles offshore, and joins the eastern end of trackline 1.

Table 1b. Aerial survey tracklines over Stellwagen Bank, 07 March 2002. Cross reference this table with the chart shown in figure 1b

Trackline Number	Latitude	Western Longitude	Eastern Longitude	Distance (nm)
1	42 08.0	70 25.0	70 10.0	11.25
2	42 10.0	70 25.0	70 10.0	11.25
3	42 12.0	70 25.0	70 10.0	11.25
4	42 14.0	70 25.0	70 10.0	11.25
5	42 16.0	70 25.0	70 10.0	11.25
6	42 18.0	70 25.0	70 10.0	11.25
7	42 20.0	70 25.0	70 10.0	11.25
			Total	78.75
			Cross Legs	12
			Total	90.75

Table 1c. Aerial survey tracklines flown over Stellwagen Bank/Basin and Wildcat Knoll, 29 March* and 05 April 2002. Cross reference this table with the chart shown in figure 1c.

Trackline Number	Latitude	Western Longitude	Eastern Longitude	Distance (nm)
1	42 38.0	69 57.0	70 30.0	24.5
2	42 35.0	69 57.0	70 30.0	24.5
3	42 32.0	69 57.0	70 30.0	24.5
4	42 29.0	69 57.0	70 30.0	24.5
5	42 26.0	69 57.0	70 30.0	24.5
6	42 23.0	69 57.0	70 30.0	24.5
7	42 20.0	69 57.0	70 30.0	24.5
8	42 17.0	69 57.0	70 30.0	24.5
9	42 14.0	69 57.0	70 30.0	24.5
10	42 11.0	69 57.0	70 30.0	24.5
11	42 08.0	69 57.0	70 30.0	24.5
12	42 05.0	69 57.0	70 30.0	24.5
			Total	294
			Cross Legs	33
			Total	327

*Tracklines 1-10 and part of 11 were completed before survey aborted due to request for support for the sighting of an entangled whale (# 1424).

Table 1d. Aerial survey tracklines flown south of Nantucket Island to Block Island, RI, 12 April 2002. Cross reference this table with the chart shown in figure 1d.

Trackline Number	Latitude	Western Longitude	Eastern Longitude	Distance (nm)
1	41 12.0	71 30.0	70 00.0	65
2	41 09.0	71 30.0	70 00.0	65
3	41 06.0	71 30.0	70 00.0	65
4	41 03.0	71 30.0	70 00.0	65
			Total	260
			Cross Legs	9
			Total	269

Table 1e. Aerial survey tracklines flown over the Great South Channel, 05 and 12 May* 2002. Cross reference this table with the chart shown in figure 1e.

Trackline Number	Latitude	Western Longitude	Eastern Longitude	Distance (nm)
1	41 28.0	69 53.0	69 00.0	40
2	41 31.0	69 53.0	69 00.0	40
3	41 34.0	69 53.0	69 00.0	40
4	41 37.0	69 53.0	69 00.0	40
5	41 40.0	69 53.0	69 00.0	40
6	41 43.0	69 53.0	69 00.0	40
7	41 46.0	69 53.0	69 00.0	40
8	41 49.0	69 53.0	69 00.0	40
			Total	320
			Cross Legs	21
			Total	341

*Eastern portions of tracklines 7 and 8 were not completed due to inclement weather for safe flying.

Table 2. Number of marine mammals and other animals seen, hours and trackline miles surveyed during aerial surveillance of Cape Cod Bay and adjacent waters, January to mid-May 2002.

Survey#	Season 2002	Eg Sighted	Eg Photo'd	Eg id'd	Ba	Bb	Bp	Mn	UNBA	UNLW	UNSW	Gm	La	Pp	UNDO	Pv	UNSE	Cm	Hours Surveyed	Trackline Miles	Tracks Completed
CCS260	6-Jan	0	0		0	0	0	2	0	0	0	0	0	0	608	0	40	0	3.6	320	1-16
CCS261	18-Jan	0	0		0	0	0	2	0	0	0	15	0	0	0	0	0	0	3.2	282	3-16
CCS262	27-Jan	0	0		0	0	0	0	0	0	0	0	0	0	245	0	12	0	3.0	320	1-16
CCS263	29-Jan	0	0		0	0	0	0	0	0	0	0	0	0	26	0	5	0	3.5	320	1-16
CCS264	3-Feb	0	0		0	0	1	0	0	0	1	0	0	0	14	0	4	0	3.3	309	1-14, 16
CCS265	7-Feb	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.0	235	3-14*
CCS266	10-Feb	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.0	94	11-15
CCS267	14-Feb	2	2	2	0	0	0	0	0	0	0	0	0	0	4	0	14	0	3.3	320	1-16
CCS268	22-Feb	2	2	2	0	0	1	0	0	0	0	0	0	0	12	0	0	0	3.0	309	1-14,16
CCS269	23-Feb	4	4	3	0	0	2	0	0	0	0	0	0	0	10	0	0	0	3.9	309	1-14, 16
CCS270	25-Feb	8	8	7	0	0	0	0	1	0	0	0	0	0	0	0	2	0	4.0	320	1-16
CCS271	1-Mar	4	4	4	0	0	0	0	0	0	0	0	0	0	7	0	0	0	3.5	247	1-11, 16
CCS272	2-Mar	7	7	6	0	0	2	0	0	0	0	0	0	0	0	0	0	0	5.0	320	1-16
CCS273	5-Mar	4	3	3	0	0	2	0	0	0	0	0	0	0	0	0	0	0	3.3	309	1-14, 16
CCS274a	7-Mar	2	2	2	0	0	3	0	0	0	0	0	0	0	20	0	0	0	4.3	320	1-16
CCS275	15-Mar	3	3	2	0	0	6	5	6	0	0	0	0	0	0	0	1	0	3.5	297	1-15*
CCS276	19-Mar	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.5	320	1-16
CCS277	20-Mar	0	0		0	0	4	0	0	0	0	0	0	0	0	0	0	0	3.0	287	1-14
CCS278	25-Mar	1	1	1	0	0	2	1	0	0	0	0	0	0	0	0	0	0	3.4	309	1-14, 16
CCS280	2-Apr	2	2	2	0	0	1	1	0	0	0	0	0	0	23	0	1	0	3.5	324	1-15+
CCS282	11-Apr	0	0		0	0	4	1	1	0	0	0	0	0	7	0	0	0	4.4	350	1-16+
CCS284	17-Apr	0	0		1	0	1	3	0	0	0	0	0	10	27	0	4	0	3.5	313	1-14+
CCS285	24-Apr	0	0		1	0	2	2	0	0	0	0	0	0	140	0	0	0	4.8	400	1-16++
Total Cape Cod Bay		40	39	35	2	0	31	17	8	0	1	15	0	10	1143	0	83	0	80.4	6934	
Adjacent waters																					
CCS274b	7-Mar	0	0		0	0	4	0	0	0	0	0	0	0	0	0	0	0	1.3	135.5	SB*
CCS279	29-Mar	10	10	10	0	0	3	0	0	0	0	0	0	0	49	0	0	0	5.7	344	SB/WK
CCS281	5-Apr	15	15	6	1	0	1	1	0	1	0	20	0	0	40	0	2	0	5.0	344	SB/WK
CCS283	12-Apr	0	0		0	0	0	1	0	0	0	0	0	0	0	0	0	0	3.3	305	NS-BI
CCS284	17-Apr	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	n/a**	n/a	SB**
CCS286	5-May	29	28	2	1	0	4	49	0	0	0	0	25	0	8	0	0	0	5.7	349	GSC
CCS287	12-May	23	23	0	3	29	3	91	2	0	0	0	0	0	177	0	0	7	4.1	314	GSC
Total adjacent waters		78	77	19	5	29	15	142	2	1	0	20	25	0	274	0	2	7	25.1	1791.5	
Total all surveys		118	116	54	7	29	46	159	10	1	1	35	25	10	1417	0	85	7	105.5	8725.5	

*Portion(s) of trackline(s) cut short due to inclement weather. ** Flight to assist with entangled whale #1424, not a survey.

"+" indicates extended Race Pt. Lines; "++" indicates additional tracks along eastern shore (off Peaked Hill, Truro).

SB= Stellwagen Bank; WK= Wildcat Knoll; GSC= Great South Channel; NS= Nantucket Sound, BI= Block Island.

Table 3. Number of opportunistic marine mammal sightings and hours at sea during vessel- based habitat sampling cruises of Cape Cod Bay and adjacent waters, January to mid-May 2002.

Cruise	Date	Eg sighted	Eg photo'd	Eg id'd	Ba	Bp	Mn	UNLW	La	Pp	UnDo	Pv	UNSE	Hours at Sea
SW240	6-Jan	0	0		0	3	1	0	0	0	30	0	0	7
SW243	24-Jan	0	0		0	0	0	0	12	0	50	1	0	7
SW244	3-Feb	0	0		0	0	0	0	0	1	0	0	0	6.3
SW245	7-Feb	0	0		0	0	0	0	0	0	15	2	2	5.5
SW246	14-Feb	2	2	2	0	0	0	0	0	0	0	0	1	5.3
SW248	17-Feb	2	2	2	0	0	0	0	0	0	0	0	0	1*
SW249	23-Feb	2	2	2	0	0	0	0	0	0	0	0	0	7.3
SW251	2-Mar	7	5	5	0	0	0	0	0	0	0	0	1	6.0
SW253	7 Mar	4	4	2	0	1	0	0	0	1	0	0	0	7.5**
SW257	13-Mar	0	0		0	0	0	0	0	0	0	0	0	6.0
SW264	2-Apr	0	0		0	0	0	0	0	0	0	0	0	5.6
SW266	11-Apr	0	0		0	0	0	0	0	0	0	0	0	5.2
SW272	24-Apr	0	0		0	0	0	0	0	0	0	0	0	4.8
SW275	20-May	0	0		0	0	0	0	0	0	0	0	0	4.7
Total Cape Cod Bay		17	15	13	0	4	1	0	12	2	95	3	4	79.2
SW271	20-Apr	2	2	2	0	0	0	0	0	1	3	0	0	8.0
SW273	5-May	2	2	2	0	0	0	0	0	0	0	0	0	1*
SW284***	21 June	{20-30}	{0}											15.3
Total adjacent waters		4	4	4	0	0	0	0	0	1	3	0	0	24.3
Total all cruises		21	19	17	0	4	1	0	12	3	98	3	4	103.5

*Habitat sampling conducted during Bay monitoring cruise.

** Day spent working with National Geographic to try to attach critter cam.

***Post season cruise from Cape Cod Bay to the Great South Channel, 20-30 right whales sighted, none photographed because vessel was conducting transect sampling.

Table 4. Number of surveys, demographic composition and number of right whales identified in Cape Cod Bay from aerial and shipboard surveys in two-week intervals from January through mid-May 2002.

Two week intervals	1-14 Jan	15-28 Jan	29 Jan-11 Feb	12-25 Feb	26 Feb-11 Mar	12-25 Mar	26 Mar-8 Apr	9-22 Apr	23 Apr-6 May	7-15 May*	Total
a) Surveys											
Aerial	1	2	4	4	4	4	1	2	1	0	23
R/V *Shearwater*	1	1	2	2	1	1	1	2	2	0	13
b) Demographics											
Male	0	0	0	0	2	0	0	0	0	0	2
Female	0	0	1	9	3	2	0	0	0	0	15
Unknown Sex	0	0	0	2	2	1	0	0	0	0	5
Calf	0	0	0	0	0	2	0	0	0	0	2
Juvenile	0	0	1	6	5	0	0	0	0	0	12
Adult	0	0	0	5	2	1	0	0	0	0	8
Unknown Age	0	0	0	0	0	0	0	0	0	0	0
c) Resightings											
New Sightings	0	0	1	10	4	3	0	0	0	0	18
Resightings	0	0	0	1	3	0	0	0	0	0	4
Total right whales id'd in Cape Cod Bay	0	0	1	11	7	3	0	0	0	0	

* This interval represents only one week.

Summary											
adult females				5	1	2					
juvenile females			1	4	2						
adult males					1						
juvenile males					1						
juvenile, unknown sex				2	2	1					

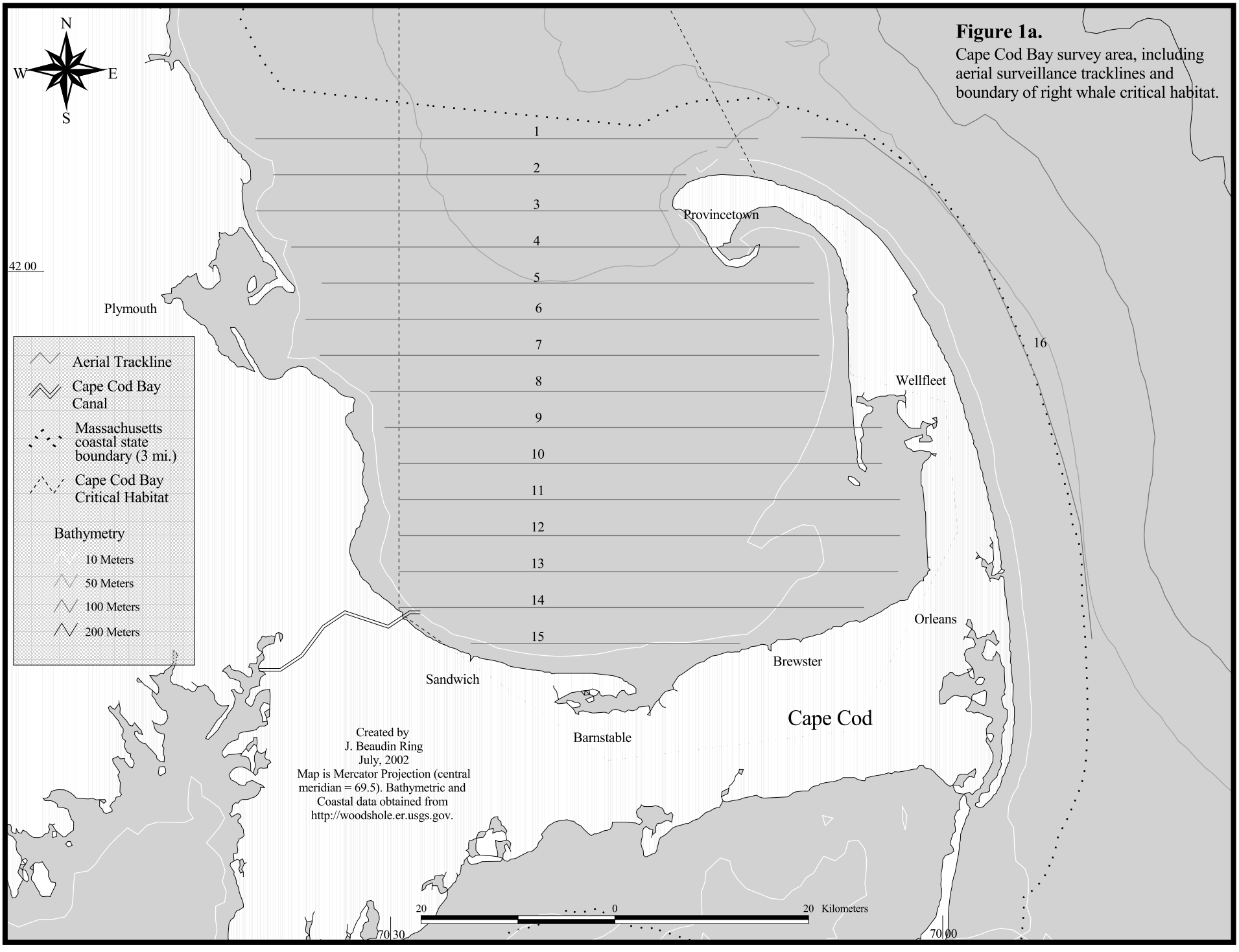


Figure 1a.
Cape Cod Bay survey area, including aerial surveillance tracklines and boundary of right whale critical habitat.

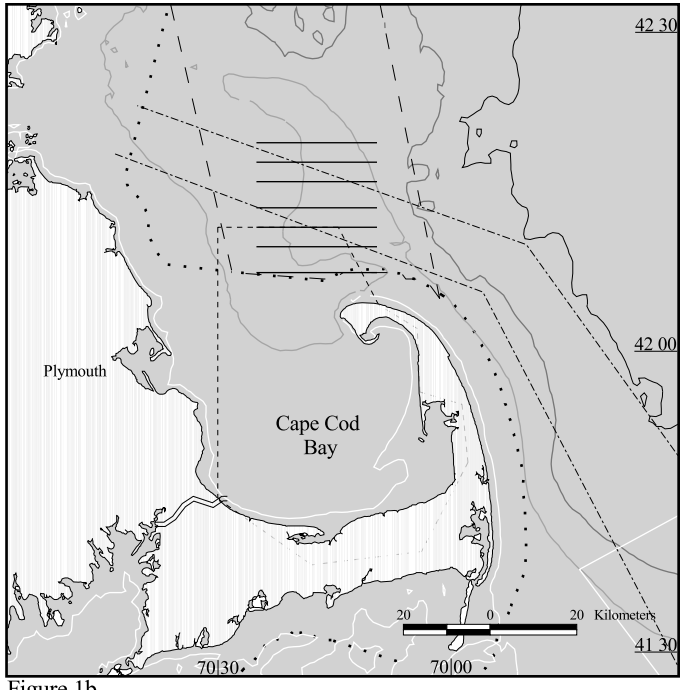


Figure 1b.

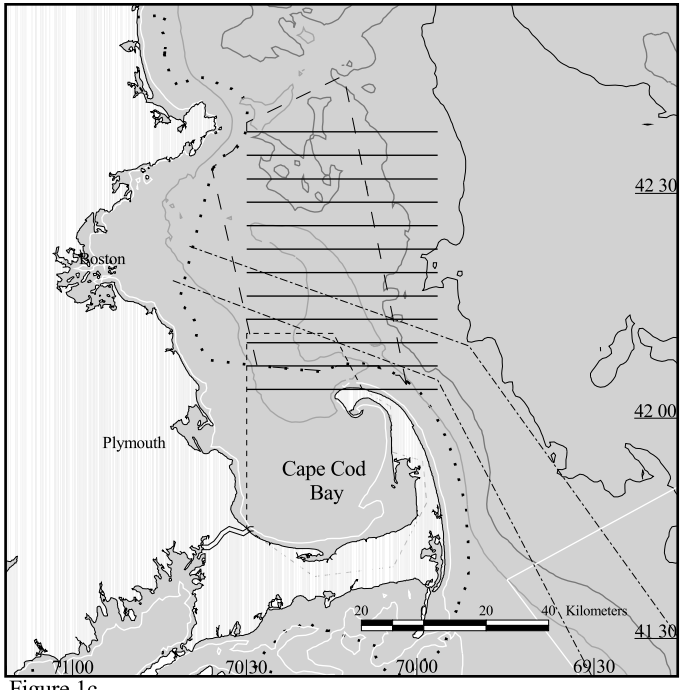


Figure 1c.

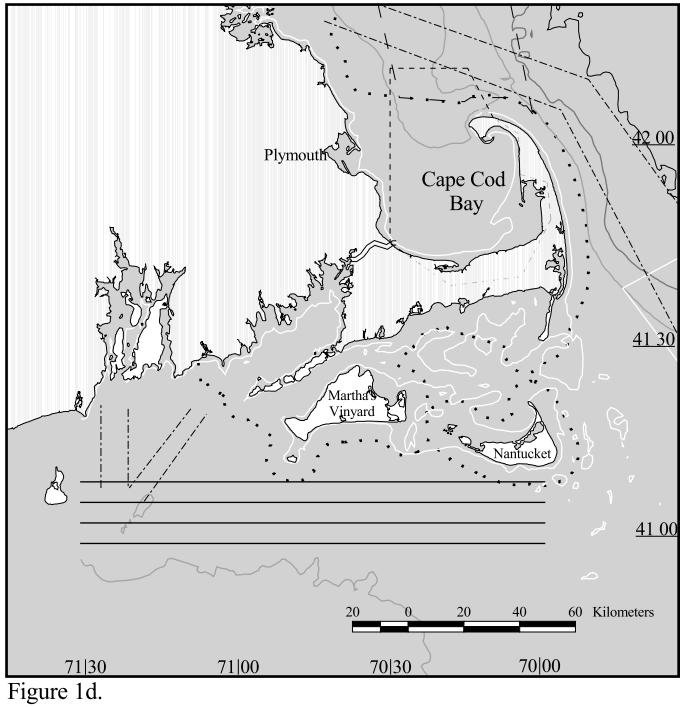


Figure 1d.

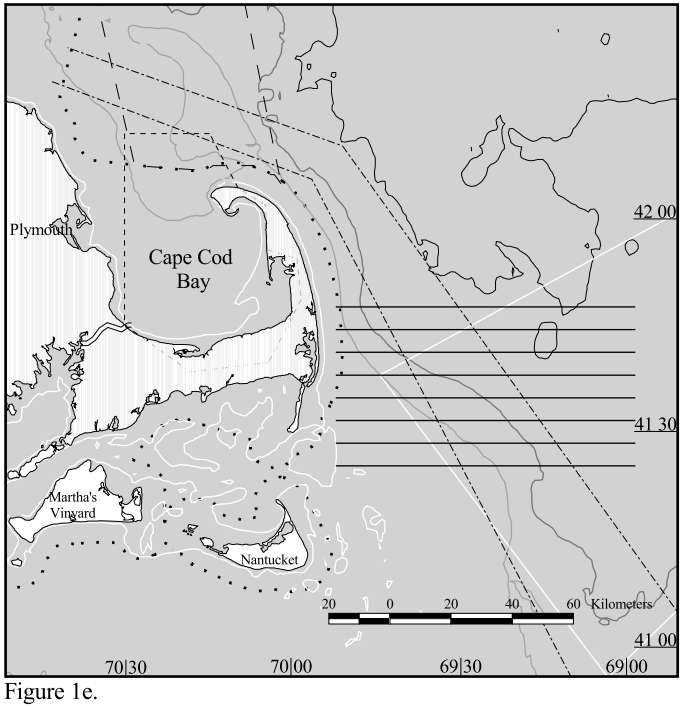


Figure 1e.

Figure 1b - e.

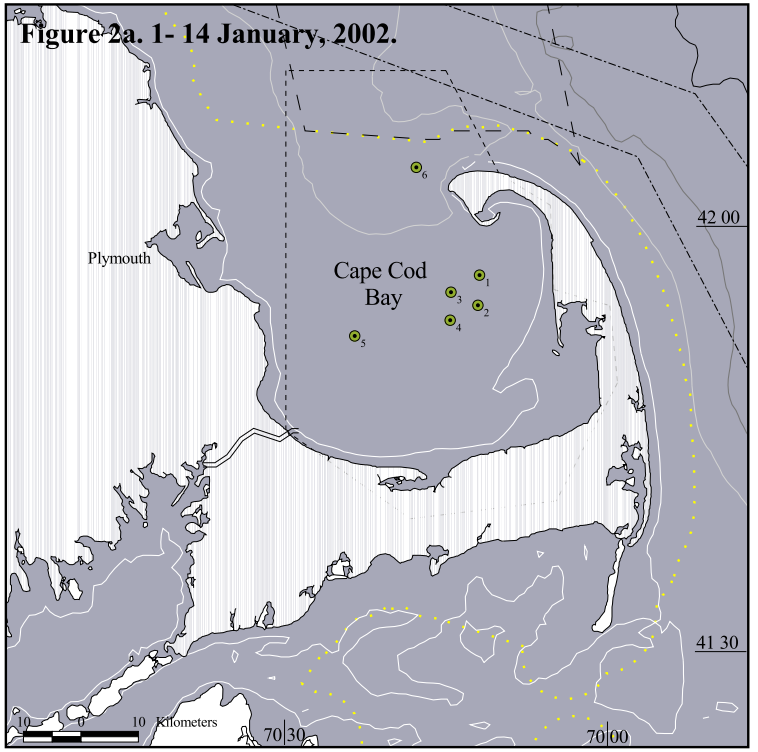
Additional survey tracklines flown in waters adjacent to Cape Cod Bay

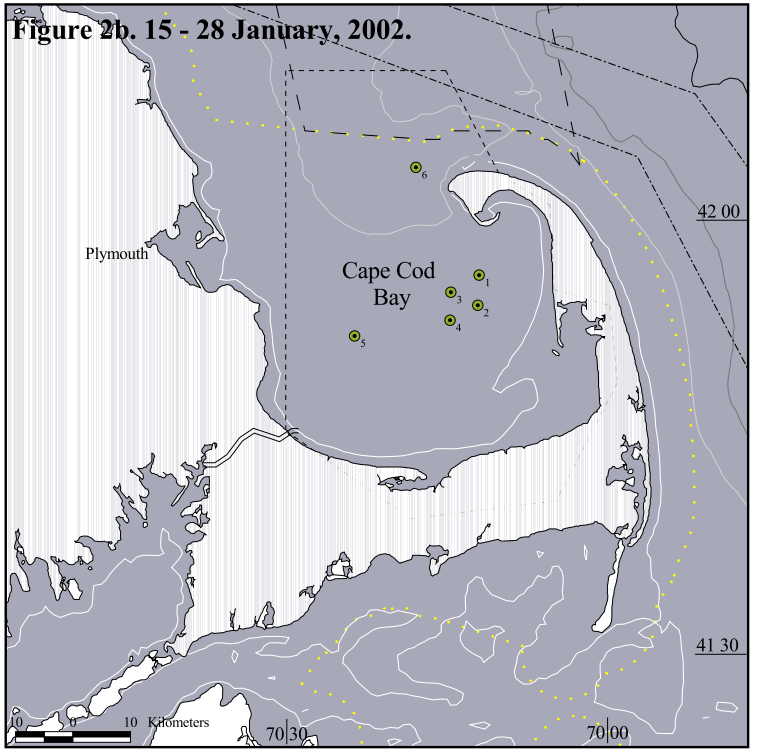
Bathymetry

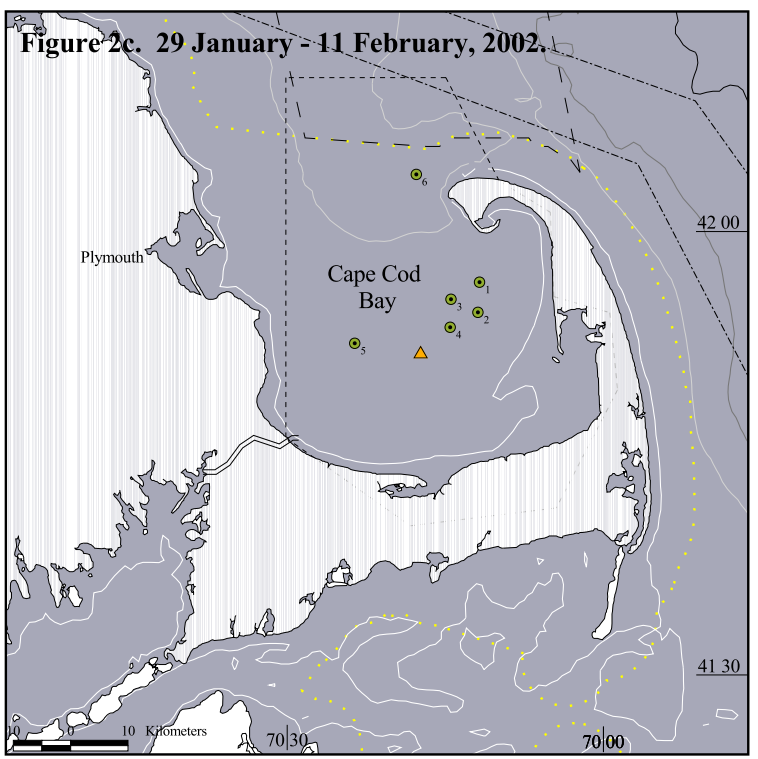
- 10 Meters
- 50 Meters
- 100 Meters
- 200 Meters

- Cape Cod Canal
- Massachusetts State Waters Boundary (3 nm.)
- Cape Cod Bay Critical Habitat
- Great South Channel Critical Habitat
- Stellwagen Bank National Marine Sanctuary
- Shipping Lanes

Created by
J. Beaudin Ring
July, 2002
Map is Mercator Projection (central meridian = 69.5). Bathymetric and Coastal data obtained from http://woodshole.er.usgs.gov.







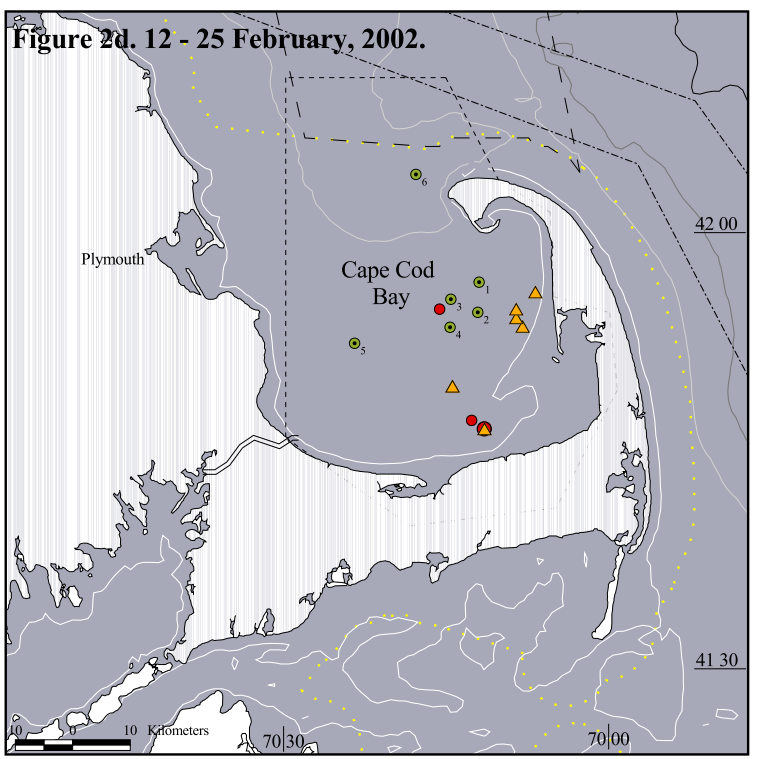
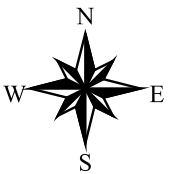
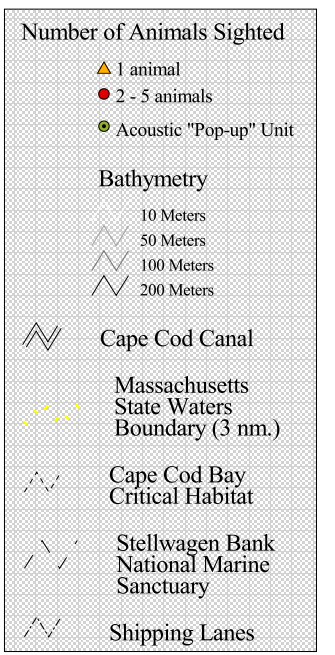


Figure 2.

Sightings of right whales from 11 aerial surveys in Cape Cod Bay, 1 January - 25 February, 2002.





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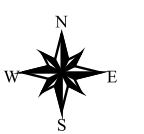
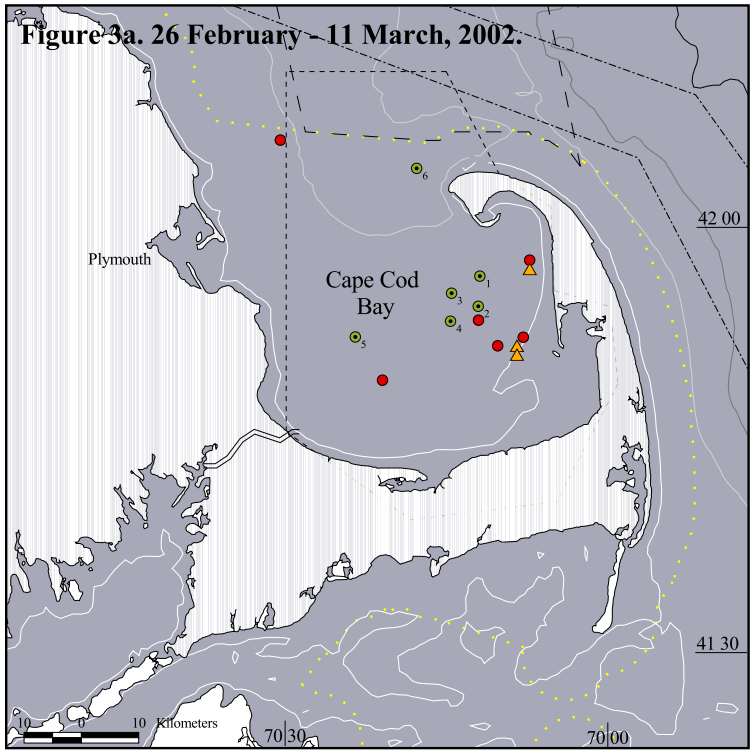
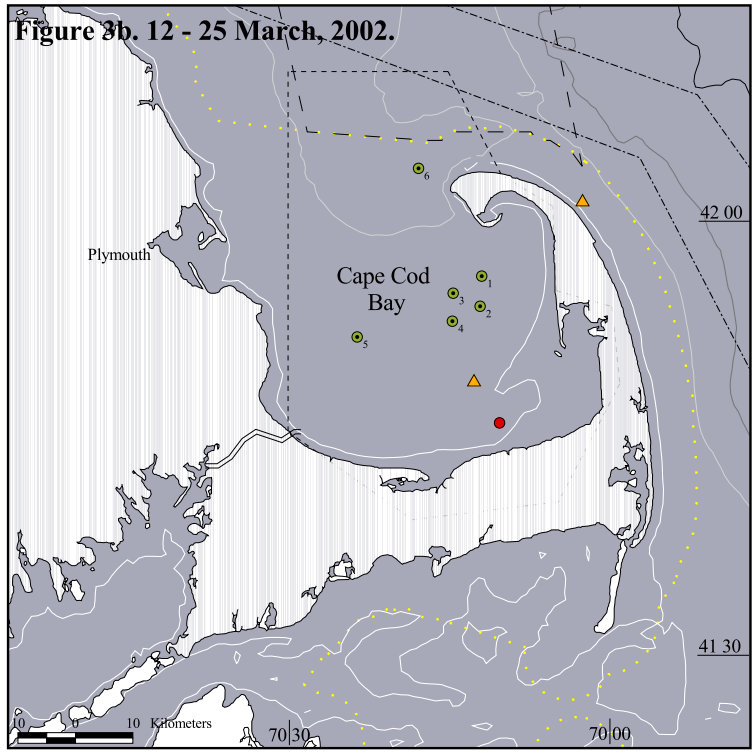
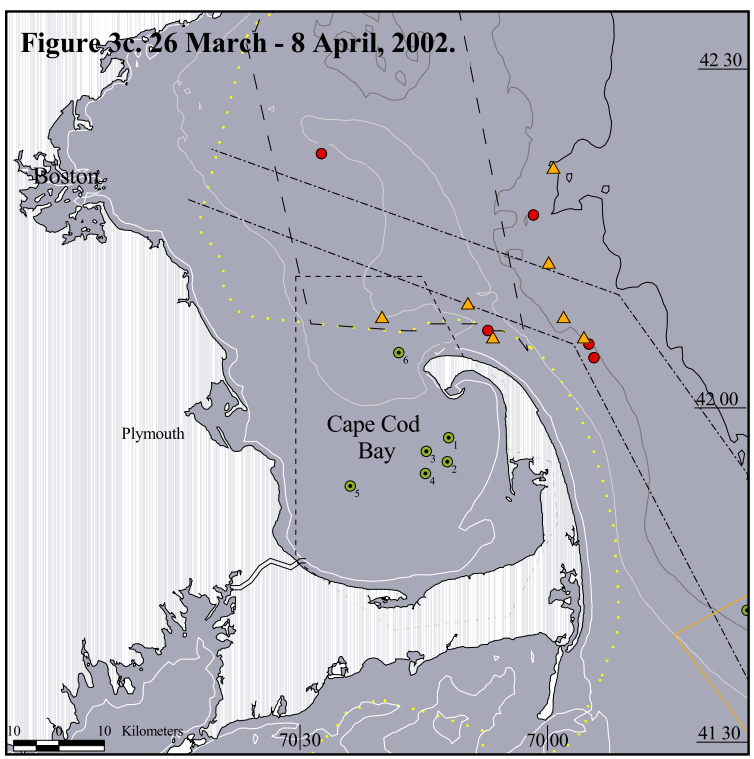
July, 2002
Map is Mercator Projection (central meridian = 69.5). Bathymetric and Coastal data obtained from http://woodshole.er.usgs.gov.









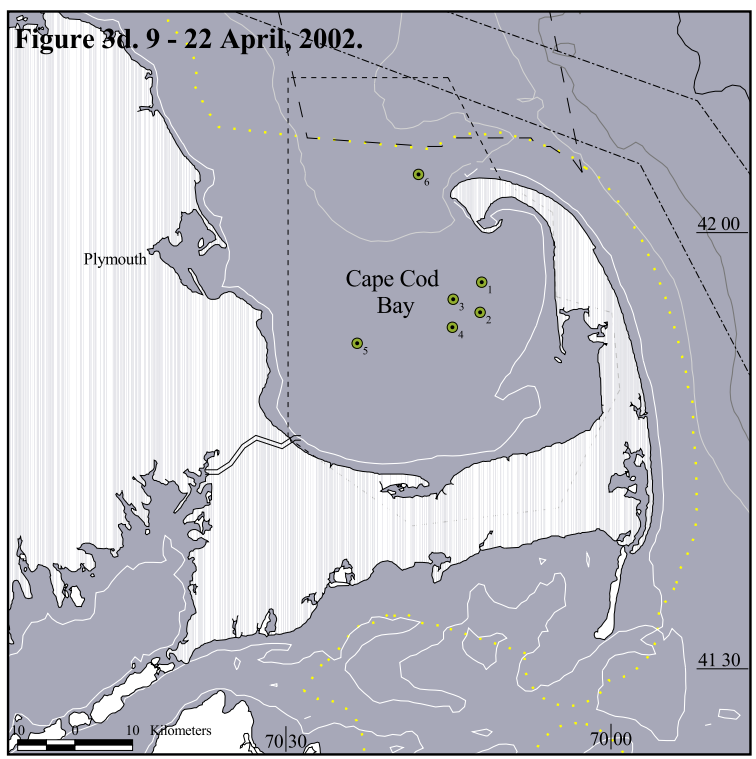


Figure 3.

Sightings of right whales from 14 aerial surveys in Cape Cod Bay and adjacent waters, 26 February - 22 April, 2002.

N
W E
S

The last sighting of right whales in Cape Cod Bay occurred on 5 April, 2001.

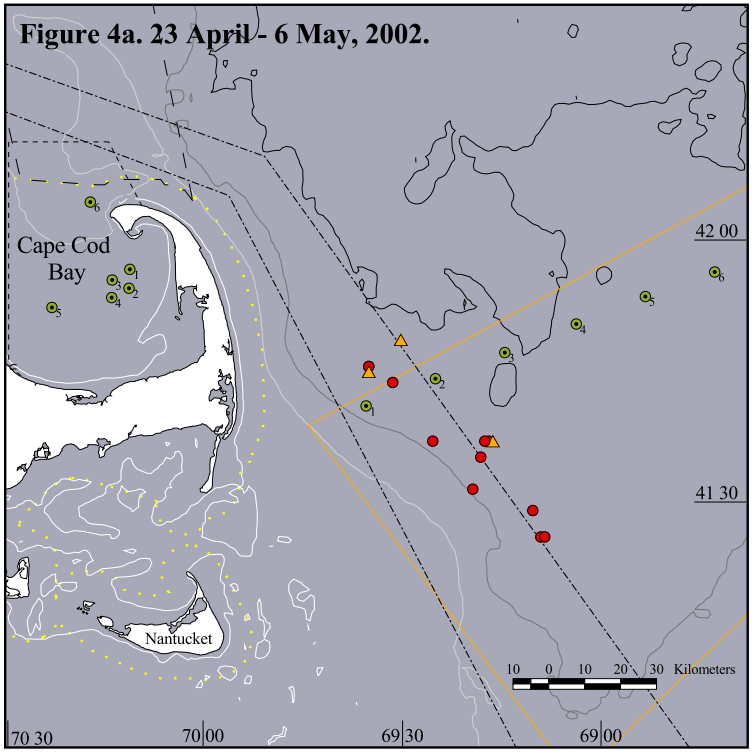
Number of Animals Sighted
- 1 animal
- 2 - 5 animals
- Acoustic "Pop-up" Unit

Bathymetry
- 10 Meters
- 50 Meters
- 100 Meters
- 200 Meters

- Cape Cod Canal
- Massachusetts State Waters Boundary (3 nm.)
- Cape Cod Bay Critical Habitat
- Stellwagen Bank National Marine Sanctuary
- Shipping Lanes

Created by
J. Beaudin Ring
July, 2002
Map is Mercator Projection (central meridian = 69.5). Bathymetric and Coastal data obtained from http://woodshole.er.usgs.gov.

N
W E
S



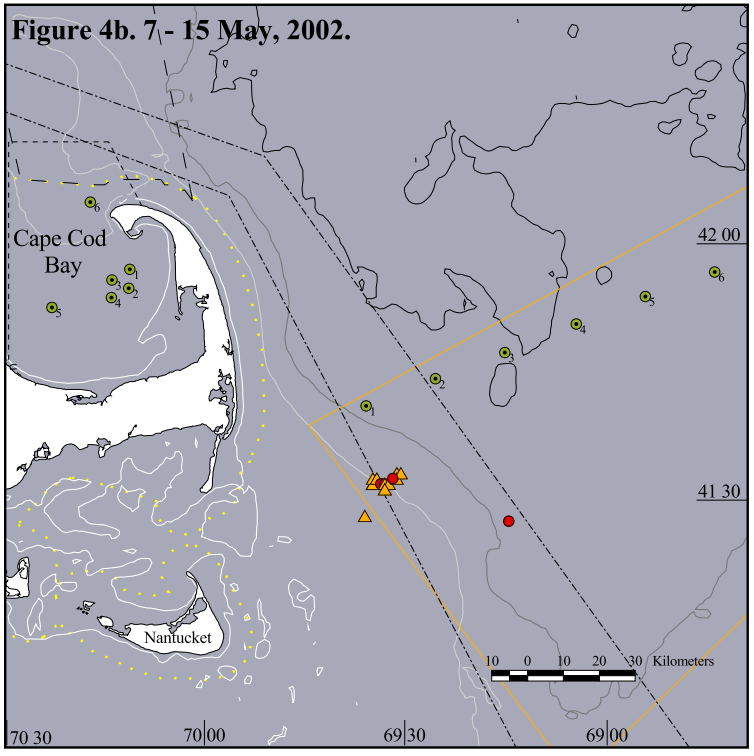


Figure 4.

Sightings of right whales from 3 aerial surveys in Cape Cod Bay and adjacent waters 23 April - 15 May, 2002.

N
W E
S

Two surveys were flown during this four week period on 5 May and 12 May, 2002. The last survey for the 2002 field season was on 12 May, 2002.

Number of Animals Sighted
- 1 animal
- 2 - 5 animals
- Acoustic "Pop-up" Unit

Bathymetry
- 10 Meters
- 50 Meters
- 100 Meters
- 200 Meters

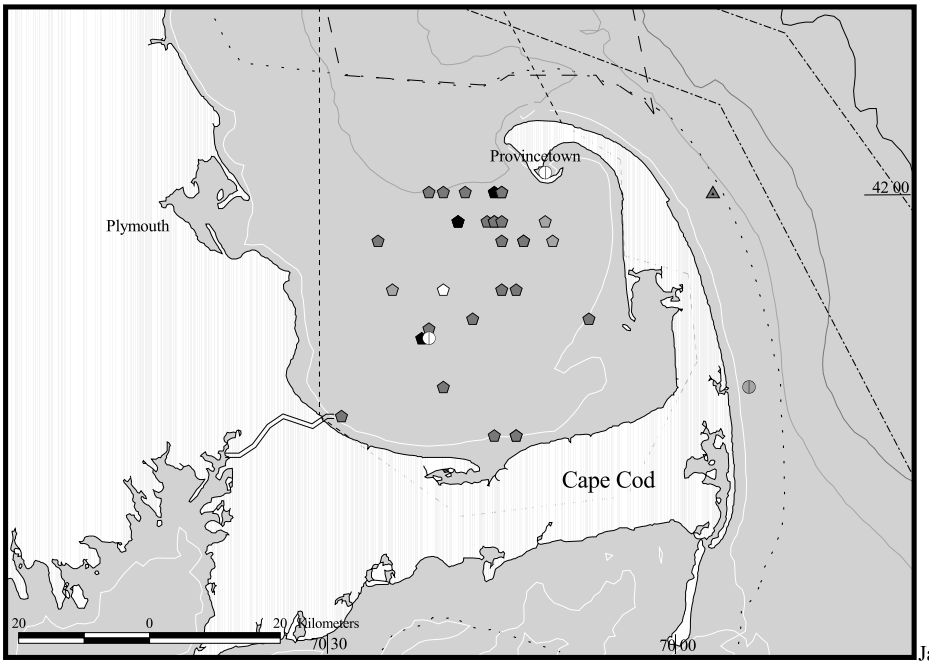
- Great South Channel Critical Habitat
- Massachusetts State Waters Boundary (3 nm.)
- Cape Cod Bay Critical Habitat
- Stellwagen Bank National Marine Sanctuary
- Shipping Lanes

Created by
J. Beaudin Ring
July, 2002
Map is Mercator Projection (central meridian = 69.5). Bathymetric and Coastal data obtained from http://woodshole.er.usgs.gov.

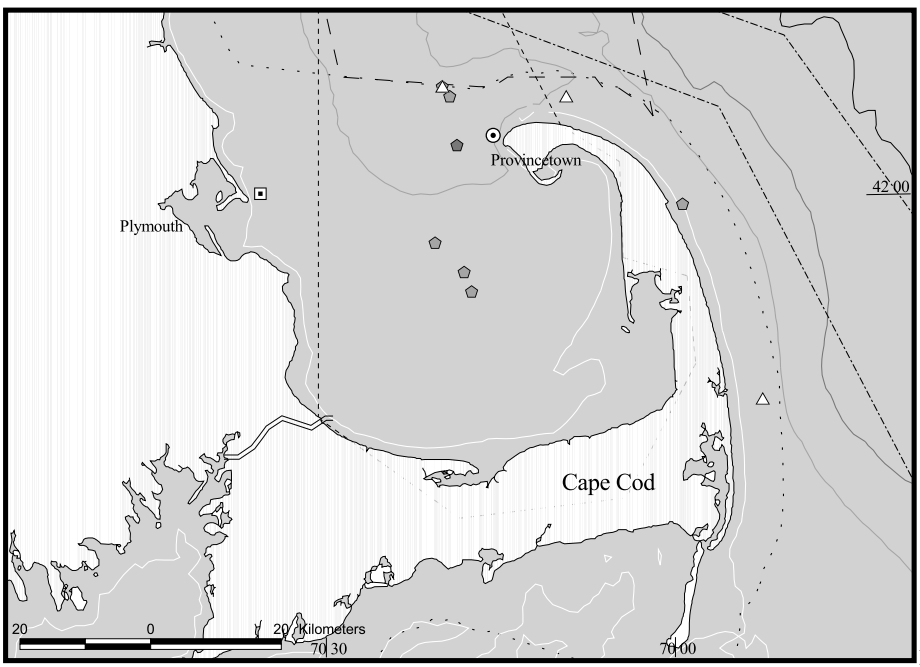
N
W E
S

Figure 5.

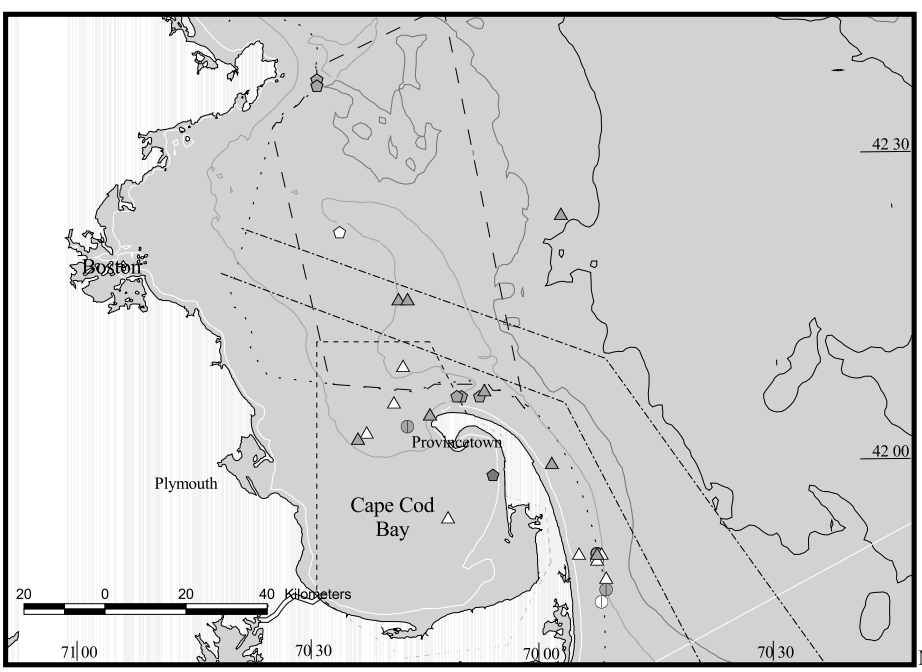
Sightings of other large whales and dolphins from aerial surveys in Cape Cod Bay, and adjacent waters January - March, 2002.



January, 2002.



February, 2002.



March, 2002.

Legend

Large Whales and Dolphins

- Fin Whale
- Sei Whale
- Minke Whale
- Humpback Whale
- Pilot Whale
- Unidentified Balaenopterid
- Unidentified Whale (large or small)
- White-Sided Dolphin
- Unidentified Dolphin
- Harbor Porpoise

Number of Animals Sighted

- 1 animal
- 2 - 10 animals
- 11 - 50 animals
- > 50 animals

Bathymetry

- 10 Meters
- 50 Meters
- 100 Meters
- 200 Meters

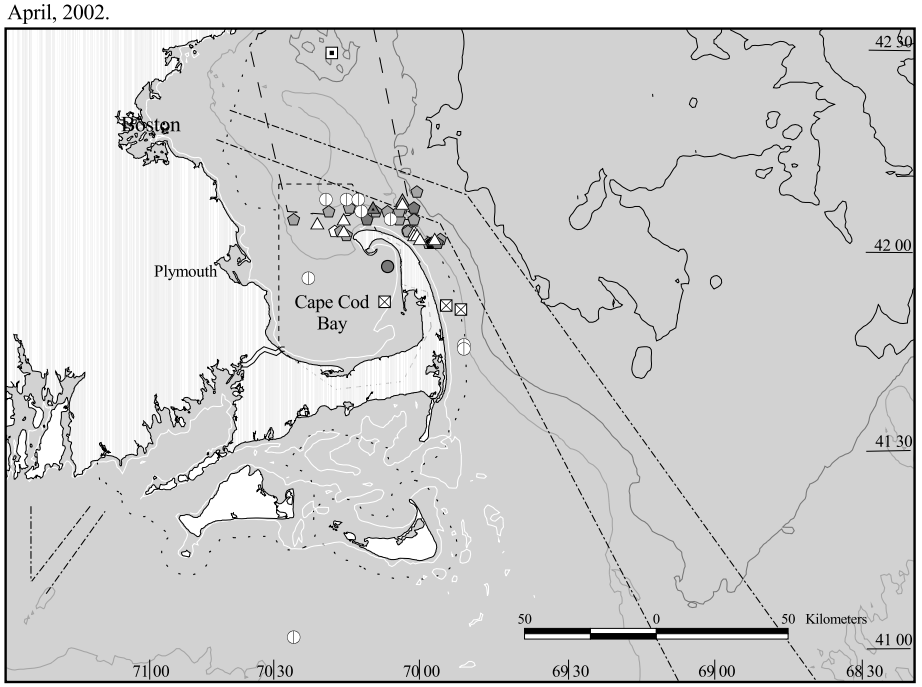
- Cape Cod Canal
- Massachusetts State Waters Boundary (3 nm.)
- Cape Cod Bay Critical Habitat
- Great South Channel Critical Habitat
- Shipping Lanes
- Stellwagen Bank National Marine Sanctuary

Created by
J. Beaudin Ring
July, 2002
Map is Mercator Projection (central meridian = 69.5). Bathymetric and Coastal data obtained from http://woodshole.er.usgs.gov.

Figure 6.

Sightings of other large whales and dolphins from aerial surveys in Cape Cod Bay and adjacent waters, April - May, 2002.

April, 2002.



Created by
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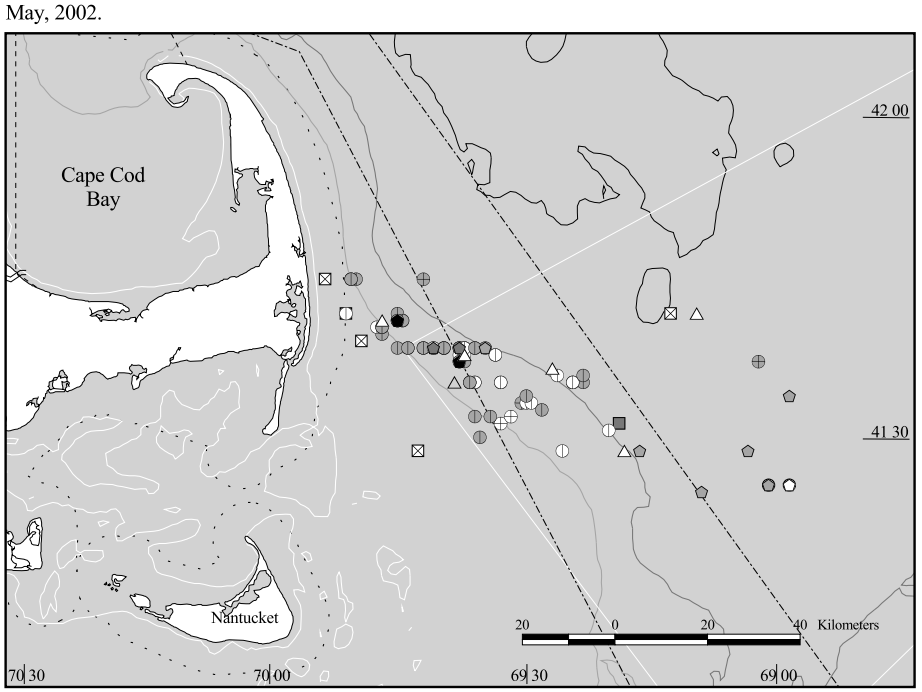
July, 2002
Map is Mercator Projection (central meridian = 69.5). Bathymetric and Coastal data obtained from http://woodshole.er.usgs.gov.

N
W E
S

May, 2002.



Legend

Large Whales and Dolphins

- Fin Whale
- Sei Whale
- Minke Whale
- Humpback Whale
- Pilot Whale
- Unidentified Balaenopterid
- Unidentified Whale (large or small)
- White-Sided Dolphin
- Unidentified Dolphin
- Harbor Porpoise

Number of Animals Sighted

- 1 animal
- 2 - 10 animals
- 11 - 50 animals
- > 50 animals

Bathymetry

- 10 Meters
- 50 Meters
- 100 Meters
- 200 Meters

- Cape Cod Canal
- Massachusetts State Waters Boundary (3 nm.)
- Cape Cod Bay Critical Habitat
- Great South Channel Critical Habitat
- Shipping Lanes
- Stellwagen Bank National Marine Sanctuary

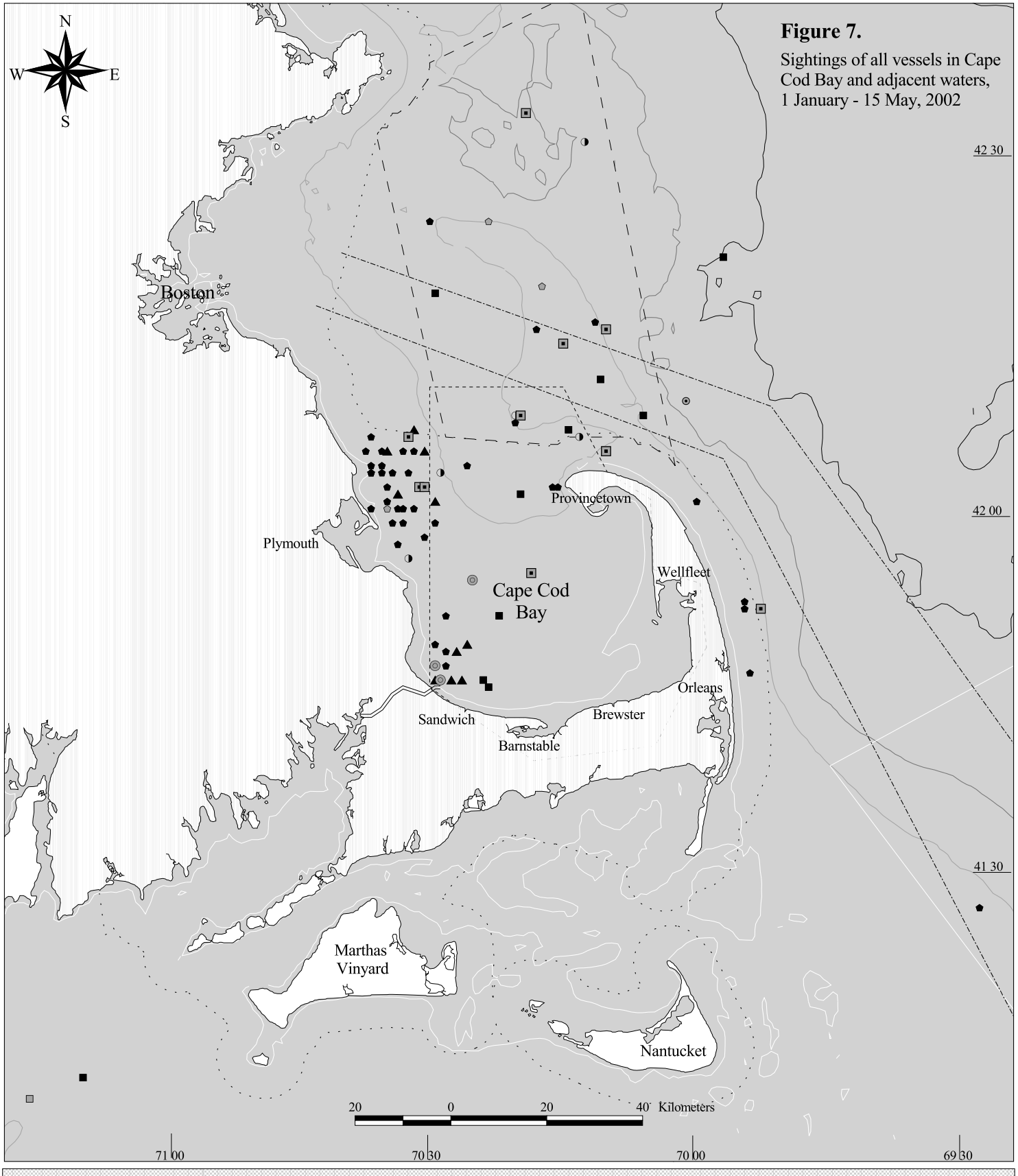


Figure 7.

Sightings of all vessels in Cape Cod Bay and adjacent waters, 1 January - 15 May, 2002

Vessels Sighted

- Single Large Merchant Vessel
- Multiple Large Merchant Vessels
- Single Recreational Vessel
- Multiple Recreational Vessels
- Single Commercial Fishing Vessel
- Sport Fishing Vessel
- Whale Watch Vessel
- Research Activity
- Single Sailing Vessel
- Shipping Lanes
- Cape Cod Bay Canal
- Massachusetts State Waters Boundary (3 nm.)
- Cape Cod Bay Critical Habitat
- Great South Channel Critical Habitat
- Stellwagen Bank National Marine Sanctuary

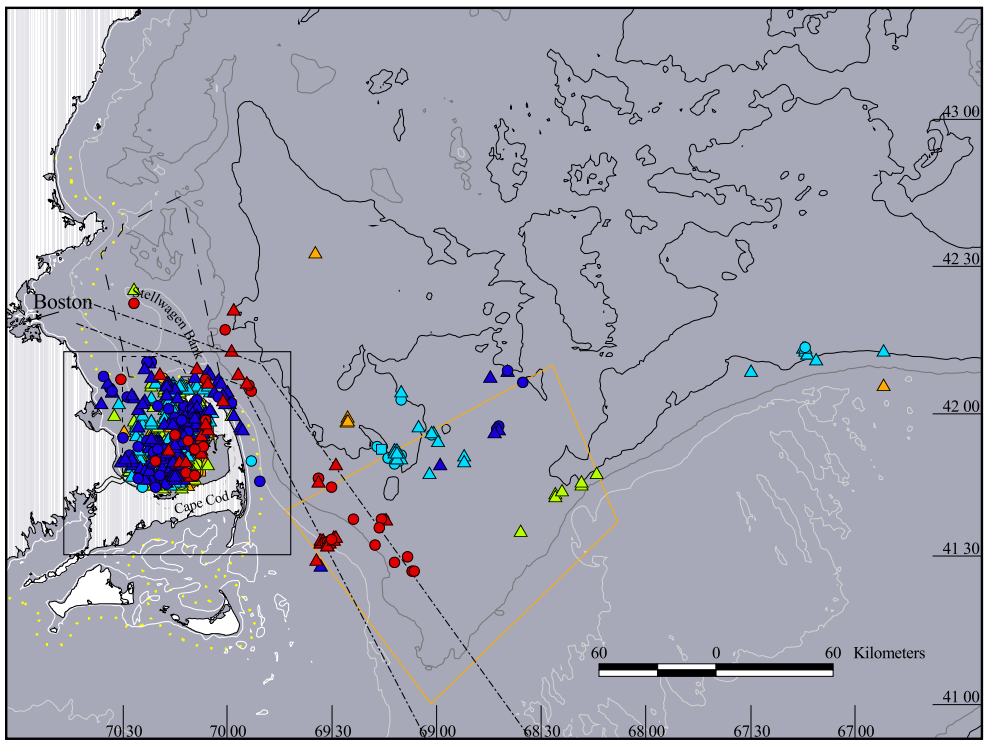
Bathymetry

- 10 Meters
- 50 Meters
- 100 Meters
- 200 Meters

Created by
J. Beaudin Ring
July, 2002
Map is Mercator Projection (central meridian = 69.5). Bathymetric and Coastal data obtained from http://woodshole.er.usgs.gov.

Figure 8.
Sightings of right whales from aerial surveys in Cape Cod Bay and adjacent waters, 1998 - 2002 field seasons.

Created by
J. Beaudin Ring
July, 2002
Map is Mercator Projection (central meridian = 69.5). Bathymetric and Coastal data obtained from http://woodshole.er.usgs.gov.



Number of Animals Sighted
- 1 animal
- 2 - 5 animals
- 6 - 10 animals
- > 10 animals

Year Sighted
- 2002
- 2001
- 2000
- 1999
- 1998

Bathymetry
- 10 Meters
- 50 Meters
- 100 Meters
- 200 Meters

- Cape Cod Bay Critical Habitat
- Massachusetts State Waters Boundary (3 nm.)
- Cape Cod Bay Canal
- Stellwagen Bank National Marine Sanctuary
- Great South Channel Critical Habitat
- Shipping Lanes

Sightings of right whales from aerial surveys in Cape Cod Bay, 1998 - 2002 field seasons.

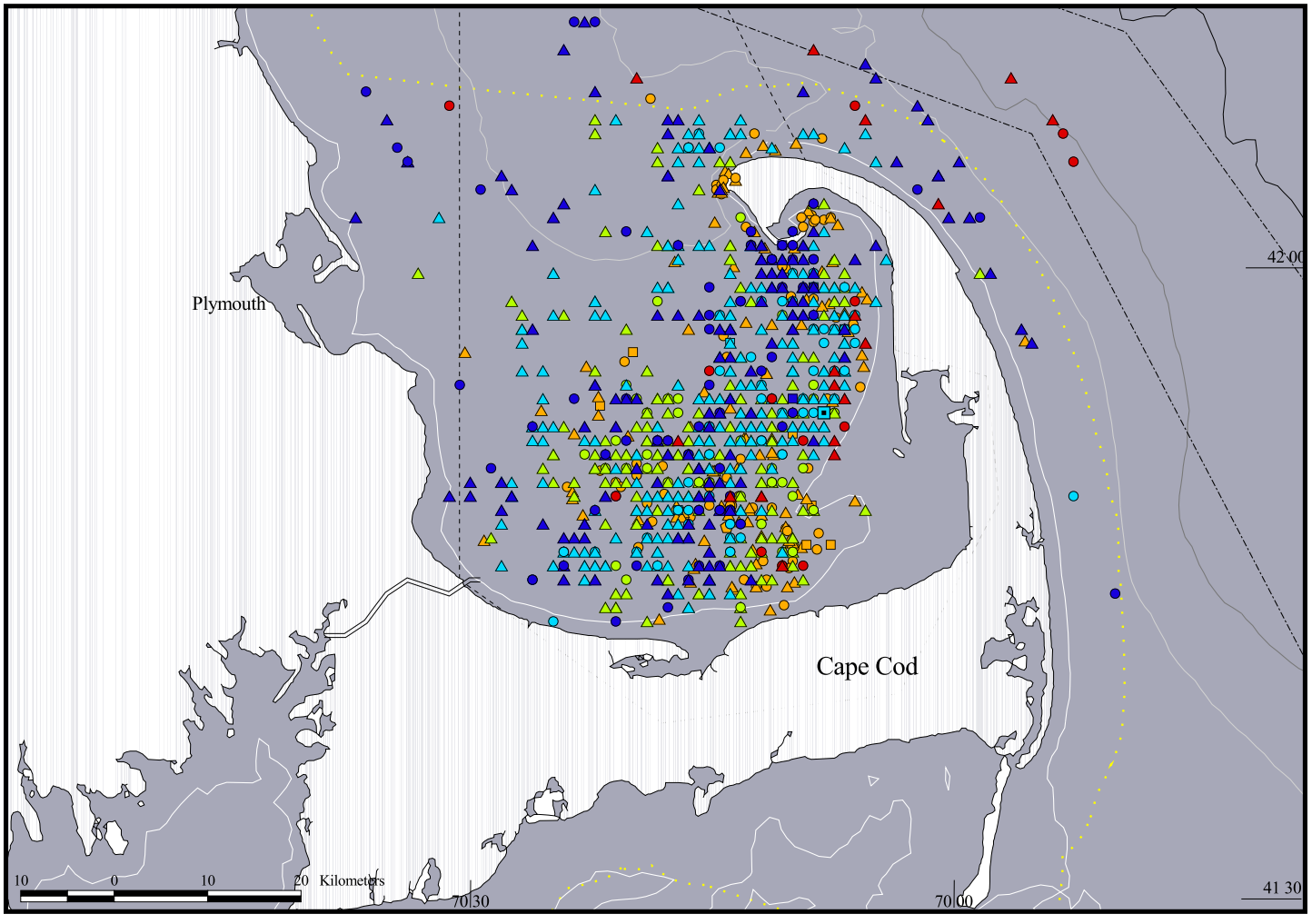
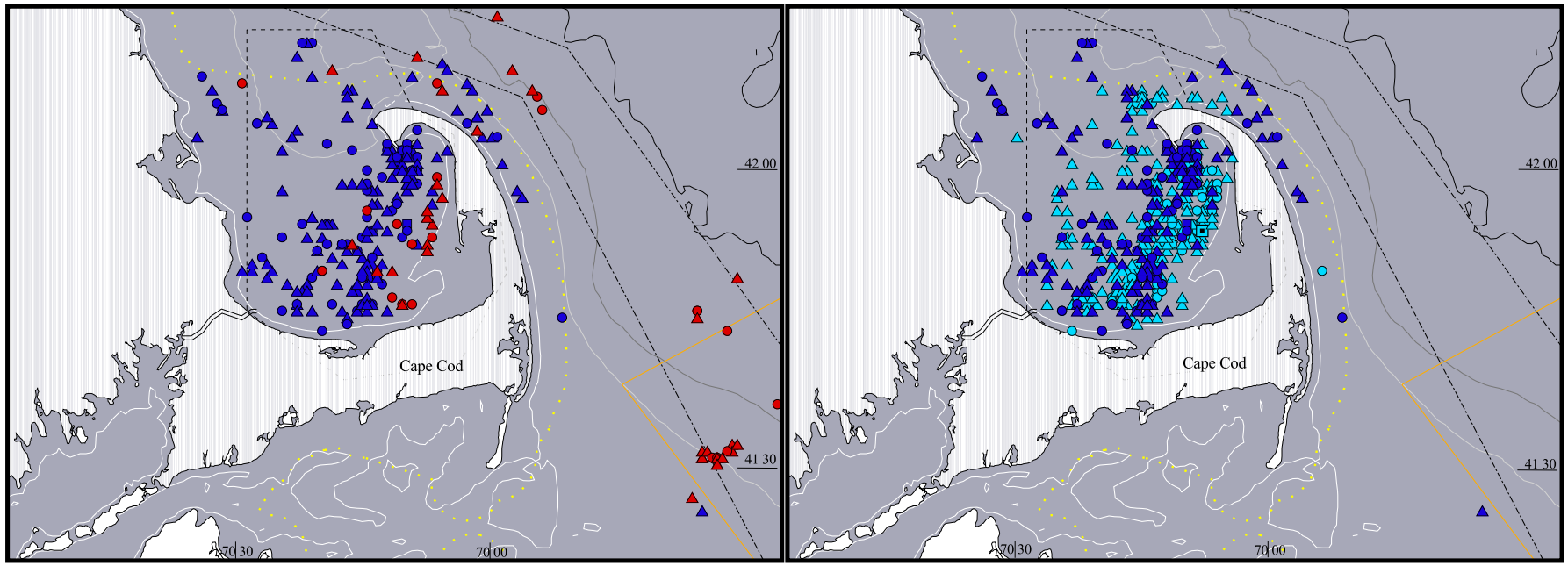
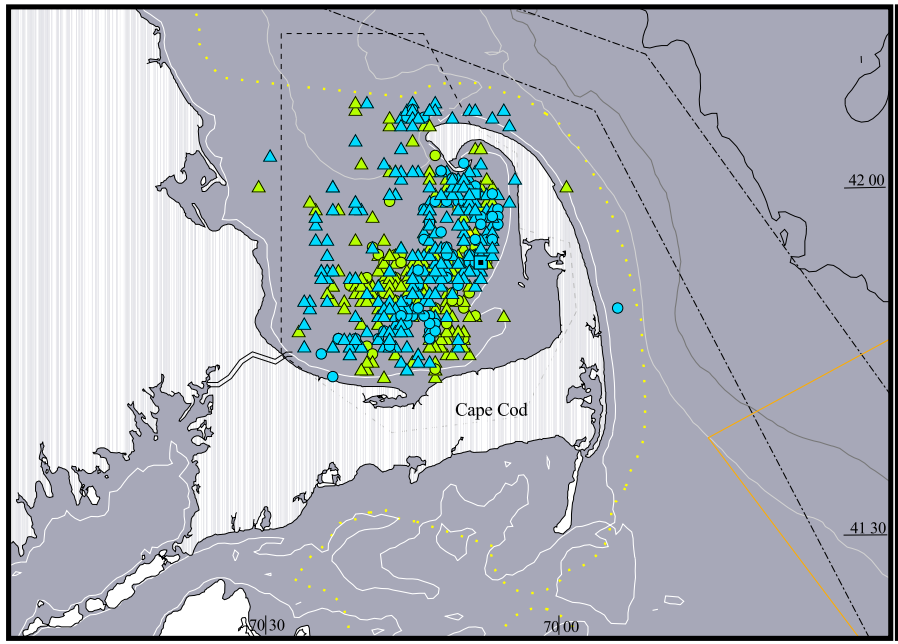


Figure 9.
Sightings (staggered by year) of right whales from aerial surveys in Cape Cod Bay and adjacent waters, 1998 - 2002 field seasons.

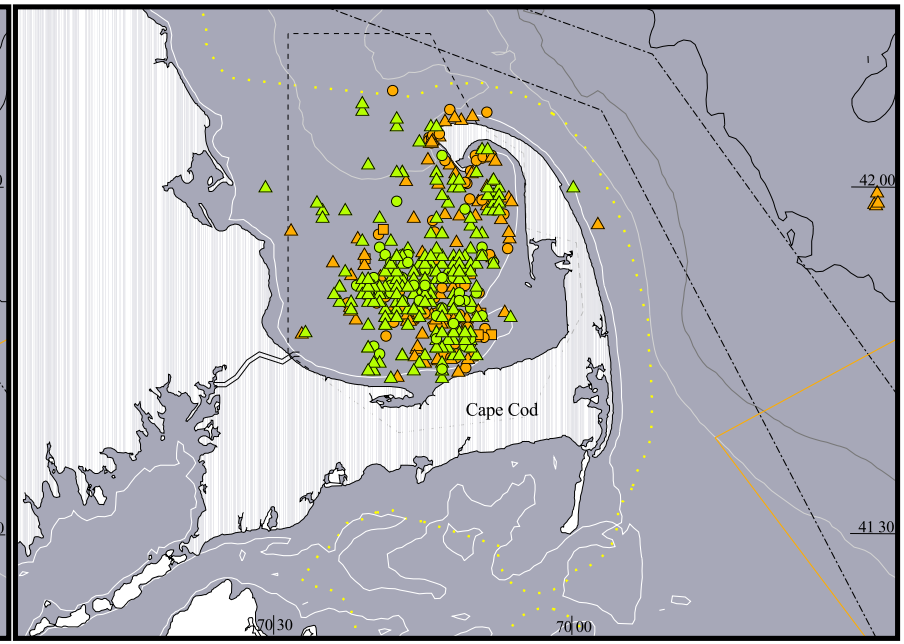


a. 2001 - 2002 Field Seasons.

b. 2000 - 2001 Field Seasons.



c. 1999 - 2000 Field Seasons.



d. 1998 - 1999 Field Seasons.

20 0 20 40 Kilometers

Year Sighted
2002
2001
2000
1999
1998

Number of Animals Sighted
1 animal
2 - 5 animals
6 - 10 animals
> 10 animals

Bathymetry
10 Meters
50 Meters
100 Meters
200 Meters

Cape Cod Bay Canal

Massachusetts State Waters Boundary (3 nm.)

Cape Cod Bay Critical Habitat

Great South Channel Critical Habitat

Shipping Lanes

Created by
J. Beaudin Ring
July, 2002
Map is Mercator projection (central meridian = 69.5).
Coastal coverages and bathymetric data obtained from http://woodshole.er.usgs.gov.

Appendix I

Confirmed right whale identifications in Cape Cod Bay and adjacent waters 1998-2002 and sighting histories. Abbreviations are listed at bottom of page.

EGNO	Sex	Y1980	Y1981	Y1982	Y1983	Y1984	Y1985	Y1986	Y1987	Y1988	Y1989	Y1990	Y1991	Y1992	Y1993	Y1994	Y1995	Y1996	Y1997	Y1998	Y1999	Y2000	Y2001	Y2002
1004	F	OF					G		SMF		S	SFO			FS	S	M	S	SF	M		G	G	
1012	F				F	M	M	SF					S				M	SMGF				S	S	O (PH)
1013	F	MF			M		SM				M					MJ		M	SM		M	M		
1014	F	MF		M	MOF					MGF	M	MS	SM				M	MS	M	M	M			
1019	M	F		GB			MF	M	B	G			M		F		MF	MGF	M	MGN	MG	S		
1027	F	F		BF	BF	SA	MG	MGBF	B	MBF	SMF	B	B		MF	F	MF	MF	MGF	MF	MF	MOF	MG	M
1033	M		M	B			M	B	B	B					F	M	M	MF		M				
1039	F	O						B			M	MS		M		M	M	SM	M	MF	F	OS	S	M
1042	U	GB	G		B			M	GB	B	GB		B					M	MO	MN	G			
1102	M	B	GO	B				B	G	B	B	B	B		F	F	MF	MF	F	MF			G	
1112	M	F	GF	BF	F	MJ	MO	B	F		FM	F		M	FJ	F	M	F	GF		F	MF	G	
1113	M		F	B		O		B	B	GB	B		B		M		M		B	N	F	M	S	
1114	F		GF		B	F		GB	MB			SM	M	M	M	M	MFS	SMF	F	M	F	MGF		
1121	M		GF	GB		MF			F	GF	GF	FB		F	F	MF	F	MFO	MF	M	F	F		
1130	M	GF	GF	F		M		B	B	GB	BJO	MF	B		F	F	FB	SMGF	MF	MF	MOF	M		
1131	M		GF	GF	GB	F	MG			B	F	F	B		F	F	F	MF	F	O	MGF	MOF	G	
1133	M		GF		B	BF	MG		B	GB	B			F	MF		M	F	F	AF	GN	M		
1136	M		F	GF		F	G	B	B	GFB	B	F	MB	F	F	MFJ	F	MF	MF	F	M			
1140	F		GF	F				M	SMGF	G		SMFJ				SMF	M	M	M	M	M	MG	SAF	
1145	F		F		G	MBF			S		SF		MF				S	S				G		M(STB)
1146	M	B	GF		M	MBF			MF	MGB	MGBF			F	F	FJ	F	MF	F	M		MF		
1150	M	O	MF	B	M		MF	F	B	FB	F		MFB	F	F	MF	F	FO	MF	MF	MGF	MBF	MG	
1158	F		F	F		MF		M	G	G	SGF	M	F	M	F	F	MF	S	MFS	SAF	MGF	FS	SG	
1162	M	B	F										B			F	F		F	M	OF	F		
1167	M		F	F			G	MB	B	GB	B		B	F	SF	F	SGF	F	F	F	F	AMOF	MG	
1170	M		F	F	MF	MGF	F	M		GF	F	F	B	F	F	F	F	FO	MF	MAF	MGF	GF	M	
1208	F		M				MG		G	GS	SAG	N	S				S	SF			M	O	M	
1209	F	M		M	B			B	F	F	SB	S	M		F	FJ	F	F	F	MF	GF	AOF	MG	
1239	M		G	F				B	GB	GB	GB		B	M	F	F	F	MFO	F	G	MF			
1240	F			F			F			G	SB	S	F		F	F	F	F	SF	M	MF	MO	G	SG
1241	F			F	MF	MF	F	GF		JF	SF	F	MFB	M	F	FS	SF	M	MF	MOF	F	MF	MG	S
1245	F			F	MF	F	MFO	A	F	F	F	F		F	OFS	SF	FS	SAMF	F	MF	F	MGF	O	
1246	F			F		G		S			SGJF										OF	GF	G	SG
1249	M			OF	F	MG	M	MB	B	GB	B	B	BF		MF	F	MF	MFO	F	MF	MGF	MF	SGO	
1267	F			J	F			GBF	B	BF	GFB	FS	M		MF	MF	MF	SMF	MF	MF	MGF	GOF	MS	M
1270	M	G		B		B				B	B	B								M				
1271	M			B	B			MF		GB	B	B	B			F	F	OF	F	M	GF	MGF	G	M (STB)
1280	U			GB		G	MB	MB	MB	B			M	M	M	M			M	M	O	AM	G	
1281	F		G	B		SM	MA	SF		G	F		B	M	SF	F	MF	SF	F		F	OFS	SM	
1301	F				MF	AM		MB		BS	SF	M	B	BS		F	MF	MF	FS	SAF	MF	MGBS	SG	M
1306	M				MF		F	G	M	GF	GF	B	B	F	F	F	F	SFO	F	F	GF	MGOF	GM	M (STB)
1310	F				GF		G	MF				FJ		O				M	S	M			G	SM (STB)
1311	M				GF		M	GB		GB	B		B	SB	F	MF	F		M		G	SMG	MG	
1317	M				SM	MBJ		GB	B	M	SB		B			OF	F	F	MF	F	MGF	MGF	MG	
1327	M			MG	M	G	M	MBF	M	MB	B	B	GB	F	MF	F	F	FO	F	F	MGF	MGOF	MG	
1328	U				G					B	F	B	G	MBF	F	F	M	M	F		M	MG	M	

B-Browns Bank, F-Fundy, O-Gulf of Maine, G-Great South Channel, J-Jeffreys Ledge, M-Cape Cod/Mass. Bays, A-Mid Atlantic, N-North, S-SE US., M(PH)-Peaked Hill NE of Truro, M(STB)-Stellwagen Bank/Wildcat Knoll, X-area unknown.

Appendix I

Confirmed right whale identifications in Cape Cod Bay and adjacent waters 1998-2002 and sighting histories. Abbreviations are listed at bottom of page.

EGNO	Sex	Y1980	Y1981	Y1982	Y1983	Y1984	Y1985	Y1986	Y1987	Y1988	Y1989	Y1990	Y1991	Y1992	Y1993	Y1994	Y1995	Y1996	Y1997	Y1998	Y1999	Y2000	Y2001	Y2002
1403	M					F		F		GB	B		B	MF		F	F	SM	F	F	GF	M	SO	
1405	F					SF	F			GF	F	F	F	F	F	F	F	SMF	SF	M	M			
1406	F					SMF	MOF			MB	FA		MF	MF	MFA	SMF	MF	M	MF	MF	MF	MOF		
1407	F	B	G	M		SF				F	SMF				SOAF	F			M	M	O	MOGS	S	
1408	F					AF	F	F	F	MF	B	F		F	FMS	SF	F	AF	F	F	GF	F	G	
1409	M					F		B	B	GB	B	B	B		SMF	F	MF	S				M	SG	
1411	M					SF		G		B	MB	B	B		F		F	F	MF	M		M	M	
1424	M		M		B	B	S	M	G	GB	GB	M	B	M	MF	F	F	SMF	F	MAF	MF	GOF	MG	SM (STB)
1425	F			G		F	M		M	B	M	M		M	MFS	SGAF	MF	MF	F	A	M		SG	
1427	M					F	JM		GB	GB	B	B	B	MF	MF	F	MF	FO	MGF	FM	MG	S	M	
1428	M		G			MGO	M	GB		MG	F	FB	B	F	F	F	MF	SMF	F	M		MOF	SM	
1430	F					M	M	MB	MB	MG	B			SM	F	MF	MF	MNS	S	MGN	MO	MO		S
1503	F						F	M	M	MB		F		M	F	F	SFM	MF	BF	MG	MF	MOF	MG	M (STB)
1505	M						MF	AM		GOB	B	B	MF		MSF	FJ	MF	SMF	MF	MOF	M			
1507	M						JOF	M	GMF	GOF	F	FB	MB	F	MF	F	F	MFO	MF	MGFJ	MGF	MOF	MG	M (STB)
1509	F	GB				M	M	SM		B	SJM	M	M	SMJ		M	MN	MNS	SF	M	MG	MS	SA	M
1511	M		G		B	G	M	MBF	B	B	B								F		M	MO	G	
1514	M						MG			MB	B	B	B				M			M		OF		
1601	F							SF	M	GF	F	F	MB		S	F	MF	F	SF	M	G	SO	S	
1602	F							SMF	MF	SMF	F		M	M	MFS	SF	MFS	SMFO	F	MF	GF	MGFS	SMG	M
1603	M							SGJMF	M		B	S	M		SF	F	MF	F	F	M	GF	SMF	M	
1606	M							MF	G	F	B				F	F	F	SMF	F	M	MF	M		
1608	F							SM	GM		F	F	MF	MF	F	F	MF	MFO	F	MF	MGF	MF	MG	M
1609	M							SM	F	F	F		B		F	F	F	SF			JMF	GFB	MG	
1611	F							SM	SF	B	B		B			F	F	MFO	SF	MGF	MF	OFS	S	
1613	M							SJM			FM	F			S	F	F	S	BF	F	F	SAGF	M	
1622	F							M	M	GBS	S	M	SM				F	MS	SMO	M	MG	M	M	S
1624	M							B		GB	GB				F	F			F		G	MG	G	
1630	U							B	B						F	F	F		F		F	MOG		
1701	F								F	F	B	B	FB		FS	F	FS	SF	OF	MF	MGF	FS	SG	
1703	F								F		F	F			SF	SF	F	SF	MF	S	SGF	MOS	SMG	
1704	F								SMGF	SMF	F	BM	MF	MF	MF	MF	MOF	MFOS	SMF	M	M			
1705	F								SMF	GF	GF	SF	F	OF	OFS	SFJ	FS	SF	F		GF	MOF	G	
1706	F								SMF	F	F	F	F		SMF	FJ	SF	MF	MFS	MF	MGF	ASGF	MG	M M(STB)
1708	M								GB	B	B			M	M			M	F	F	MG	MGF	SM	
1709	M								M	JB	B	B	B	M	SF	F	F	F	F	SMF				
1710	F								SM				JM					S				GS	SMG	
1711	F								SM	GB	MB						F	SMF	F	M	SMG	MS	SG	
1712	M								SAM		B	B	B			F	F	F	M		MF	S	SG	
1716	M								B	B	B		B		F	F	F	F	F	G	MF	GF		
1802	F									MGF	MF	MF	MF	F	SMF	F	MF	MFS	F	MF	MGF	MGOFS	SGM	
1803	M									JF		F	F	S	SMF	F	F	M	OF	S	MGF	F	MG	
1804	M									GO	F	F	F	F	F	F	F	F	MF	SF	MGF	AMGF	MG	
1812	F									B	B		B		SF	F	F	S	F		MGF	MOGBF		S
1817	F									B	SB		S	S	SF	SF	FS	SF	F	S	G	MFS	SMG	
1820	U									B	B	B	B		M	F		SMF	MF	M	MF	MOF	MG	

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EGNO	Sex	Y1980	Y1981	Y1982	Y1983	Y1984	Y1985	Y1986	Y1987	Y1988	Y1989	Y1990	Y1991	Y1992	Y1993	Y1994	Y1995	Y1996	Y1997	Y1998	Y1999	Y2000	Y2001	Y2002
1901	M										SGF		S	SF	SF	SF	SF	SMF	SMF	F	MGOF	SOFB	SGM	M (STB)
1909	F										SJM	MJ	B	M	SMF	F	SF	F	MF	MF	SMOGF	GOF	G	
1911	F										F	M				F	MF	M	MF	MF	SMGF	MF	SG	M (STB)
1934	F										SMO		B	M	SF	MF	MF	M	MF	MGF	MGF		G	
1946	F										SGJF	F		M	SF	F	F	FS	SMF	F	F	OF	M	
1960	M																							M (STB)
1968	F										GF		B	B	S	F	F	OF	F	M	MF	MFS	SM	M (STB)
1971	M										F	F		F	F	F	F	F	GF	F	GF	MSAOBF	GO	M (STB)
1980	M										B							SM		M		SMG		
1981	U										F	F			S	F	F	SOF	FS	F	MGF	F	G	
2010	M											FJ	M	M	S	F	F	SF	MF	SM	MGF	SMOB	MO	
2027	M											MJF			F	F	F	MFO	F	M	F	MF	MG	
2040	F											MJF			F	F	F			O	G	MF	SG	S
2048	M											F	F		F	F	MF	M	F	F	MF	SGOB	M	M
2050	F											M		M	SM		MF	SMF	MF	MGF	MGF	MGFS	SMGO	
2114	F											S	SB		M	F	MF		F	M	GF	FB		
2123	F												F	MF	SF	FS	FS	SMFO	SMF	SMAF	MGF	MF	SMG	M (STB)
2135	M												MF	MF	SF	F	F	SMOF	GF	MF	MJOGF	SMF		
2140	M											S	F	F	S	MF	F	SMF	F	MF	MGF	GF	SMG	
2143	F												SF	F	F	F	F	FO	MF	F	GF	SMF	MG	
2145	F												MF	F	MF	F	F	MOF	M	MF	MF	SMF	SMG	M
2150	F												M			F							SMG	
2158	M												F	MF	F	F	MF	MF		SM	MF	MOF	M	
2201	M													SF	SMF	F	MF	SFO	F	SF	MF	GF	M	
2209	M													SMJ	M	F	MF	SMFO	F	AF	MGFS	MGOF	MG	
2212	M													SJM	M		F	F	F	MF				
2215	M													SB	MF	F	MF	SMFO	MF	SMF	MGOF	MF	MOG	
2223	F													F	F	F	F	O	F	MGF	MGFS	MF	MG	O
2240	F													SF	SF	F	F	SFO	F	MG	OGF	MOF	SG	
2271	M													SF	F	F	F	SMOF	F	M	MGF	AGOF	M	
2303	M														SF	SMF	MF	SF	M	SAF	MGF	GF	G	
2304	M														M	F	F	MF	F	F	MOF	MGO	M	
2310	M														F	F	F	F	FS		F	F	MG	
2320	F														S	F	F	SF	SMF	S	GF	MOBFS	MG	M (STB)
2330	F														M		F	F	F	SF	F	GF	SMG	S
2340	M														F	F	M	F	F		MGF	MGF	M	
2350	U														F	F	MF		F		MGF		SMG	M (STB)
2406	U														A	SMF	M	F	F	MF	MGF	MGOF	MG	
2425	F															SGAF	MF			MF	MGF	SMGF	MG	M
2427	M															M	F	MFO	F	F	GF	MF	MOG	
2430	F															F	MF	F	F	F	MGFS	MF	M	
2460	F															F	MF	F			GF	MOF	MG	
2470	U															F	F	MF	F	MF	MGF	MGF	S	
2479	U															F	F	MF	MF	MF	MGF	MF	M	
2503	F																SFM	F	F	MF	F	MF	MG	
2510	U																M			MN		G	SG	

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EGNO	Sex	Y1980	Y1981	Y1982	Y1983	Y1984	Y1985	Y1986	Y1987	Y1988	Y1989	Y1990	Y1991	Y1992	Y1993	Y1994	Y1995	Y1996	Y1997	Y1998	Y1999	Y2000	Y2001	Y2002
2540	M																F	F	F	F	F	MOF	MG	
2602	M																	SMFOA	F	F	F	MF	MG	
2605	F																	SF	F	MF	F	F	G	
2608	M																	AF	F	F	F	MF		
2614	F																	SMF		M	GF		G	
2617	U																	SF	SF	F	F	MF	MO	
2630	U																	F	F	MAF	MF	GF	G	
2645	F																	SAMF	SMF	F	MS	MF	MG	M
2701	F																		SF	SMF	F	A		
2704	M																	S	SMF	MF				
2705	U																		SF	SMF	F	F	MG	
2709	M																		SF	SF	F	MF	MG	M (STB)
2710	U																	S	SF	F	MF	F	G	
2720	U																		F	MF		MF	MG	
2740	M																		SF	F	MF	F	MG	S
2746	F																	S	SMF	F	F	F	M	S
2750	M																		SF	F	MGF	MF	MG	M
2760	U																		F	GFM	MOF	MF	G	
2820	M																			SF	F	F	G	M (STB)
2910	U																				M	F	G	
2920	U																				SMG	MG	MG	
98-443																				M			M	
01-178																						F	M	
01-185																							M	
01-401																							M	
3181																							M	
3102																							M	M
3103																							M	M (Canal)
3110																							M	S
3150																							M	
3160																							M	SM
3180																							M	
3139																								M
1509y																								M
1145ca																								M (STB)
1240ca																								G
1246ca																								G
1310ca																								M (STB)

B-Browns Bank, F-Fundy, O-Gulf of Maine, G-Great South Channel, J-Jeffreys Ledge, M-Cape Cod/Mass. Bays, A-Mid Atlantic, N-North, S-SE US., M(PH)-Peaked Hill NE of Truro, M(STB)-Stellwagen Bank/Wildcat Knoll, X-area unknown.

Appendix II. Sighting records of right whales seen in Cape Cod Bay and adjacent waters, January to mid-May 2002. F (female), M (male), A (adult), J (juvenile), U (unknown), Y (yearling).
In id# column, four digit number is actual right whale individual indentification, five digit number is annual sighting number of unmatched individuals.

Id #	Sex	Age	7-Feb-02	10-Feb-02	14-Feb	17-Feb	22-Feb	23-Feb	25-Feb	1-Mar	2-Mar	5-Mar	7-Mar	15-Mar	19-Mar	20-Mar	25-Mar	29-Mar	2-Apr	5-Apr	11-Apr	15-Apr	17-Apr	20-Apr	24-Apr	5-May	12-May	# of days sighted
IN CCB																												
2645	F	6	X						X																			2
1039	F	22			X																							1
3139	U	1			X						X																	2
1509	F	A				X																						1
1509Y	U	1				X																						1
1027	F	A					X	X	X																			3
1301	F	21					X	X	X																			3
02010								X																				1
2425	F	8						X	X	X	X	X	X															6
1267	F	10							X																			1
02019									X																			1
1608	F	6							X																			1
1706	F	5							X	X	X																	3
2145	F	11								X	X																	2
3160	U	1								X	X																	2
2750	M	5									X	X																2
2048	M	12										X	X															2
02048													X															1
02049													X															1
3102	U	1												X														1
1602	F	8												X														1
02054														X														1
2223	F	10															X											1
3103	U	1																				X*						1
Egs per day			1	0	2	2	2	4	8	4	6	3	4	3	0	0	1	0	0	0	0	1	0		0			
OUTSIDE CCB																												
1145	F	A																X										1
1145c	U	CALF																X										1
2320	F	U																X										1
1960	M	U																X										1
2820	M	U																X										1
2123	F	11																X										1
1271	M	A																X										1
1901	M	13																X										1
2350	U	U																X										1
1424	M	A																X					X					2
1968	F	13																	X									1
1012	F	A																	X									1
02068																				X								1
02069																				X								1
1503	F	17																		X								1
1306	M	A																		X								1
1911	F	13																		X								1
2709	M	5																		X								1
02074																				X								1
1971	M	13																		X								1
1706	F	15																		X								1
02077																				X								1
02078																				X								1
02079																				X								1
02080																				X								1
1507	M	17																		X								1
02082																				X								1
1310	F	A																						X				1
1310C	U	CALF																						X				1
02087																									X			1
02088																									X			1
02089																									X			1
02090																									X			1
02091																									X			1
02092																									X			1
02093																									X			1
02094																									X			1
02095																									X			1
02096																									X			1
02097																									X			1
02098																									X			1
02099																									X			1
02100																									X			1
1240	F	10																							X			1
1240C	U	CALF																							X			1
02103																									X			1
02104																									X			1
02105																									X			1
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X* 3103 photographed by DMF in eastern side of Cape Cod Canal

** These two whales were seen during a aerial survey but on extended tracklines to the north of trackline 1. No right whales were observed in Cape Cod Bay on 2 April.

Yankee Engineer 38(8): 4

Northern Right Whale visits Cape Cod Canal

Story by Joe Mazzola
Photos by John Murner
Cape Cod Canal

The Cape Cod Canal was closed to commercial traffic for five hours on April 15 due to an unexpected visit from an endangered Northern Right Whale. A visitor bicycling along the Canal reported sighting a whale in the middle of the land cut to Marine Traffic Controller Brian Mulvey at around 1 p.m.

The patrol boat CATAUMET, operated by Capt. John Murner, was dispatched to investigate. Upon arrival, deckhand Bob Blackwell identified the marine mammal as a juvenile Northern Right Whale, a critically endangered species.

The Canal was closed to large commercial traffic while the whale remained in the Canal. One tug and barge unit was already in transit at the time of closure and was escorted around the whale by the CATAUMET.

While the patrol boat maintained a protective escort, Marine Traffic Controllers were busy coordinating the closure and maintaining contact with the delayed commercial traffic.

One Coast Guard Cutter and six tug and barge units were held over in Buzzards Bay, while one coastal tanker was delayed in Cape Cod Bay.

The new radar tracking system recently installed at the Canal was instrumental in monitoring the locations of the stalled traffic as visibility in Buzzards Bay was limited by fog. The ability to keep a track on all eight radar targets throughout the closure allowed for a safe flow of traffic into the anchorages, and later the Canal.

The whale exited the eastern end of the Canal at approximately 6 p.m., five hours after the initial sighting and closure. Marine Traffic Controllers then arranged an orderly transit of the backlogged marine traffic and normal operations were resumed.

Cape Cod Bay, the body of water abutting the Canal's eastern entrance, is a critical habitat area for Northern Right Whales from January to early July. NOAA estimates that less than 300 of the whales remain.

The Corps of Engineers, New England District plays an active role in Right Whale conservation.

The Cape Cod Canal Field Office participates in a multi-agency partnership, headed up by the National Marine Fisheries Service, called the Right Whale Sighting Advisory System (SAS) that informs mariners of Right Whale sighting locations.

Top left: The lost right whale peeks its head out of the canal to look at passing boats. Above: The whale heads out of the canal back to the ocean.

Appendix IV

Acoustic Detections of Northern Right Whales in Cape Cod Bay, sampled 23 December 2001 - 29 May 2002

Christopher W. Clark, Cornell Bioacoustics Research Program, 607-254-2408 cwc2@cornell.edu

There is good evidence from previous studies to support the assumption that passive acoustic methods can provide an effective mechanism for detecting and estimating the number of right whales. Preliminary research to evaluate this working assumption was first initiated in late spring 2000 in the Great South Channel, then again in 2001 in Cape Cod Bay and the Great South Channel using autonomous acoustic recorders referred to as "pop-ups". The results were very encouraging. In both seasons and in both locales right whale sounds were detected, and there was a positive association between the presence of whales, as sighted from aircraft, and the number of whale sounds as detected on pop-ups.

For Cape Cod Bay, this applied research continued in 2002 in collaboration with the Center for Coastal Studies[1]. The primary hypothesis is that there is a statistically reliable relationship between the number of right whales in an area and the number of right whale sounds produced. A second hypothesis is that there is a statistically reliable relationship between the activities of right whales and the types of sounds produced.

During winter and spring 2002, the Cornell Bioacoustics Research Program deployed two sets of six pop-ups in Cape Cod Bay. The first set recorded from 23 December 2001 to 3-10 March 2002 at a sampling rate of 1000Hz for an effective frequency range of 10 - 500Hz, on a 2 hours "on" and 1 hour "off" schedule. The second set recorded from 28 March 2002 to 22-29 May 2002, also at a sampling rate of 1000Hz, but with a 3 hours "on" and 1.5 hour "off" schedule. Pop-up positions are shown in Figure 1. Positions were the same for both deployments, four units in a diamond array approximately 5 nmi south of Wood End, one unit north of Sandwich near the "fingers", and one unit off Race Point. All acoustic data from the "Sandwich" and "Race Point" units have been processed for right whale sounds. Array data from only the first deployment have been processed for right whale sounds. None of the array data has been processed for acoustic locations.

Figure 1 shows daily counts of right whale calls for the processed data. The first right whale call was heard on the Sandwich pop-up on 24 December 2001, while the first right whale call was not heard at the Race Point or array units until 2 January 2002. Very low numbers (0-8) of right whale calls were heard throughout January at all three locales. The first obvious increase in vocal activity occurred off Sandwich in the early hours of 1 February. This signaled an overall increase in acoustic activity throughout the Bay for the remainder of the first deployment. There was a hiatus in recording until 28 March. At that time daily call counts were as high as those in early March. Calling decreased throughout April and was sporadic throughout both April and May. It is particularly interesting that almost all calls detected were "contact" calls. No active group sounds, surface slaps from aerial behaviors, or "gunshot" sounds were detected on nearly 5000 hours of recordings.

[1]. This research was initiated in 2000 and supported in 2000 and 2001 by collaboration with the International Fund for Animal Welfare. It is presently supported by a grant from the Northeast Consortium. We also receive logistical support from Daniel Mckiernan of DMF.

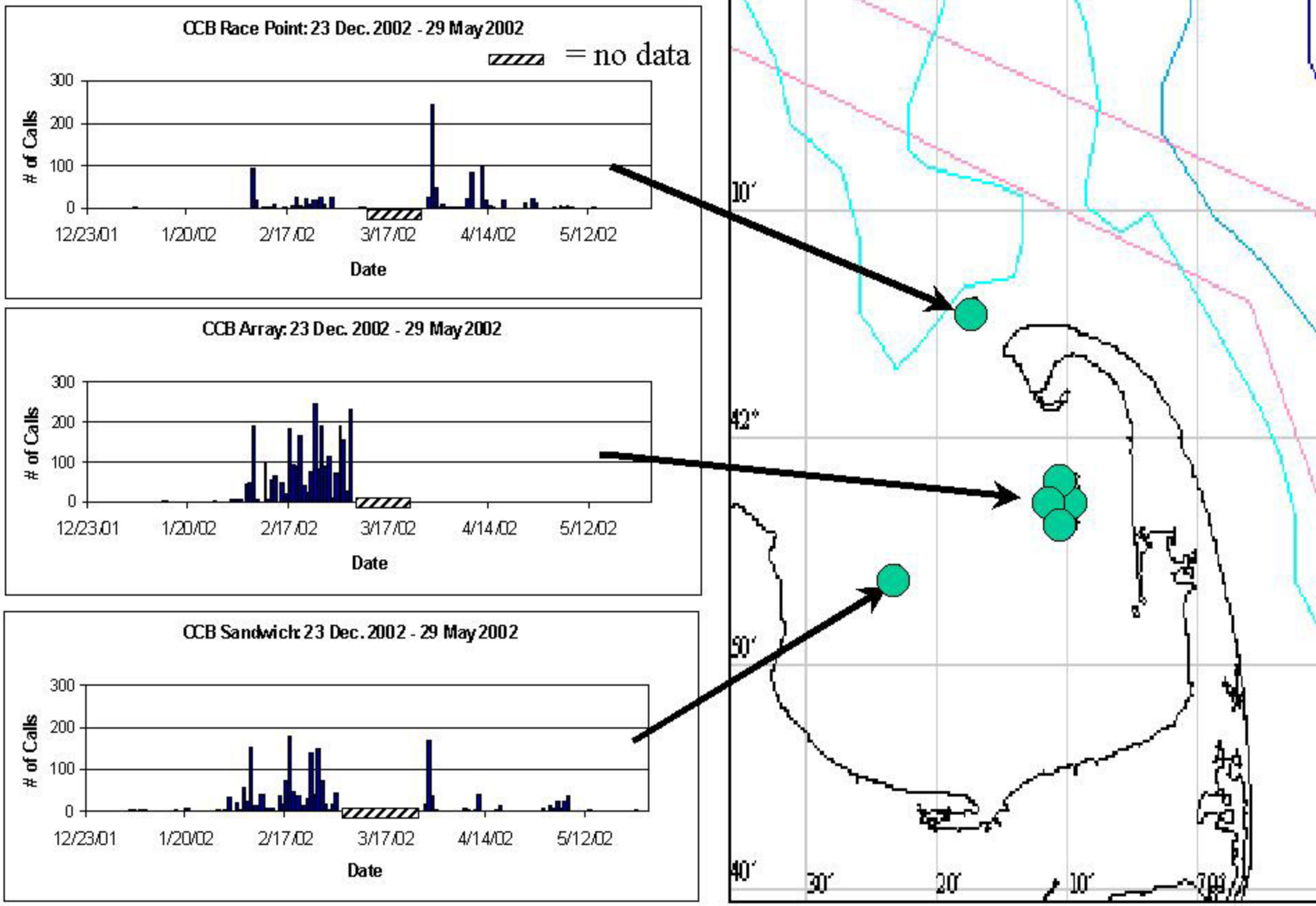

Figure 1. Daily counts of right whale calls in Cape Cod Bay.

Right Whale Occurrence and Habitat Measures in Cape Cod Bay: during a year of change 2002

Final Report
Chapter Two

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Executive Summary

As in the past years the zooplanktonic food of the right whales was collected at locations through out Cape Cod Bay in order to describe the resource that is believed to attract the whales to the region. In 2002, during the usual residency period for right whales in the winter and early spring, a shorter than expected residency period coupled with reduced numbers of whales presented an opportunity to explore the relationship between food resources and whale occurrance patterns.

The results of the comparisons of food density counts and whale residency measures over the past 4 years of coordinated habitat sampling and aircraft surveys suggests that zooplankton densities during January and February, principally of the copepod genera *Centropages* and *Pseudocalanus,* may have resulted in suppression of whale occurrance in those months. However, the comparisons in January and February do not wholly explain the reduced density of whales we observed, perhaps because zooplankton sampling in past years was not focused on the description of the quality of the bay's food resources. In mid- March through early April, the usual time of greatest whale abundance and the peak in the richest of the food resource, the copepod *Calanus finmarchicus,* the late stages of *Calanus* capturable by right whale baleen were absent from the collections. This decrease in available food was associated with a departure of the right whales. Such a decline in food availablility has not been documented in Cape Cod Bay in 19 years of study. The patterns of taxonomic dominance in the 2002 samples reflected the changes observed in the food density characteristics, with the early and mid season showing a copepod dominance by *Centropages* and *Pseudocalanus* respectively, but with the *Calanus* resource being replaced by the estuarine copepod *Acartia tonsa*. This change in dominance was not a typical replacement of one species by another which might be signaling a change in the fundamental character of the Cape Cod Bay system, but instead, as the minimal increase in *Acartia* density suggests, simply a reflection of the failure of late-stage *Calanus* during the early spring. Late spring *Calanus* densities rebounded, suggesting that the observed changes in the food resource that so influenced the right whales was due to a delay in the appearance of the *Calanus* resource rather than a loss of the species to the system.

The observations suggest that directed monitoring of food resources in Cape Cod Bay may be a useful addition to the present management paradigm, permitting prediction of the degree and timing of whale residency. Combined with small-scale sampling for locating whale aggregations, habitat-quality monitoring of the kind used in 2002 can inform existing management efforts to improve the accuracy and responsiveness of conservation schemes to the benefit of both whale conservation and the fishing industry.

Introduction

The unusually low occurrence rate of the right whales in Cape Cod Bay during 2002, as detailed in the earlier chapter of this report, offers an opportunity to compare the environmental conditions that are less favorable to right whales with those conditions in past years that supported the whales' long residency during the winter and early spring. This section of the 2002 report makes such comparisons and offers some suggestions for the use of habitat measures in the management and prediction of whale occurrence in Cape Cod Bay and adjacent waters.

The biology of the right whale has been widely reviewed (Gaskin, 1982; National Marine Fisheries Service, 1991), yet a clear understanding of the influence of the habitat on the distribution of whales is just being developed. The relationship between areas of dense food and the aggregation of whales has been described by Beardsley *et al.* (1996) and Mayo and Marx (1990), and presented in a conceptual model by Kenney *et al*(2001). This relationship is more than of passing interest because solutions to the most pressing issues of management of this nearly-extinct species depend upon knowledge of where and when whales are in habitats (Mayo and Bessinger, ms. in prep.). The identification of habitats needing protection based on occurrence patterns underlies the management of anthropogenic causes of mortality, hence the use of habitat measures deduced from the 2002 studies may substantially improve our ability to develop management schemes that better reflect the occurrence of whales and thereby better protect the whales.

In Cape Cod Bay, the conflict between fisheries activities and whales has been managed on a seasonal basis, using the distribution and occurrence of whales observed in past years as a foundation for the temporal and spatial management of habitats where whales may occur. Thus Cape Cod Bay is regulated during the winter season when whales are present in the region. During that season the presence of whales in the bay has been monitored by aircraft as described earlier. In Cape Cod Bay the co-occurrence of seasonally intense fishing activities and aggregations of whales has led the Commonwealth of Massachusetts through its Division of Marine Fisheries (DMF) to undertake the most intensive monitoring project in the waters of eastern North America. The goal of the monitoring is to develop an understanding of the occurrence of whales complete enough to permit management of the fisheries to reduce the likelihood of entanglement in fishing gear. Particularly important in the development of the surveillance-based management scheme envisaged by the DMF is the accurate documentation of whale occurrence in the waters of Cape Cod Bay coupled with, if possible, some verification and predictive capacity. Armed with good surveillance and predictive data, a reduction in the threat to whales from entanglement may be accomplished without the disruption of the economically stressed fishing industry.

If the timing and geographic coverage of conservation regulations were improved by adding surveillance techniques that profile the conditions that govern the whales' residency patterns then management strategies would be both more predictive and reactive to the natural variation in the habitat use patterns of the whales. The decreased residency of whales in 2002 in Cape Cod Bay presents an opportunity, unique in the study of whale habitats, to focus on the underlying influences of food distribution and habitat quality on the broad-scale presence of whales. By comparing selected previous years' whale occurrence patterns with habitat descriptions, indicators of whale presence may be defined. It is important to note that only in Cape Cod Bay are the systematic survey efforts and the requisite long time series studies of habitat quality available to permit assessment of the value of environmental indicators of right whale presence.

Background

The basis for the widely held belief that the occurrence patterns of right whales are principally influenced by the distribution of their food comes from an understanding of the feeding ecology of the species. The right whale feeds by filtering water through two dense racks of finely divided baleen (Pivorunas, 1976). The whales feed by swimming with mouth gaped, water entering the buccal cavity through the anterior opening between two walls of baleen. Thus trapped in the mouth cavity and under hydraulic pressure, water exhausts through the baleen filtering wall catching planktonic food organisms on the inner, finely-fringed surface of the racks. Right whale feeding appears to be nearly-continuous (Gaskin, 1982), the dominant behavior of the whales in the high latitude part of the range of the species (Kenney *et al*, 2001). That "grazing" dominates the life of the whales is clearly a response to the need of the individual whales to capture a substantial daily caloric ration from a system in which resources are not easily predictable at the small scales at which harvest occurs. Thus the high-latitude movement and distribution of the right whales is largely governed by the feeding imperatives of searching and area restricted foraging behavior.

The relationship between whales' presence and their food in the Cape Cod Bay region has been described by Mayo and Marx (1990) and Watkins and Schevill (1979). We use the findings of those authors as a basis for exploring the unusual occurrence patterns of whales in Cape Cod Bay in 2002. Generally we seek to test the hypothesis that changes in food distribution and occurrence in the bay resulted in the decline in whales observed during the surveys reported in the earlier chapter.

Methods and Materials

To examine the hypothesis that food quality is the principal influence on right whale occurrence, we compare the food resources of Cape Cod Bay with the density of whales estimated from trackline surveys during the 1999-2002 winter and early spring. The foundation of the methods for the zooplankton estimation has evolved from studies conducted over the past 19 years detailing the distribution and occurrence of zooplanktonic foods of the right whales in Cape Cod Bay. The methods used for the estimation of zooplankton density are described in detail in earlier reports to the Division of Marine Fisheries and the Massachusetts Environmental Trust.

Habitat studies in 2002 were focused on collections of zooplankton that could be used to describe the food resource that is thought to control the occurrence of whales. Sampling was conducted throughout the Cape Cod Bay system focusing on the area of the federally designated Right Whale Critical Habitat, with samples for comparison with past years made at stations that have been sampled since 1984. Such sampling at regular stations is the foundation of the comparative efforts of 2002 because it characterizes the quality of the bay as a whole and the conditions that likely influence the activities of right whales. Additional zooplankton samples were collected where whales were present and in locations where, in past years, aggregations of whales were resident and feeding. These sampling protocols represented respectively the conditions in the area of harvest and the resource quality associated with particularly productive parts of the embayment. Taken together the regular-station, whale-present, and productive-area collections offered a basis for comparison of the 2002 observations with those of past years, particularly during 1999-2001 when whales were common in the bay and documented by aircraft survey.

Zooplankton samples were collected using (1) surface conical zooplankton nets towed behind the vessel, (2) vertical pump collections taken at intervals throughout the water column, and (3) transect sampling using a collector placed less than 1 m. beneath the transom of the vessel. All collections were made using 333μm mesh to approximate the capture of zooplankton of the sizes filtered by right whale baleen (Mayo *et al,* 2001). Therefore, the zooplankton resource we characterize may be viewed as that available to right whales. The samples collected by conical surface net tow were corrected as described by Mayo *et al* (2001). Samples were enumerated with the aid of a dissecting microscope, identifying zooplankton organisms to the lowest practically identifiable taxon based upon established descriptions (Murphy and Cohen,1978). Zooplankton densities were expressed in organisms/m^3.

To compare the available zooplankton resource in Cape Cod Bay with the whales' aggregative behavior, we developed a measure of whale density averaged over the entire bay. The density calculation for each survey was made using the number of right whales sighted along the survey tracks divided by the estimated number of 'on-trackline' miles completed to produce an index of whales per unit of effort. All tracks in the standard CCB survey design (see Chapter 1) were used in the calculation, with the exception of track 16 (along the eastern shore of the Cape). This treatment and the rigidity track survey protocol permitted us to reliably estimate the density of whales observed on each survey and make comparisons with zooplankton richness.

For both zooplankton and whale density analyses, data were averaged for 2 week periods of the season starting with 1 January. We chose for particular focus two two-week periods of the mid- and late-winter/early spring when whales are usually present in Cape Bay and during which they were in low numbers or absent in 2002: 2/12 - 2/25 and 3/26 - 4/8.

Results

The average surface density of total copepods is shown for the four years of comparison in Figure 1.

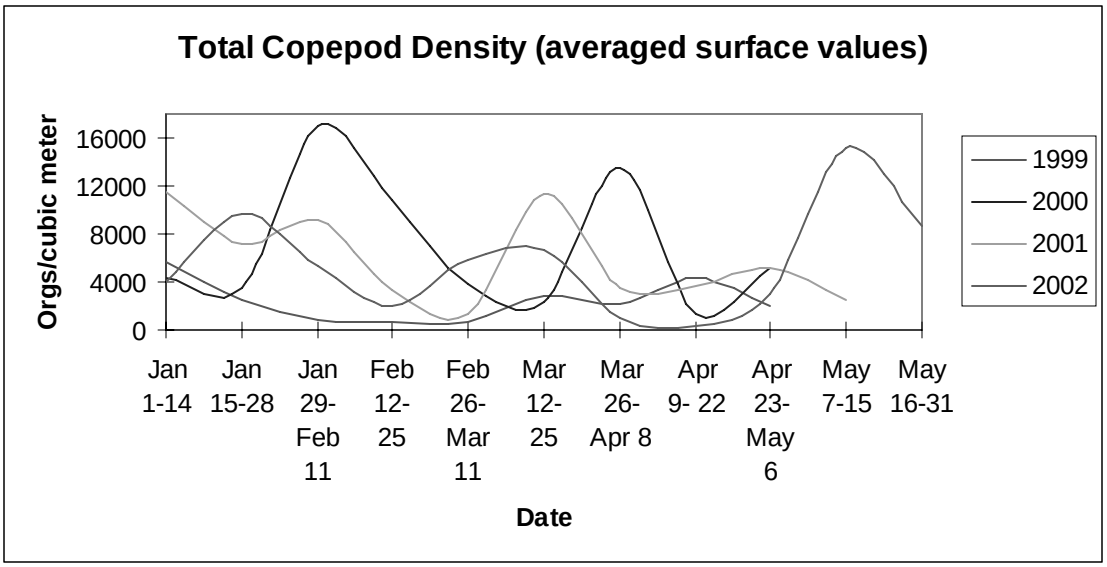

Figure 1. A comparison of total copepod densities averaged by 2 week periods

The estimated whale density/trackline mile from Cape Cod Bay aircraft surveys reported in chapter 1 and earlier reports to DMF for 1999-2002 are presented in Table 1.

	1999	2000	2001	2002
Jan 1-14	0.0252	0*	0.031	0
Jan 15-28	0.0275	0.0068	0.0112	0
Jan 29-Feb 11	0.0582	0.0335	0.0444	0.0011
Feb 12- 25	0.0582	0.0608	0.0255	0.013
Feb 26-Mar 11	0.0441	0.1058	0*	0.0156
Mar 12- 25	0.054	0.1395	0.0896	0.0026
Mar 26- Apr 8	0.077	0.133	0.0603	0
Apr 9- 22	0.0554	0.0053	0.0491	0
Apr 23- May 6	0.0176	0	0.031	0
May 7-15	0	0	0	0

Table 1. Mean sighting rate of right whales from air surveys during 1999-2002 averaged by two week period expressed in whales per trackline mile. * No aircraft surveys conducted during this period.

The relationship between food and whale density over the 4 years of the study is shown in Figure 2 - 5 and summarized in Figure 6. To make the comparisons with past years we compared all data analyzed from zooplankton samples collected at stations (presented in Figure 1) with the whale sighting rate (Table 1).

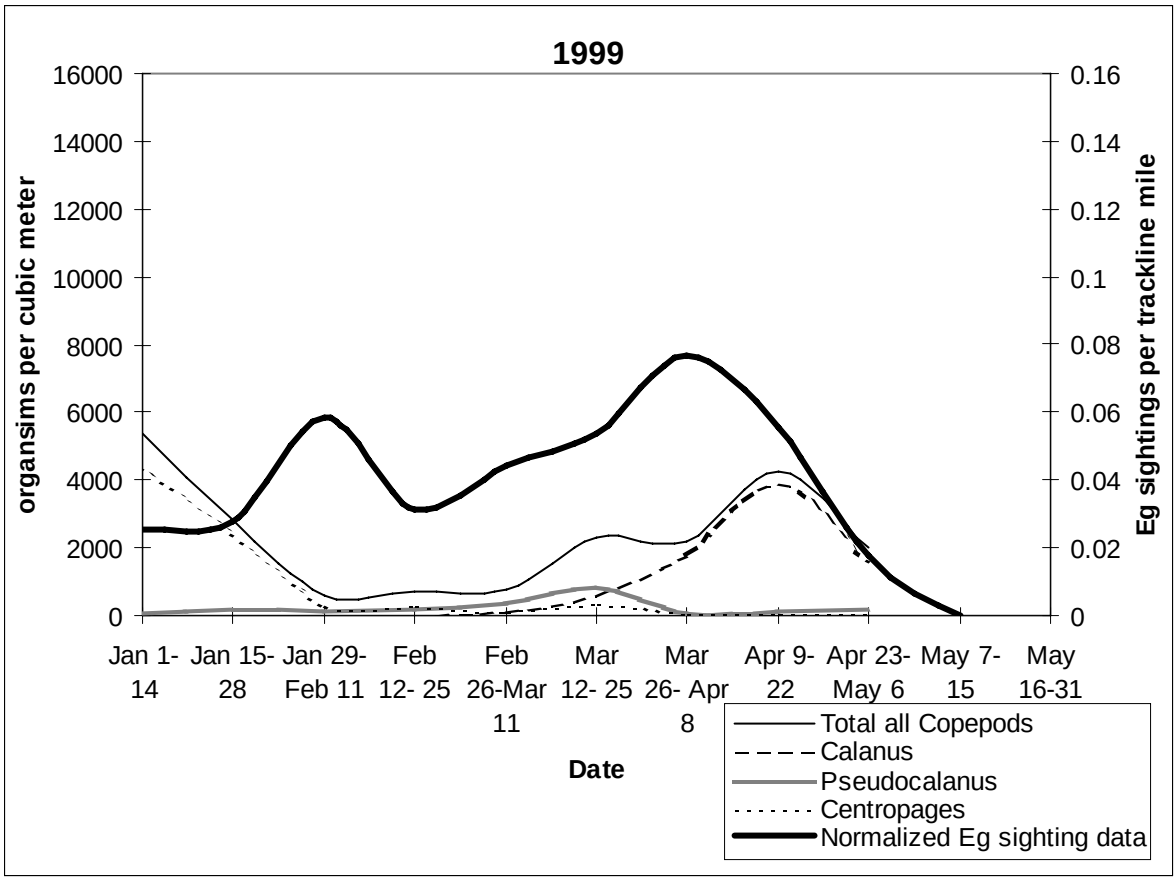

Figure 2. A comparison of the whale density estimated from aircraft survey with zooplankton density from Cape Cod Bay averaged by two-week period during 1999.

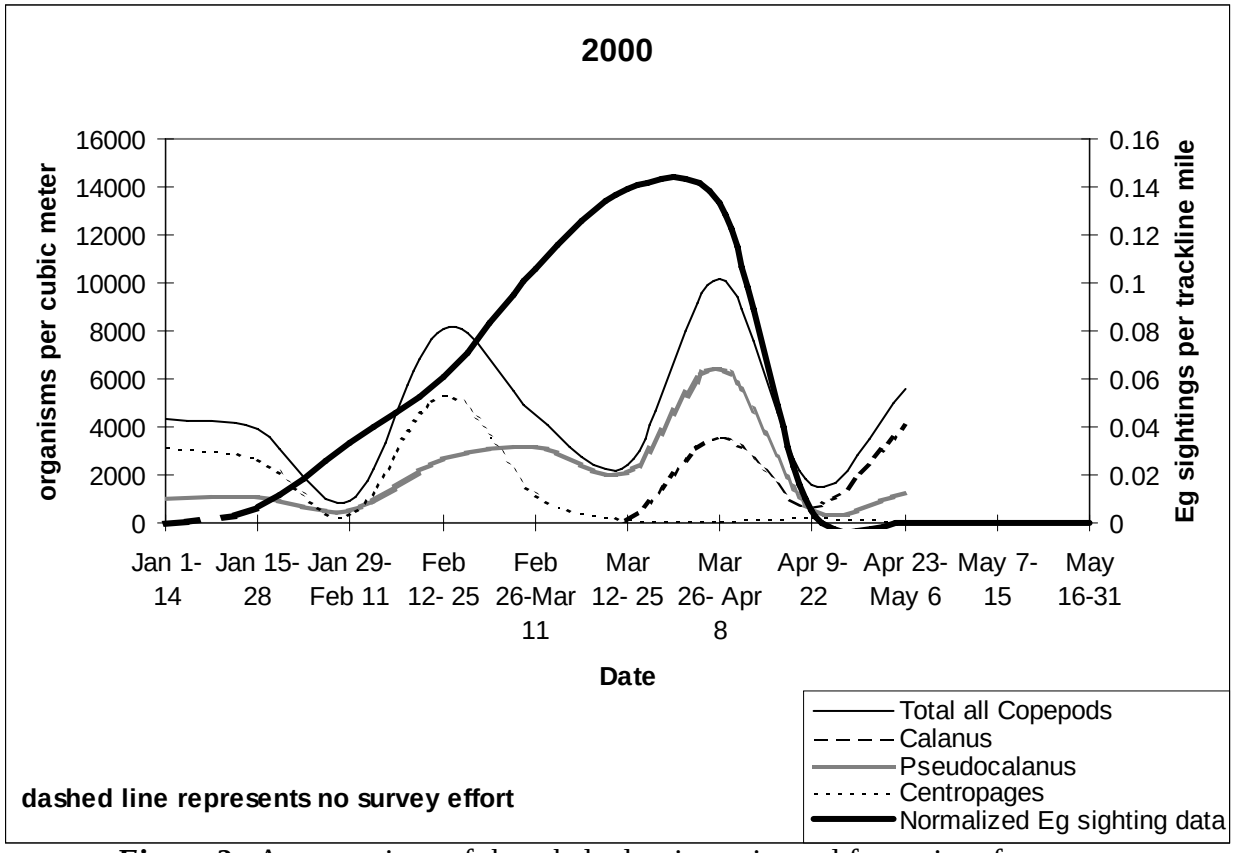

Figure 3. A comparison of the whale density estimated from aircraft survey with zooplankton density from Cape Cod Bay averaged by two-week period during 2000.

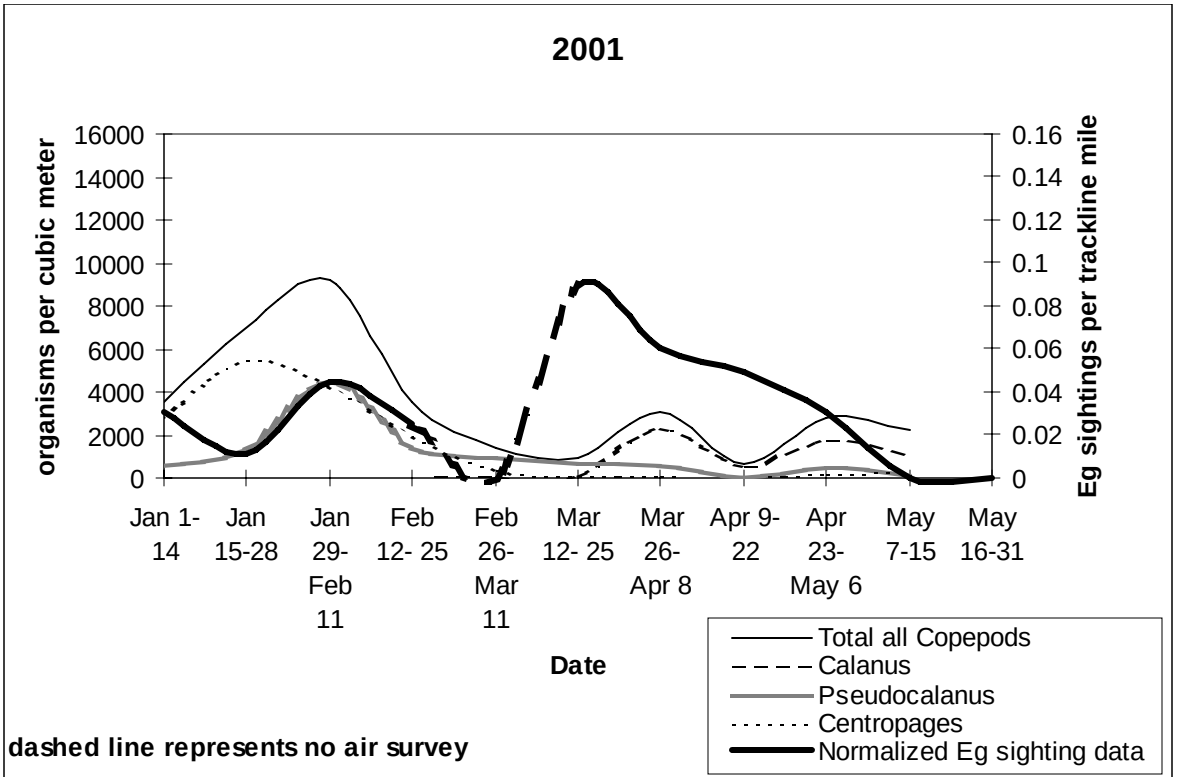

Figure 4. A comparison of the whale density estimated from aircraft survey with zooplankton density from Cape Cod Bay averaged by two-week period during 2001.

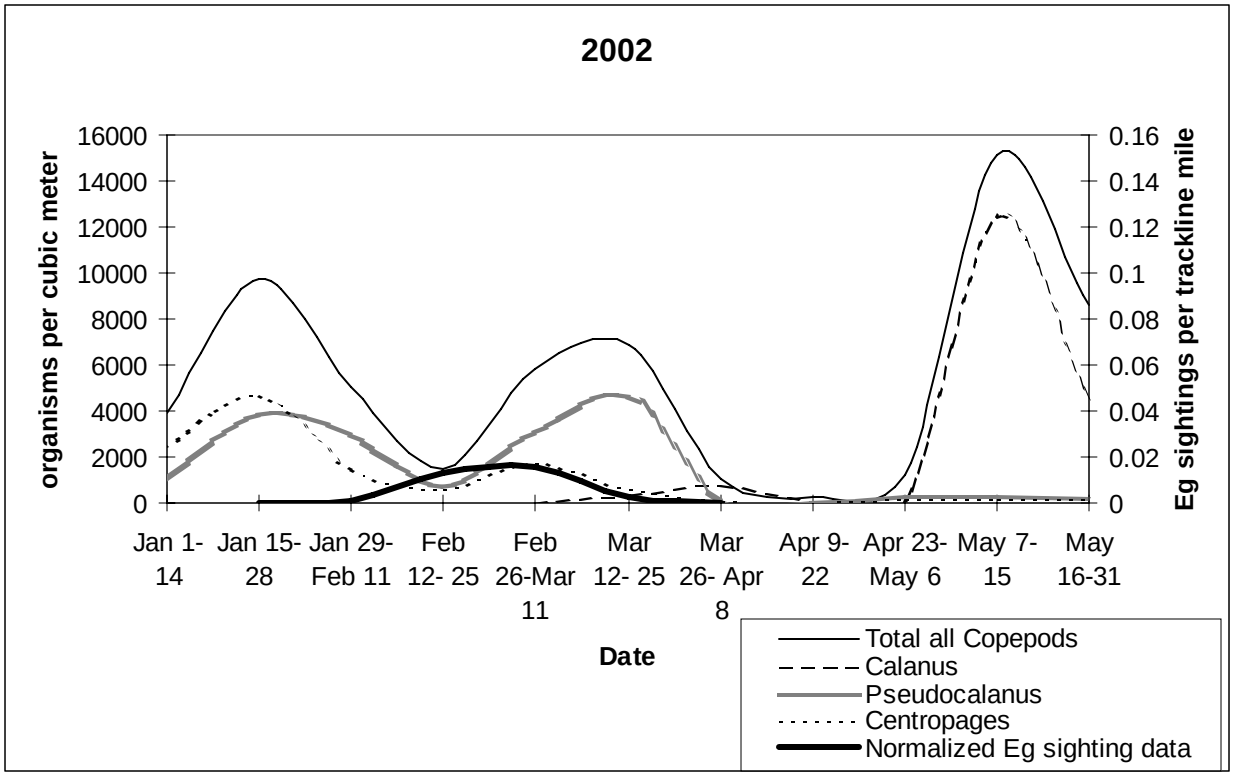

Figure 5. A comparison of the whale density estimated from aircraft survey with zooplankton density from Cape Cod Bay averaged by two-week period during 2002.

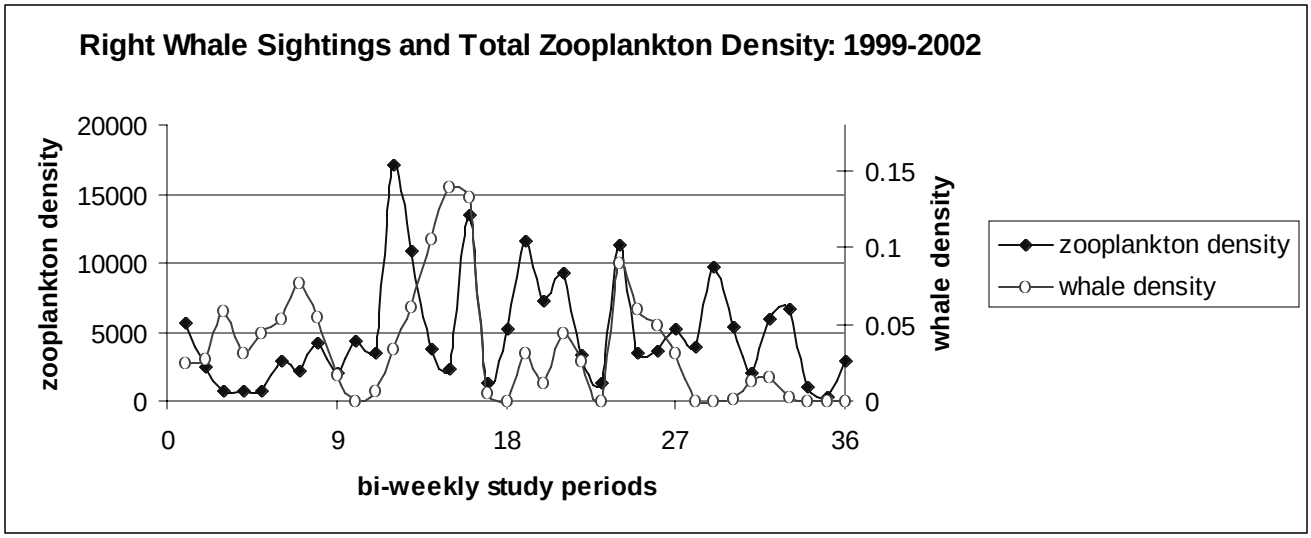

Figure 6. A comparison of the whale sighting rate and total zooplankton density through the winter seasons as detailed in Figures 2-5.

A comparison of copepod dominance by species is shown in Figures 8-11. For the treatment in these figures we have chosen to analyze and compare the densities during two two-week periods, mid-winter, 12-25 February, and late winter and early spring, 26 March - 8 April. These periods were chosen because it is during those weeks that right whales are usually abundant along with two of the most important and dependable food resources of the winter right whale season, those of *Pseudocalanus minutus* and *Calanus finmarchichs*.

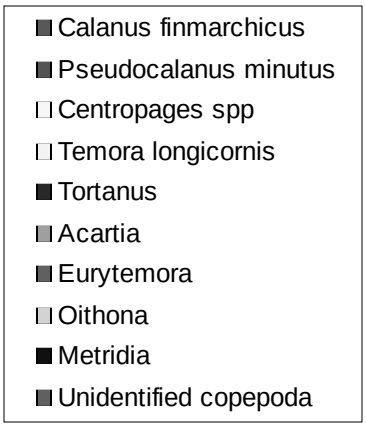

Figure 7. Legend for figures 8-11 showing copepod species dominance 1999 - 2002.

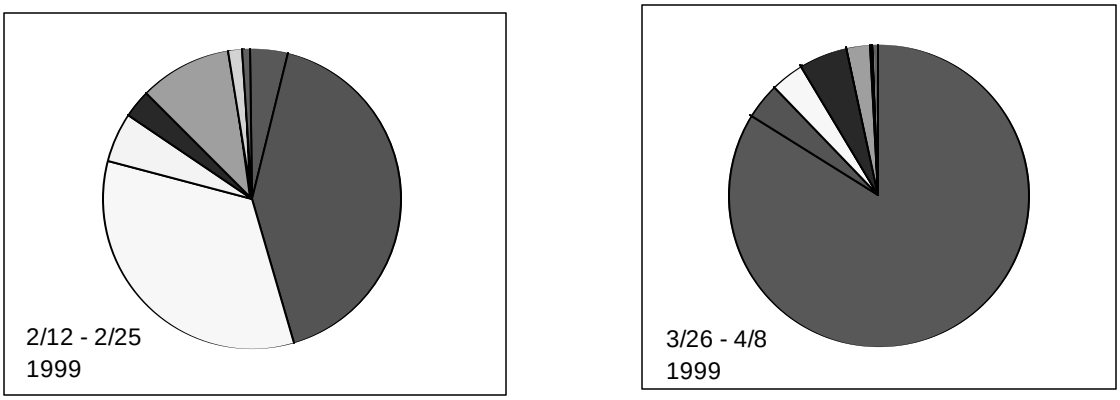

Figure 8. Species composition of zooplankton collected at regular stations during representative two week periods of the 1999 season.

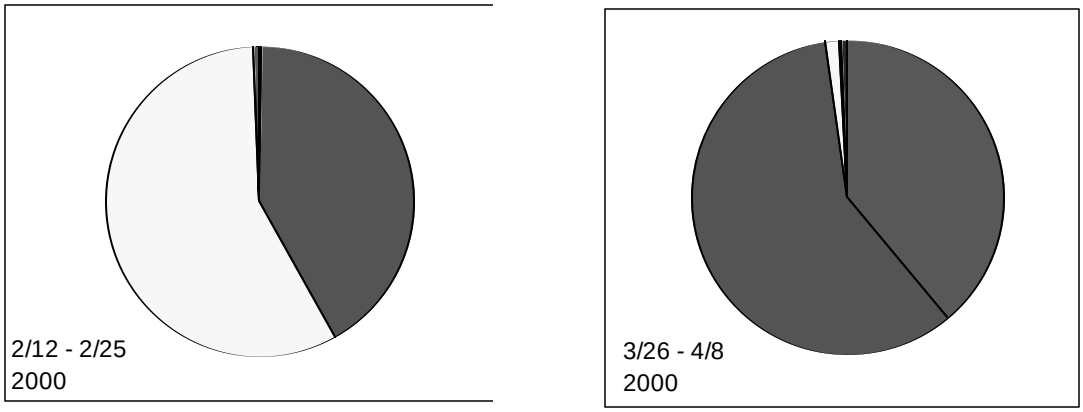

Figure 9. Species composition of zooplankton collected at regular stations during representative two week periods of the 2000 season.

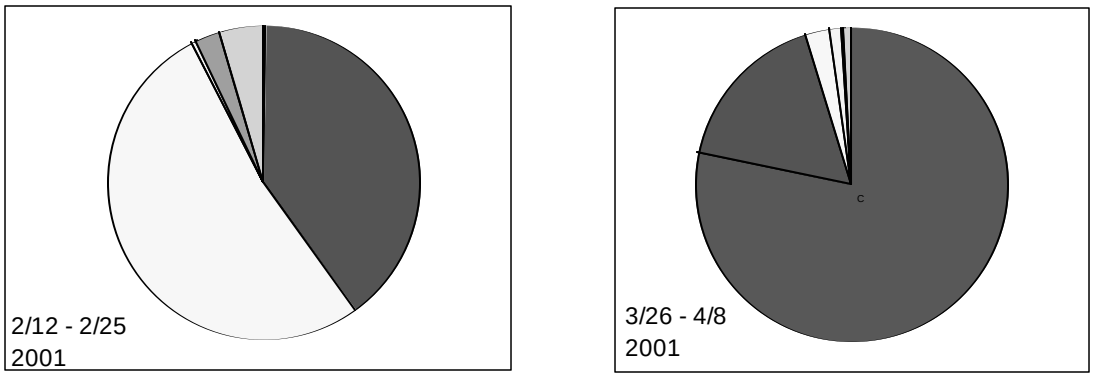

Figure 10. Species composition of zooplankton collected at regular stations during representative two week periods of the 2001 season.

Figure 11. Species composition of zooplankton collected at regular stations during representative two week periods of the 2002 season.

The suggested dominance of *Acartia tonsa* appearing in the foregoing pie charts during 2002 (Figure 11) is examined in Figure 12 in which its density during the 1999 - 2002 seasons is summarized.

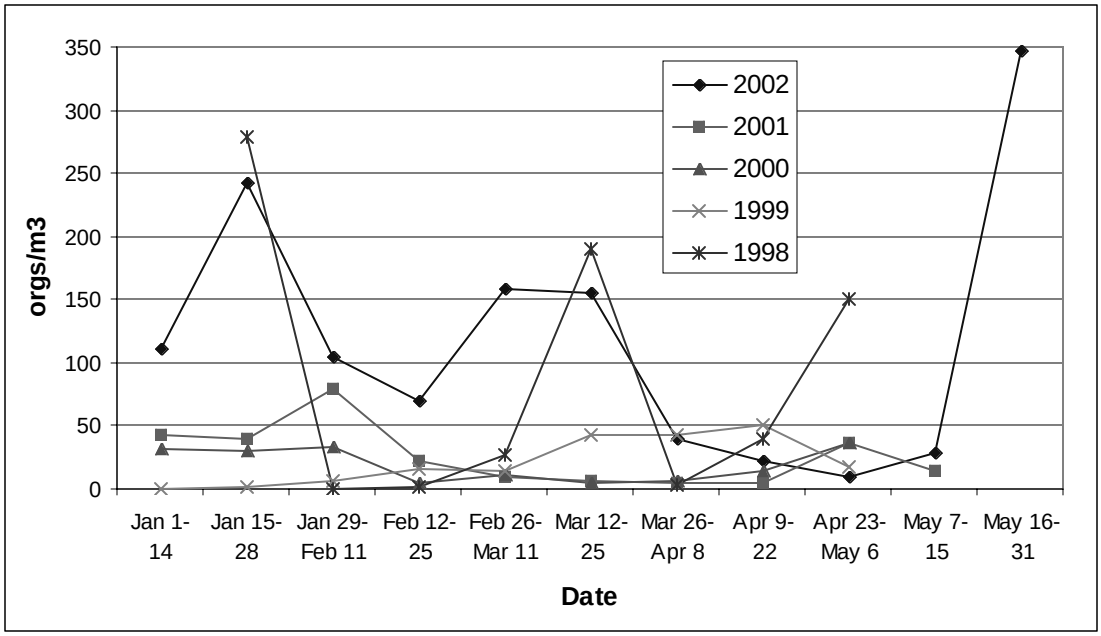

Figure 12. Variations in the density of *Acartia* during 1999 - 2002 as estimated from zooplankton collections at regular stations.

Interpretation

Because right whales spend much of their time feeding while in Cape Cod Bay, it has long been assumed that dramatic variations in whale occurrence within the bay are primarily influenced by changes in the condition of their food resource. In their study of the area, Watkins and Schevill (1979) suggested that the small-scale movements of right whales were controlled by the distribution of food patches. More recently similar conclusions have resulted from observations in a number of habitats frequented by right whales (Murison and Gaskin, 1989; Kenney and Wishner, 1995; Baumgartener and Mate, 2001) and advanced work using satellite imagery has been undertaken to identify regions of high primary productivity, on the assumption that such conditions encourage the development of the whales' food resources resulting in whale aggregations (Wagner and Bisagni, 2000).

The analysis in this chapter was aimed at a comparison of zooplankton data and airsurvey estimation of

whale density through the last four years of study. Figure 1 demonstrates the extreme variability in the total available zooplankton resource, the resource harvestable by right whales, while Table 1 shows the measure of whale density for the same period. Those two sets of data brought together in Figures 2-5 suggest that bay-wide patterns of food resource availability impact whale occurrence. These figures detail the variations in copepod taxa collected by the 333m mesh net intended to mimic the filtering capacity of right whale baleen. Clearly shown is the seasonal progression of taxonomic dominance of the midwater copepod resource that influences whale residency, with *Centropages, Pseudocalanus,* and *Calanus* assuming dominance or near-dominance during the early-, mid-, and late winter respectively. Also apparent is the late winter and early spring peak in total zooplankton, perhaps a response to the spring bloom of diatoms. Our concept of the patterns of zooplankton enrichment that appear in the figures may be refined by an understanding that all copepods are not of the same size or caloric content, thus total organism counts only approximate the richness of the food resource. While the adult and late stage forms of most copepod taxa are generally of comparable food value (Laurence, 1976), the exceptions are *Calanus* that is larger and calorically more valuable per individual and *Pseudocalanus,* a smaller and less valuable food item. For example, when *Calanus* is available in th late winter and early spring, the caloric enrichment of Cape Cod Bay by the second trophic level copepods is considerably greater than suggested by the zooplankton density values shown in the series of figures. Thus the late winter/early spring *Calanus* enrichment should have an even greater impact on the whales' energy intake than suggested by a simple comparison of the density estimates of the dominant species of copepods. So too, control of the presence of whales in the bay by the rich *Calanus* resource should be greater than implied by the trajectory of simple zooplankton density.

The trackline density of right whales calculated from the survey efforts (Table 1) demonstrates several characteristics typical of their winter residency in Cape Cod Bay. Most years as seen in Figures 2-4 whale density peaks in March with occasional smaller peaks and valleys in estimated density shaping each season's occurrence pattern. The within-season variation in density suggests that occurrence of whales in the bay is the result of pulses - with peaks followed by declines in density over periods of several weeks. These variations and individual identification analysis reported in chapter 1 suggest a pulsed pattern of emigration and immigration. The question that remains is: are these pulse patterns observed from aircraft survey reflective of changes in the zooplankton resource? More simply, can the data show the putative influence of food resources on whale aggregation and dispersal?

With consideration of the differences between caloric richness and the counts presented in the figures, the comparisons presented in Figures 2-5 demonstrate the characteristics of the general association between copepod and whale density. The influence of the food resources on whale presence is summa-

rized by the following characteristics of the observed relationship:

Timing: The association between the food resource and whale density is particularly clear during the late period of the right whale season when a dip in total zooplankton is usually closely associated with a decline to zero in the whale density. However, a Spearman Rank Correlation Analysis does not demonstrate a simple association ($p > 0.1$) between variations in whale density and variations in total zooplankton. We assume that the effects of a variety of influences not directly related to the development of the food resource are confounding such an analysis. Among those variables that may be affecting the association between trends are (1) the influence of other feeding areas on the movement of whales, a "competition" between feeding areas and (2) the tendency of zooplankton density data to vary in extreme ways to which whale densities cannot respond in like degree.

Taxonomic Composition: The influence of taxonomic composition on the seasonal patterns of right whale residency in Cape Cod Bay appears to be an important consideration in the bay's attraction to right whales. Sightings during the earliest survey flights in 1999 and 2001 show that right whales were present in Cape Cod Bay before 1 January and zooplankton collections confirm that a moderately high copepod resource, principally *Centropages*, formed the basis for the feeding activities that lured whales into the bay in December. Though variable in its density, *Centropages* was followed each year by *Pseudocalanus* which appeared to peak in the surface station samples in from late February to mid March. In mid March of 1999-2001, as *Pseudocalanus* declined, *Calanus* increased and formed a rich food resource, perhaps the richest of the three species that support right whales in the bay. In 2002, while the densities of the first two species of copepods that support the residency of whales during the early part of the year in Cape Cod Bay were low, the clearest difference between the years was associated with an absence of the rich late-stage *Calanus* during the usual peak period of late March and early April. In 2002 the anticipated *Calanus* increase failed and other taxa did not "fill in".

Figures 2-5 demonstrate that the time of departure from Cape Cod Bay varies and this variation is probably associated with a decline in zooplankton resources expressed in total zooplankton density.

Species Dominance and Potential Ecosystem Change: In some respects the 2002 season progressed as the previous three, with copepod density in the early winter, first in *Centropages* and later in *Pseudocalanus* appearing relatively typical if reduced from previous seasons. Nevertheless, right whale presence was depressed in the early and middle parts of the season. Most dramatically, at the end of the *Pseudocalanus* portion of the season, during the early and middle part of March, the usual increase in *Calanus* capturable on 333m mesh did not occur. A review of our database shows that, of the 19 years of study, the failure of late-stage *Calanus* during late winter was unique to the 2002 season. The failure of late-stage *Calanus* in the late winter of 2002 appears to be a factor cuing the early departure of whales

from Cape Cod Bay at a time when, in past years, aggregations of whales were commonly observed. Furthermore, it is clear in Figures 8-11 that the pattern of species dominance at the critical late winter and early spring period was unusual. During 2002 the mid winter zooplankton resource was dominated by *Pseudocalanus* as was typical of previous years and of all seasons back to 1984. However, in 2002 the usually dominant *Calanus* of the late winter and early spring was replaced by the estuarine calanoid copepod *Acartia tonsa*. For a system that is seasonally and reliably characterized by a period of richness based on *Calanus*, the effects of a change to an *Acartia* - based system would be profound and, as in 2002, would assuredly change the relationship of a midwater planctivorous species such as a right whale to Cape Cod Bay.

Was the change in dominance from *Calanus* to *Acartia* (compare Figure 10 early spring 2001 with Figure 11 for the same bi-weekly period) a true species shift, one that might profoundly reduce the value of the bay to right whales in future years? This question is of ultimate importance to conservationists and managers since, as 2002 demonstrated, a long-term change of the quality of the winter feeding grounds of Cape Cod Bay would affect the health and well being of the species and would impose patterns of habitat -use substantially different than those against which DMF has managed the embayment in the past. It is of course not possible to predict the patterns of copepod dominance in the bay, given the complex influences on the system. However we can explore the basis for the change observed in 2002. While the change appears to be profound in the comparisons in Figures 8-11, the seasonal density description (Figure 12) shows that the events of 2002 were <u>not due to a replacement</u> of *Calanus* by *Acartia*. Instead *Acartia* remained at typically low densities through into the early spring while, because of the failure of the development of the late-stage *Calanus*, nevertheless dominating the copepod resource available to right whales. The change from a *Calanus* system to an *Acartia* system that apparently contributed to a shortened residency of right whales was in fact due to a failure of late-stage *Calanus* resource to develop at the usual season. We suggest that the absence of *Calanus* during the early spring weeks was due either to a change in the physical processes that advect copepods into Cape Cod Bay or to a delay in the development of the *Calanus* resource and hence the slowed development of the late-stages of the species. Supporting these hypotheses are the data from the mid- to late spring (Figure 5) when a peak in *Calanus* appears in 2002. These data suggest that the changes in Cape Cod Bay that so profoundly affected right whale presence in the late winter and early spring were due to a delay in the timing of the development of the usable *Calanus* resource. The cause of this delay is unknown, however should the processes that resulted in the changes in the timing of *Calanus* enrichment be again coupled with weakness in the development of the early and mid - winter species of copepods, we should expect that use of Cape Cod Bay by right whales will again be limited and short in duration.

Management Value: The forgoing interpretation suggests the use of zooplankton resource measures to aid in the management of whale - fisheries conflicts. With such measures from stations it should be possible to define the richness of the Cape Cod Bay system and therefore its attractiveness to right whales. To aid in an evaluation of the capacity of the system to attract and hold whales, particular attention should be paid to two measures that appear important to whale residency:

(1) the development of the typical seasonal progression of taxa with particular attention to the development of a capturable (= on a 333m mesh) *Calanus* resource during the period of 1 March to 15 March. We emphasize this particular resource because its absence appears to have had a significant influence on whales in 2002 and because *Calanus* is a nutritionally rich copepod that supports the peak right whale aggregations during many years. Monitoring of the *Calanus* resource during the late winter should permit prediction of either continued whale residency or departure.

(2) the productivity of the genera of copepods that support feeding from December through early March, *Centropages* and *Pseudocalanus*. The 2002 study suggests, and future study should confirm, that low available biomass of the two early-season copepods reduced the attractiveness of the habitat. To quantify such an influence and to use it in prediction will demand tracking of the resource starting in early December to establish a baseline for ongoing comparisons within the season and with other seasonal patterns. If the baseline is low in December it seems likely that the remainder of the season has a good chance of being low too.

Tracking of the early season zooplankton density and of the development of the *Calanus* resource will allow a process that should directly inform the management process with respect to the need to extend management actions or to shorten them because of anticipated changes from the historic occurrence patterns on which regulation has been based.

Conclusions

It is not possible to define with absolute certainty the causes of the unusual occurrence patterns of right whales in 2002. Nevertheless, the evidence presented here does strongly suggest that a combination of conditions unfavorable to right whale foraging activities led to the low residency and early departure from Cape Cod Bay. Contributing to the low occurrence rate in January and early February was a reduced total zooplankton density due to lowered productivity of *Centropages* and *Pseudocalanus* as

appears in the data summarized in Figure 1. This figure shows that total zooplankton density was low through the entire 2002 season, though not as low as in 1999. The nadir was reached when late-stages of *Calanus finmarchicus* did not appear in the mid March to mid April period. We suggest that a number of conditions in Cape Cod Bay, most dramatic of which was the failure of the usual late-winter and early-spring peak of *Calanus* following a low midwater copepod resource, led to the mid- and late season absence of whales. Further it is likely that other regions of the southern Gulf of Maine were richer in zooplankton resources and better supported the whales during the period, presenting an irresistible lure to roaming whales not anchored by the Cape Cod Bay food resource. The changes in zooplankton richness, particularly in *Calanus*, were not attributable to a widespread alteration in the bay system as *Acartia*, that became the dominant species in late winter, did not fill in the niche left when late stages of *Calanus* did not appear. Although the causes of the decline in *Calanus* during the late winter will remain conjectural, the result in the form of decreased right whale residency was clear. In 2002 this change in whale occurrence was dramatic and could be of consequence to the success of right whales if the resources of Cape Cod Bay are irreplaceable and play a significently role in the support of the species. The circumstances we have described and the process we have hypothesized do imply that the residency of right whales in Cape Cod Bay is more tenuous than has been thought.

By monitoring the copepod resource in Cape Cod Bay and making comparisons with previous years' observations it will be possible to inform management actions in the bay. Predictions of the occurrence of whales in Cape Cod Bay based on identifiable patterns of copepod species and density characteristics should, once fully developed, offer a new tool for the management of the anthropogenic causes of right whale mortality. The foundation for management based on such a predictive method is an understanding of the processes that influence the characteristics of the copepod foods and the whales' response to them.

Recommendations

1. The development and refinement of a method for using habitat measures in the assessment of the quality of right whale habitat and as a predictive tool to aid in the management of fisheries/whale conflicts should include:

☉ Aircraft surveillance coupled with directed study of the food resources of the Cape Cod Bay system and adjacent areas beginning 1 December and ending 30 May.

☉ Coupling of all broad-scale assessment methods recommended here with the fine-scale assessment methods recommended in a manuscript reported to DMF (Mayo and Bessinger, ms. in prep).

☉ Application of fine- and broad-scale food resource assessment methods to the Great South Channel and the waters between the channel and Cape Cod Bay to test the techniques in adjacent areas of different oceanographic characteristics.

☉ The refinement of the broad- and fine-scale tools for predicting and assessing whale aggregations should be based on statistical methods of evaluating incoming data, hence a process of analysis, statistical treatment, and interpretation should be designed in order to develop a method usable by managers.

2. Should the conditions of 2002 repeat in 2003, agencies cooperating with private institutions, should undertake a research project to determine the cause of the changes in the food resource and to further confirm the relationship between whale presence and the quality and structure of the zooplanktonic foods.

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