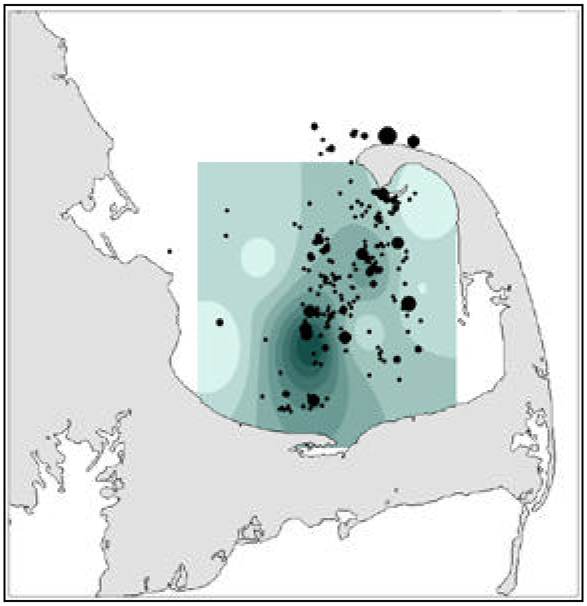

Surveillance, Monitoring and Management of North Atlantic Right Whales in Cape Cod Bay and Adjacent Waters - 2004

Final Report

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EXECUTIVE SUMMARY

In 2004, the right whale surveillance program for the Commonwealth of Massachusetts Division of Marine Fisheries (DMF) was conducted in Cape Cod Bay and adjacent waters from 1 January through 15 May by the right whale research team at the Center for Coastal Studies (CCS). The program included bi-weekly aerial surveys and weekly habitat sampling. Collaborative efforts were conducted with researchers at Cornell University on passive acoustic sampling with bottom-mounted hydrophones deployed throughout the season from 14 December through 31 May.

The right whale research team was prepared to survey for 136 days between 1 January and 15 May 2004. Right whales were determined to be present in Cape Cod Bay for 90 days, from 10 February through 10 May. In 2004, a total of 367 right whale sightings were recorded from all platforms, of which 297 were photographed. Of those 297 photographed sightings, 296 were in Cape Cod Bay, and 1 was in an area east of the Cape. To date, 263 (89%) of the photographed sightings have been matched to 55 known right whales. These results are preliminary because most of the matches have yet to receive final confirmation. There was a minimum of 54 different right whales identified in Cape Cod Bay, and one outside of Cape Cod Bay. Photo analysis is still underway to match the remainder.

Upon completion of each survey, all sightings were reported to the NOAA Fisheries Sighting Advisory System (SAS) and the US Army Corps of Engineers Cape Cod Canal Field Station. Based on late season sightings, DMF issued an advisory to mariners extending the fishing gear modifications for 15 days beyond 30 April and a request for boaters to slow down and post a lookout when traveling in Cape Cod Bay.

The spatiotemporal distribution and demographic profile of right whales in Cape Cod Bay in 2004 more closely resembled observations during the first four years of this study than in 2002 or 2003. A late-season scattered distribution of right whales distributed just north of Provincetown was reminiscent of the near-shore aggregations of feeding whales seen northeast of Provincetown in 2002 and a few miles east of Cape Cod in 2003. Sightings of large numbers of feeding whales in waters on the fringes of or immediately adjacent to the Bay, particularly when food resource levels within the Bay appear high as occurred in 2004, are indications that high-quality patches of food resource can develop close to the Bay and at the periphery of the area normally surveyed and sampled. It may be useful to expand survey effort a few miles north and east of the standard survey area on a more regular basis to determine if these aggregations occur consistently. In the past, these near-shore aggregations have occurred close to or within the shipping lanes north and east of the Cape and deserve particular attention from a management perspective. In future years, if an aggregation is detected in the expanded survey area, directed habitat sampling at its location could allow comparison with habitat conditions in the Bay and provide data to incorporate into a proposed model of competition between habitats.

In 2004, the right whale habitat sampling team was ready to cruise aboard the R/V *Shearwater* in Cape Cod Bay for the 136-day field season from 1 January through 15 May. Twenty-one cruises were completed between 4 January and 11 May, totaling nearly 150 hours at sea. Despite the exceptionally cold 2004 winter conditions that caused ice buildup on equipment and sea ice cover in Provincetown Harbor and Cape Cod Bay during several cruises, a total of 726 zooplankton and phytoplankton samples were collected, and 136 oceanographic depth profiles were recorded.

The technique developed in 2003, using four parameters of zooplankton richness to predict the occurrence, aggregation, and residency of right whales in Cape Cod Bay, was continued in 2004. Eight stations located throughout the bay were selected and sampled on every cruise (weather permitting) to maintain a baseline data set. Data, graphics and written assessments from every cruise were sent out within a few days via an e-mail distribution list to an increasing number of interested academic, governmental, scientific, and management agencies and individuals for the purposes of aiding effective management of right whales within the Cape Cod Bay Critical Habitat. Additionally, faxes detailing cruise duration, sampling locations and types, opportunistic sightings of fishing gear, and marine mammal sightings were sent to Division of Marine Fisheries state biologists immediately following every cruise. This continually evolving habitat assessment technique repeatedly demonstrated its utility of explaining the movements of right whales, often in a predictive capacity.

A preliminary effort to compare zooplankton abundance with aerial survey sightings of right whales generally demonstrated the value of combining the two principal data sets of the project. The combined plots permit a comparison of the data that informs the DMF in their development of management actions for Cape Cod Bay. The contoured zooplankton density and whale distribution plots will be integrated in the assessment reporting of 2005 after every cruise in order to present a more robust and usable management report.

The comparative plots offer some insights into the influence of the zooplankton resource on whale distribution. Clearly the long-held view that the zooplankton resource in the eastern two thirds of the Critical Habitat is the controlling factor in the tendency of the whales to reside in the eastern bay is shown in the comparisons presented. The comparisons also show that the zooplankton sampling methods used in 2004 do not fully document the controlling influence of the food resource, failing to represent the importance of deep layers of plankton that may result in the aggregation of whales. Future assessment and surveillance of the Cape Cod Bay habitat will be founded on new techniques that present a more synoptic and detailed view of the zooplankton resource in order to provide a more accurate prediction of whale occurrence.

To improve the quality of the predictions that are regularly made available to DMF, future work will include the building of a small-scale predictive model that will increase the power of the assessment methods used in the Cape Cod Bay Critical Habitat.

ACKNOWLEDGEMENTS

We are grateful to all of our colleagues who worked with us in the air, on the water, and in the lab to make this work possible. John Ambroult, Philip Kibler, and Jack O'Brien (Ambroult Aviation) provided top-quality aircraft services and a commitment to getting the job done. Philip Kibler deserves special appreciation for his dual role as research assistant and co-pilot and his extra effort in the air and on the ground to make the season a success. CCS research assistant Mike Reardon provided sharp eyes as an observer and hard work in all areas of the project. Marc Costa kept R/V *Shearwater* shipshape and on station during difficult winter conditions, with Don Viprino assisting as a second captain. CCS intern Lisa Barrett, associate scientist Jamie Collier, and able volunteers Judith Lazak and Sue Tuxbury acted as observers during research cruises and provided assistance with oceanographic sampling and data entry. Dr. Anne Hampton conducted phytoplankton analysis. David Morin, Scott Landry (CCS Disentanglement Team), Pauline Kamath, and Jooke Robbins (CCS Humpback Whale Research) provided additional shipboard photographs of right whales taken during the field season. Philip Hamilton, Heather Pettis, Beth Pike and the staff of the Right Whale Research lab at the New England Aquarium (NEAq) provided valuable assistance with photo-identification data. Special thanks are due to Monica Zani (NEAq) for working with us as we faced the challenge of aerial survey data collection with a reduced number of scientists and new equipment. Without her assistance and the opportunity to work with her team, the transition to digital data collection would have been far more difficult. Lisa Conger (NEAq) provided valuable assistance with aerial photography and joined the CCS team as an observer for a day. Mason Weinrich (Whale Center of New England) assisted as a shipboard observer and provided additional photographs. Shoreline and boundary data used in GIS plots were obtained courtesy of the United States Geological Survey. Jennifer Beaudin Ring and Kerry Lagueux provided assistance with GIS mapping and analysis. We wish to thank the many individuals who work on the waters of Cape Cod Bay and maintain vigilance with respect to right whales, including Peter Hanlon and the Massachusetts Environmental Police, the master and crew of the M/T *Margara*, Fran Donovan, Bill Norman and the marine traffic controllers at the US Army Corps of Engineers Cape Cod Canal Field Station. Captain Judith Keene, Commander, and the staff of the United States Coast Guard Group Woods Hole and Air Station Cape Cod continued their commitment to ensuring our safety during aerial surveys by facilitating scheduled communications and providing a pre- and post-flight call-in service. Finally, we wish to thank Dan McKiernan, Deputy Director, Massachusetts Division of Marine Fisheries (DMF). His continued support of this project, now ending its seventh year as part of the Commonwealth's Right Whale Conservation Plan, has set a standard for scientific study and management of a critically endangered population of animals. Assisting Dan is Protected Species Specialist Ed Lyman, who continued to participate directly in aerial and shipboard surveys in addition to his role at DMF.

Aerial and shipboard surveys were conducted under Scientific Permit to Take Marine Mammals No. 633-1483-04, issued by NOAA Fisheries to Dr. Charles Mayo. Additional photographs of entangled right whales reported herein were obtained by the CCS disentanglement team under NOAA Fisheries Permit No. 932-1489.

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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 1979, Schevill *et* al. 1986, Hamilton and Mayo 1990, Mayo and Marx 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 autumn and winter through late spring from at least the early 1600s (Allen 1916, Mitchell and Reeves 1983, Reeves *et al*. 1999, Reeves *et al*. 2002).

Since the 1980s, right whales have been 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 six years (1998 – 2003) have demonstrated that Cape Cod Bay is an important feeding and socializing area from December to May for as many as 85 to 95 individuals annually, almost a third of the known catalogued population (Brown and Marx 1998, 1999, 2000, Brown *et al*. 2001, 2002, 2003).

Range-Wide Concerns

Despite international protection from commercial hunting since 1935, the North Atlantic right whale 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 1973. 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; researchers have documented an average of 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 per year), an increase in the calving interval (Kraus *et al*. 2001, Kraus 2002), and a decline in the survival rate (Caswell *et al*. 1999, Fujiwara and Caswell 2001) suggest we should view the present situation with greater concern.

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* Adjacent waters include those state waters outside of the Cape Cod Bay Critical Habitat and federal waters over Stellwagen Bank/Wildcat Knoll in Massachusetts Bay, as well as those east of Cape Cod.

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). A total of 62 right whale deaths were documented from 1970 through October 2004 (Knowlton and Kraus 2001; New England Aquarium unpublished data). Of those 62 mortalities, 21 (34%) were attributed to ship strikes, six (10%) were a result of entanglement in fixed fishing gear, 18 (29%) were adult and juveniles that died of unknown causes, and 17 (27%) were calves that died of neonatal or unknown natural causes. Ship collisions kill more right whales than any other documented causes of mortality and more than half of the ship collision mortalities have been recorded since 1990. Entanglements, however, can result in long-term deterioration and may be responsible for more deaths than previously thought (Knowlton and Kraus 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 (presumed dead when not seen in more than 6 years; n=100 through 2004, Hamilton *et al*. 2004), and it is obvious that not all deaths are seen on the beach (Knowlton and Kraus 2001). Caswell *et al*. (1999) estimated that if human related mortality is not reduced, this population could become extinct in less than 200 years. Upon further analysis, Fujiwara and Caswell (2001) suggested that preventing the death of only two female right whales per year could increase the population growth rate to replacement level.

Right Whales in Cape Cod Bay and Adjacent Waters

The use of the Cape Cod Bay ecosystem by right whales has occurred for hundreds of years (Reeves *et al*. 1999, Reeves *et al*. 2002). Since the cessation of whaling in the late 1800s, other human activities have affected the right whales using 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 were likely 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 showed that the cause of death was blunt trauma, likely the result of a collision with a ship (Brown and Marx 1999). In all three events, the location of the collision between vessel and whale was not known. Modeling work using data collected during previous years of this project is presently underway and will identify areas of potential risk to right whales from shipping traffic in the Bay (Nichols *et al*. 2004).

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 Division of Marine Fisheries, Commonwealth of Massachusetts. Some fishing activity is prohibited (gill nets), or use of modified gear is required in the Cape Cod Bay Critical Habitat area.

These modifications include sinking or neutrally buoyant ground line between lobster pots, traps set in trawls of four pots or more with vertical buoy lines on each end or in "doubles" where two pots are strung together with only one buoy line, and a 500-pound break away link in all buoy lines (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 Bay Critical Habitat area is located in the northern margins in depths greater than 30 fathoms. A few right whales have been reported west of the critical habitat area in the past (Brown *et al.* 2003, this report). Fixed fishing gear is also set to the west of the western margin (070° 30' W) of the Critical Habitat in State waters that is not subject to the above gear restrictions because it is outside the federally designated critical habitat area; that gear is now modified as described above as of January 2003. In addition to the above conservation measures, a Division of Marine Fisheries ghost gear removal program is carried out in the winter months in order to reduce entanglement risk.

Over the last twenty years, more than 70% of the catalogued 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 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 2003 (Brown and Marx 1998, 1999, 2000, Brown *et al*. 2001, 2002, 2003, 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 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.

Program Objectives – 2004

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 and has continued for the past seven years (Brown and Marx 1998, 1999, 2000, Brown *et al*. 2001, 2002, 2003, and this report). The program of research directly addresses concerns identified by the Right Whale Conservation Plan submitted by the Commonwealth of Massachusetts to federal courts in 1996 and by the Northeast Implementation Team, and supports goals in the federal Atlantic Large Whale Take Reduction Plan, the Right Whale Recovery Plan (NMFS 1991), and the ESA. This report consists of the results of the research activities conducted in 2004 as described below. The objectives of the 2004 surveillance, monitoring, and management program in Cape Cod Bay and adjacent waters were:

I) To document right whales in the Cape Cod Bay Right Whale Critical Habitat area and adjacent waters from January through mid-May, 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, demographics and predictability of occurrence. Photographic and sighting data are 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 are reported promptly to NMFS/SAS at the completion of each survey. The goal is 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 winter portion of these surveys provide almost all of the data for the NMFS advisory system in the northeast, there are no other surveys being conducted by other states or federal agencies during the winter months (January through March).

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

IV) To collect food resource information on weekly vessel cruises, from January to mid-May, designed to develop an understanding of the characteristics of the habitat to which right whales respond. These data, combined with data from past habitat studies in Cape Cod Bay by the Center for Coastal Studies, provide additional information on the conditions that are believed to cue the movements and activities of right whales in Cape Cod Bay and adjacent waters. Management agencies (e.g. MA DMF, NMFS) have used these data to forecast whale movements and residency times within the study area and have issued vessel speed advisories and amended seasonal gear restrictions on a real-time basis in response to right whale distribution predictions based on controlling characteristics of the food resource in the bay and adjacent waters.

V) 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.

Objectives I through III and V are the focus of the first section of this report; Objective IV is discussed in the second and third sections.

SECTION 1: SURVEILLANCE OF NORTH ATLANTIC RIGHT WHALES IN CAPE COD BAY AND ADJACENT WATERS - 2004

Introduction

In the following section of this report, results of the 2004 research activities are discussed that address Objectives I through III and V of the CCS/DMF right whale surveillance and monitoring program. Objective I was to document right whales in the Cape Cod Bay Right Whale Critical Habitat area and adjacent waters from January through mid-May, using photo-identification techniques to identify individual whales. The 2004 season included a number of changes in the research techniques used in this component of the study. Aerial survey methods, including data collection protocols and photography, were modified with the intention of increased safety. Photo-identification was conducted entirely with digital cameras in 2004, and the associated changes in photo-analysis and data management are discussed. The spatiotemporal distribution and demographic profile of right whales in Cape Cod Bay in 2004 are compared to observations during previous years of this study. Objective II was to provide sighting data to the National Marine Fisheries Sighting Advisory System (SAS). Dissemination of information to the maritime community, including that which passes through the SAS system, is discussed. Objective III was to monitor right whales in the study area for evidence of entanglement. While no newly entangled whales were sighted during the 2004 field season, three previously entangled whales were sighted; an updated assessment of the condition of two whales that remain entangled and one whale now free of gear is presented. Objective V was 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. Additional information is presented that pertains to the management goals of this program, including mitigation of right whale mortality due to ship strikes. Objective IV was to collect food resource information on weekly vessel cruises designed to develop an understanding of the characteristics of the habitat to which right whales respond. The results of this work are discussed in the second and third sections of this report. Two collaborative studies were continued in 2004. Dr. Christopher Clark (Cornell University) conducted a fourth year of passive acoustic monitoring of Cape Cod Bay (Appendix III). A pilot project begun in 2002 to assess if CRITTERCAM™ technology is a useful tool to examine right whale interactions with their habitat was completed in 2004; results are presented in Appendix V.

Methods

Aerial Surveys

Aerial surveys were conducted from 1 January 2004 through mid-May 2004 in the Cape Cod Bay Critical Habitat and adjacent waters. The aerial survey protocol for Cape Cod Bay, as described in Kraus *et al.* (1997), was adopted with some modifications. Fifteen track lines 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 track line, 25 nm in length, paralleled the outer coast of Cape Cod from east of Chatham to the eastern end of track line one at a distance of about three nm from shore (Figure 1a, track line 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; glare is a significant factor in sightability of marine mammals. On east-west track lines, 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 deemed safer to have the aerial survey track lines begin and end near land. The turn at the end of each track line was initiated and completed about 1.5 nm from shore in Cape Cod Bay to maximize the opportunity to observe any whales near shore. A total of 306 nm of 'on-track line' miles were flown during each completed survey (Table 1a). "On-track line" 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 excluded all miles flown between track lines (cross legs) or while circling. Additional track lines were established and flown at various times during the season to respond to reports of right whales in adjacent waters or to search for right whales in nearby locations when they were not being seen in the bay (Tables 1b-c, Figures 1b-c).

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. Most aerial surveys originated at Chatham Airport, Chatham, MA, although a few surveys originated out of Provincetown Airport. Aerial surveys were conducted in a Cessna 337 Skymaster (N700AM), 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, and a marine VHF radio with external antenna. Safety equipment included a life raft, four immersion suits, floating ditch kit (contents), a medical kit, a waterproof VHF radio, a portable 406 MHz EPIRB, and an aircraft mounted ELT (emergency locator transmitter). All occupants wore FAA approved aircraft PFDs (personal floatation device) during the entire flight. Both pilots and observers wore Nomex flight suits and FAA-approved life vests with the following equipment attached: 406 MHz Personal Locator Beacon (PLB), Helicopter Aircrew Breathing Device (HABD), strobe light, dye marker, knife, and signal mirror. Additional safety measures adopted during the 2003 field season (Brown *et al.* 2003) were continued with minor modifications, most of which were made to comply with NOAA Fisheries Northeast Region Commercial Aviation Services Requirements (CASR, 26 October 2003).

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 two pilots 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 recorded sightings when they were abeam of the aircraft. In order to maintain a standardized sighting effort, the pilots were instructed not to alert the observers to any sighting of marine mammals until after it had been passed by the aircraft and clearly missed by the observers.

In 2004, surveys were flown with two pilots, eliminating the data recorder position in the copilot's seat as used in previous years. In order to allow data collection by the observers without diverting their attention from the water's surface, data were recorded using a laptop computer running an interactive data-logging program (Logger 2000, International Fund for Animal Welfare). Logger 2000 was configured to automatically record an event at 10-second intervals as well as at a keystroke by an observer. At each event, latitude, longitude, time, altitude, and heading were obtained through an interface with the aircraft GPS. At manually entered events, the observers recorded additional data using a digital voice recorder (Sony ICD-ST10). A distinct voice file was created for each manually entered event. The file name of each voice file included date, time, and a sequentially assigned number that corresponded to the record number of the event entered in Logger 2000 to facilitate accurate post-flight transcription (see section on Data Management, Analysis, and Interpretation). The clocks of the logger computer and voice recorder were synchronized prior to each flight to aid transcription in the event of a mismatch between filenames and event record numbers.

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 track line 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 not immediately identified by species, the aircraft departed from the track at a right angle to the sighting and circled over the animal to determine species and obtain identification photographs. Photographs were obtained of as many individual right whales within a given aggregation as possible. For each right whale sighting, behavior and interaction with other whales or any nearby vessels or fishing gear was noted. At the conclusion of photographic effort at each sighting, the aircraft returned to the track line at the point of departure as recorded by the pilot's GPS. These methods conform to research protocols followed by the North Atlantic Right Whale Consortium and approved by NOAA Fisheries.

Shipboard Data Collection

CCS maintains a 40' (12m) long, twin diesel engine research vessel *Shearwater*. The R/V *Shearwater* has been used successfully for habitat sampling and photo-identification in the winter and spring surveillance program in Cape Cod Bay from 1997 through 2004 (Mayo 1997, 1998, Mayo *et al*. 1999, 2000, 2001a, 2001b, Mayo and Bessinger 2002, Bessinger *et al.* 2003, this report). The results of this part of the program are reported on in sections 2 and 3 of this report.

Although the primary objective of these vessel cruises was habitat sampling, sightings of marine mammals were recorded on an opportunistic basis. Observers were on watch as often as weather and available personnel permitted. An observer from the aerial survey team was present on board R/V *Shearwater* whenever possible to aid in opportunistic data collection. Identification photographs of right whales were collected during sampling and transits to and from sampling locations. Photographs of right whales obtained during habitat studies were integrated with the photographs collected during aerial surveillance. These vessel-based sightings were also included in the analyses of residency, capture rates, demographics, and life history. Sighting data from the daily vessel logs were entered into the Right Whale Initiative DBase program as opportunistic sightings.

Photo-Identification Techniques

i) <u>Identification Photographs</u>

During aerial and shipboard surveys, photographs were taken using hand-held 35-mm digital cameras equipped with 300-mm telephoto lenses. 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 vessels, photographers attempted to collect good 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 image numbers shot by each photographer in the daily log. Digital images were downloaded and backed up immediately following each flight and cruise.

ii) <u>Photo-Analysis and Matching</u>

Photographs of right whale callosity patterns are used as a basis for identification and cataloguing of individuals, following methods developed by Payne *et al.* (1983) and Kraus *et al.* (1986). The cataloguing 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, Hamilton and Martin 1999). 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 31,078 sightings of 459 individual right whales have been archived, of which 342 were thought to be alive as of 31 December 2003 (Hamilton *et al.* 2004).

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 catalogued and archived at NEAq.

Once images were submitted to NEAq, analysis was conducted using Image Capture Tool (ICT) software*. ICT was developed to help right whale researchers process digital images of whales, link them to sighting records, and code those sightings and images for subsequent searching and matching. The program was written in MS Visual Basic and populates 17 tables in MS Access that are compatible with the current right whale database.

All images from a day were downloaded from the camera onto a computer and into a folder labeled with the date and platform. Every right whale photographed in a day was considered a "sighting". Time, latitude, longitude, Eg letter (the whale identifier for the day), and notes for each sighting were entered and the corresponding images were assigned by a simple click and drag feature. Each sighting was coded for behavior, association (mother/calf, SAG, echelon feeding, etc), and for 26 identification criteria, including callosity pattern, scars, and other notable features. The identification coding allows for future searches and comparison to both identified and unidentified whales. In addition to sighting coding, each image is also coded for quality, body-part visible, view direction and photographer. This coding system aids the matching process and simplifies image access for ongoing studies such as entanglement scar analysis (Marx *et al.* 1998) and health assessment (Pettis *et al.* 2004).

iii) <u>Photographic Data Archiving</u>

Original digital images are kept on file at CCS on CD-R and an external hard drive. As 2004 was the first year that digital photography was used exclusively, an in-house system that allows image management and archiving in the same manner as slides is not in place at the time of this writing. In the future, ICT will be available for use by those outside of NEAq, and similar software will likely be used to manage digital images at CCS. All CCS digital images form the 2004 season were archived at NEAq and are available for access by collaborators per North Atlantic Right Whale Consortium protocols.

Data Management, Analysis, and Interpretation

i) Data Management

At the end of each aerial survey, data from the voice recordings were downloaded and backed up on CD-R along with the digital voice recordings. Digital voice files were managed and played back using proprietary software (Digital Voice Editor v. 2.13, Sony Corp.). Data recorded in individual voice files during the flight were manually transcribed into corresponding entries in the MS Access database created by Logger 2000. The database was then queried to generate a table formatted for compatibility with the North Atlantic Right Whale Consortium database. Data from aerial surveys and

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* ICT was developed by Philip Hamilton of NEAq and Jim Hosey of Fulcrum Technologies in Providence, RI with funds from the National Science Foundation and the International Fund for Animal Welfare.

opportunistic sightings were submitted to Dr. Robert D. Kenney, curator of the Consortium Database maintained at the University of Rhode Island.

ii) Data Analysis and Interpretation

All sightings were incorporated and integrated into the right whale catalogue and Consortium database 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 were used to describe the number, age, sex, and reproductive status of the right whales sighted in the Cape Cod Bay habitat area in 2004. Sighting data from the aircraft were plotted 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 were plotted for comparison with the locations of right whales to assess the level of overlap between right whales and vessels in the area.

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*. 1995). 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 were 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).

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, we notified the shift commander at the Pilgrim Nuclear Power Plant of our flights. Following the completion of each aerial survey and habitat sampling cruise, the number of right whales seen and the location of these sightings were verbally reported to the NOAA Fisheries Sighting Advisory System coordinator. The NOAA Fisheries/SAS office disseminates this information by fax, e-mail, Navtex, and marine weather radio to the appropriate agencies and mariners. Prior to reporting to the NOAA Fisheries/SAS, on days when any other whale research vessels were operating in Cape Cod Bay and adjacent waters, additional sightings, if any, 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. In the event that a right whale was seen in Cape Cod Bay, the US Army Corps of Engineers Canal operators were also notified at the completion of a flight so they could relay the sighting location to transiting ships. If right whales were sighted in close proximity to Canal traffic, sightings were relayed during flight via VHF radio.

Results and Discussion

Aerial Surveys

In 2004, the CCS/DMF aerial survey team was in position to survey for 136 days from 1 January through 15 May. Out of 27 surveys completed, 25 were flown in Cape Cod Bay and 2 were flown in waters east of the bay and over Stellwagen Bank/Wildcat Knoll (8 and 12 May respectively; Table 1 and 2, Figure 1). Inclement weather prohibited flight operations for the first three weeks of the season. The first flight was conducted on 21 January, during which only the northern portion of the bay was surveyed (Table 2) due to initial difficulties encountered with scientific equipment. Those difficulties were subsequently addressed, and a full survey was completed at the next available weather window on 27 January; no right whales were sighted (Table 2). The next full surveys of the bay were completed on 2 and 3 February; no right whales were sighted in the bay. As a result, a track line was flown east of the standard survey area (track 1 continued east to 69° 45' W and then south to 41° 40' N) on 3 Feb following the bay track lines. A single feeding right whale was sighted approximately 12 nm east of Nauset Light (Table 2, Figure 2x). Two right whales were seen in Cape Cod Bay on the next flight on 10 February. Right whales were sighted on every subsequent flight in the bay through 10 May (Table 2, Figure 2). The last survey of the season was completed in waters east of the Cape on 12 May (Table 1, Figure 1). While another survey of the bay was planned due to the sighting of one right whale on 10 May, it could not be completed before 15 May due to weather conditions and required aircraft maintenance. In total, the CCS/DMF aerial survey team spent nearly 139 hours airborne and surveyed over 7,100 nautical miles.

The average duration of the standard Cape Cod Bay survey was approximately 5.6 hours for surveys that were not aborted early due to an increase in wind speed, sea state (above Beaufort 4) or decrease in sighting conditions (to visibility less than two nm). This was 1.6 hours longer than the mean survey length for 200 surveys from 1998 through 2003 (ca. 4 hours). The longer survey length is attributable to the longer time required to adequately photograph individual right whales with only one photographer in the rear seats, as opposed to earlier surveys flown with one pilot and a photographer in the copilot position and a secondary photographer in the rear. The longest flight in 2004 lasted 8.5 hours, during which 24 whales were photographed. For comparison, the longest flight of the 2001 season lasted 5.7 hours, during which 28 whales were photographed. The rear seat offers a smaller viewing area and less opportunity for photographing whales; consequently, more passes over an animal were required to obtain photographs of high enough quality for matching.

Shipboard Data Collection

In 2004, the right whale habitat sampling team was in position in Cape Cod Bay for 136 days from 1 January through 15 May. The primary purpose of the habitat sampling cruises was to collect oceanographic data in the Cape Cod Bay Critical Habitat area on a weekly basis for 19 weeks to compare distribution and abundance of right whales from aerial surveys with that of the food resource as determined from plankton samples obtained at sea. See sections 2 and 3 of this report for the results and discussion of this portion of the program.

The R/V *Shearwater* completed a total of 21 cruises between 4 January and 11 May (Table 3). Habitat sampling cruises ranged in duration from 1.8 hours to 10.3 hours (average 7.1 hours) depending on sea state and temperature conditions. Some trips were shortened due to sea ice that impeded passage of the vessel. Whenever conditions and numbers of personnel permitted, sightings of marine mammals were recorded on an opportunistic basis. The vessel crew documented the first right whales in Cape Cod Bay on 10 February; these whales were the first animals seen in the bay in 2004 and were reported to R/V *Shearwater* by the aerial survey team via marine VHF radio. Right whales were seen on all but one subsequent cruise through 5 May (Table 3); many of these sightings were initially recorded by the aerial survey team and radioed to the vessel to facilitate collection of photo-identification and behavioral data and oceanographic sampling in the location of feeding whales. Sightings of other species were recorded on an opportunistic basis. The CCS/DMF right whale team spent nearly 150 hours at sea in 2004. In addition to the work described above, several cruises were conducted in collaboration with Cornell University to deploy and recover bottom mounted autonomous acoustic sensors, or "pop-ups", in four locations in Cape Cod Bay (see Appendix III).

In addition to habitat sampling and recording opportunistic sighting data, the vessel team also photographed 39 right whale sightings (Table 3) during the course of their work. Six additional sightings were recorded and photographed by the CCS disentanglement team during sea trials on 1 March and assessments of entangled whales on 19 April and 28 April (see Human Impacts). The CCS humpback whale research team contributed 5 sightings photographed on 28 April. These photographs provide a valuable complement to the data collected by the aerial survey team, particularly on days when weather prohibits flight operations and when calves are photographed. Shipboard photographs are the best means of documenting lip ridges and chin callosities of calves, which are particularly important for matching sightings in subsequent years (Hamilton and Martin 1999). All of the shipboard photographs have been compared to those obtained from the aircraft and were included in the same matching process as described above, the results of which are detailed in the following analyses.

Sightings and Photo-Analysis

In 2004, a total of 367 right whale sightings were recorded from all platforms, of which 297 were photographed and analyzed in this report (Tables 2 and 3). Of those 297 photographed sightings, 296 were from Cape Cod Bay, and 1 was from an area east of the Cape. To date, 263 of the 297 (89%) photographed sightings have been matched to a total of 55 known right whales; photo analysis is still underway to match the remainder. Most of the matches are awaiting final confirmation. The numbers of sightings by area and platform are presented in the table below (CCB = Cape Cod Bay, Outside CCB = east of Cape Cod):

Platform and Location	Sightings	Photographed sightings	Matched to a known Eg	Sightings to be matched	Unmatchable sightings
Aerial - CCB	270	246	220 (50)	24	2
Aerial - Outside CCB	1	1	1 (1)	0	0
Habitat Vessel - CCB	85	39	33 (21)	6	0
Other Vessel - CCB	11	11	9 (8)	2	0
Totals	367	297	263 (80)	32	2

The number in parentheses indicates the number of unique individuals identified from the matched sightings. This number is higher than the total number of individuals identified (n=55, Appendix II) because 25 of the whales photographed from vessels were also seen from the aircraft. There were three right whales that were only photographed from vessels in Cape Cod Bay (#s 1425, 2320, and 2430) on 3 days when the plane was not surveying. One whale (# 1934) was only photographed from a vessel on two days although there was an aerial survey on one of the days. Of the 32 sightings that remain to be matched, 24 have been inter-matched to 6 right whales that are different from the individuals that have already been identified. Thus, as of this date, the minimum count for Cape Cod Bay is 54 identified right whales including two mother calf pairs (#s 2145 and 2460) plus 6 yet to be matched for a total of 60 right whales. Only one right whale (# 1140) was seen outside of Cape Cod Bay.

Right Whale Identifications

The sighting histories of right whales photographed and matched to an individual in the catalogue during the duration of this project (1998-2004) are presented in Appendix I. This appendix includes all right whales seen in Cape Cod Bay (classified in this appendix as “M” for Massachusetts Bay) as well as whales seen by CCS in other habitats (e.g. “G” for Great South Channel). At the time of this writing, 55 individual right whales have been identified from all platforms combined. There was only one right whale (# 1140, an adult female) sighted outside of Cape Cod Bay during the 2004 season; this was the first right whale seen (3 February) and the only sighting of this individual during the season. The remaining 54 whales were seen only in Cape Cod Bay (Appendix I and II).

Of the 54 right whales identified in Cape Cod Bay, four had never previously been documented in the bay: #s 1207, an adult male; 3130, a 3-year-old female; 3190, an animal of unknown age and sex; and 3302, a yearling of unknown sex. The latter animal (# 3302) was born to # 1802 in 2003. The last sighting of # 1802 in the bay was in 2000, and she and calf # 3302 were seen in the Southeast, the Great South Channel, and the Bay of Fundy in 2003 (Appendix I). Number 1802 was the second whale to be seen in Cape Cod Bay in 2004 (10 February), and was sighted five more times through 24 March, and one last time on 24 April, while # 3302 was seen only once on 8 April. It is noteworthy that # 1802 seemingly did not bring # 3302 to the bay as a calf in 2003, nor did # 3302 appear to accompany its mother to the bay as a yearling in 2004. No yearlings were seen in the bay in 2003, and of the six yearlings seen in the bay in 2002, all were either with their mothers or were brought to the bay as calves in 2001 (Appendix I, CCS unpublished data). None of the calves seen with their mothers in the bay in 2003 were seen there in 2004 (Appendix I). There was one whale (# 1048), an adult male, which had only been seen in the bay once, by CCS in 1988. The remaining 49 whales have been seen in Cape Cod Bay at least once since 1998 (with the exception of two calves, see "Mother Calf Pairs" below). Twenty-one of the right whales seen in the bay in 2003 returned in 2004. Fifteen of the whales seen in 2004 had not been seen in the bay since 2002, five had not been seen since 2001, five had not been seen since 2000, and one had not been seen since 1998 (Appendix I). As in 2002 and 2003, a number of whales that were present in the bay during the early years of the study (1998-2001) were not seen in 2004. The overall number of individuals seen in the bay (n=54) was lower than in 1998-2001 (~80 individuals/year), but the highest since 2001.

Mother Calf Pairs

There were two mother calf pairs (#s 2145 and 2460) photographed in Cape Cod Bay in 2004. Number 2145 and calf were first sighted on 7 April and seen four more times through 28 April; # 2460 and calf were first seen on 21 April and seen two more times through 6 May (Appendix II). While # 2145 and her calf were photographed previously in the southeast US calving ground (see table below), this was the first sighting of # 2460 and calf. To date, the latter pair has only been sighted on one other occasion, in the Bay of Fundy on 27 September (NEAq unpublished data). Both mothers have been seen in Cape Cod Bay in previous years. This was the first documented calf of # 2460 and the second for # 2145. The latter was one of nine 2001 mothers to give birth again in 2004. She brought her 2001 calf (# 3170) to Cape Cod Bay as well, and he returned with her to the bay in 2002 as a yearling. The presence of these two mother calf pairs in Cape Cod Bay represents 13% of the known reproduction (n=16) of right whales in 2004.

Sightings Between Habitat Areas

Four right whales were seen both in the southeast US and Cape Cod Bay (see tables below). The mean number of days between sightings in the two areas was 54 (SE ± 19). The number of days between sightings ranged from 26 to 75.

Catalogue number	Southeastern US (off the coast of Florida and Georgia)	Cape Cod Bay	Days elapsed between sightings
1301	15 December 2003	29 February 2004	75
1817	18 December 2003	24 February 2004	67
2145 and calf	20 February 2004	7 April 2004	46
3302	12 March 2004	8 April 2004	26

In the last seven years, a total of 57 right whales (not including calves) was identified in both the southeast US and Cape Cod Bay (or waters immediately adjacent to the Cape in 2003) 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 Cape Cod Bay to the southeast in 2000 (Brown and Marx 2000). In 2004, right whales were last seen off the southeastern US from mid-December to mid-March and arrived in northern waters in February and April. These sightings are important because they provide some information on the timing of the migration of right whales through the mid-

Atlantic region, which will be used in part to determine the season for the implementation of management measures for various ports along the east coast that will hopefully reduce the effect of shipping on right whales.

The table below summarizes the maximum transit time over the last seven years (calves are not included in the total because their movements are dictated by those 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
2003	9 whales; 5 M, 4 F	20 - 103	60 ± 23
2004	4 whales; 3 F, 1 unknown	26 - 75	54 ± 19

Photographs from other non-CCS/DMF survey efforts in the Great South Channel and Canadian habitat areas have not yet been fully analyzed, thus it is not possible at this time to document movements of right whales between Cape Cod Bay and nearby habitats later in the 2004 season. The sighting summaries by whale and area presented in Appendix I have been updated through early 2004 and allow inter-habitat comparisons of whales seen in Cape Cod Bay over the years.

Capture Rates and Residency of Individuals

Right whales are often seen multiple times in Cape Cod Bay over the four-and-a-half month field season. Of the 54 right whales identified or "captured" in Cape Cod Bay in 2004, 15 (28%) were seen only once (see below).

Days Photographed in CCB 2004	1	2	3	4	5	6	7	8	9	11	13
Number Photographed in CCB (n=54)	15	7	12	3	2	5	6	1	1	1	1

The greatest number of days on which a whale was captured was 13 (# 1027, an adult female; Appendix II). For the purpose of this report, a series of sightings (sighting history) of an individual uninterrupted by a sighting in another habitat is defined as "residency" in Cape Cod Bay. To quantify residency, the number of days between first and last sighting was calculated for 39 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 of the 39 whales ranged from 1 to 74 days, with the mean being 26 days (SE ± 18). The whale with the longest residency was # 1802, another adult female, captured 7 times from 10 February to 24 April (74 days). There was a one-month gap in the sighting history of this whale from 24 March to 24 April, during which she may have left the bay. The second longest 2004 residencies were 64 days each by two adult females: # 2123, captured 11 times from 17 February to 21 April and # 1503, captured 7 times from 20 February to 24 April. In each of the first four years of this study (1998-2001), an adult female was always resident for the longest period and almost always for the second and third longest periods (# 1802 was captured the greatest number of times and resident the longest in 2000 as well). Maximum periods of individual residency in 2004 were shorter than those observed in three of the first four years of this study (1998, 1999, 2001), but longer than in 2002 and 2003 when the longest sighting histories spanned only 18 and 20 days respectively. For comparison, in 2001 the two whales with the longest sighting histories for the season were seen over 132 days and 76 days. Mean residency (26 days) in 2004 was higher than the maximums observed in 2002 and 2003 but lower than the combined means for 1998 through 2001 (32 days). There were substantial gaps in the sighting records of several right whales despite multiple surveys during the gaps (Appendix II) which indicated that some animals were likely moving in and out of Cape Cod Bay more than once during the winter and spring. A detailed analysis of capture rates and residency that takes survey effort into account could provide clarification of this issue, which is of particular importance as whales entering and exiting the bay almost certainly cross the shipping lanes into the port of Boston.

Demographics

The demographic profile of individually identified right whales in Cape Cod Bay (n=54) in 2004 was similar to previous years of this study with the exception of 2002 (see table below). Of 54 right whales, there were slightly more females (27) than males (22) identified (5 were of unknown sex including 2 calves), but there was no significant difference from a one to one sex ratio (chi-square test; $P = .475$). The age structure of animals of known age class (Hamilton *et al*. 1998) in the catalogued right whale population consists of approximately 84% adults and 16% juveniles, excluding calves (as of December 2003; Hamilton *et al*. 2004). Of the 54 whales identified in Cape Cod Bay in 2004, 50 were of known age class, excluding 2 calves and two animals of unknown age. The majority (47) of the 50 whales were adults (94%) and three were juveniles (6%). This age structure is significantly different from the right whale catalogue (Hamilton *et al.* 2004; $P = .054$) and from the approximately 75%/25% adult/juvenile ratio observed by Hamilton *et al.* (1998) for the entire catalogue through 1996 and by Brown *et al.* (2001) in Cape Cod Bay during the first four years of this study ($P = .003$).

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	19	10 : 9	0	2 : 12	5
2003	27	21 : 3	1	14 : 10	3
2004	54	47 : 3	2	22 : 27	5

The last two years (2002 and 2003) were not included in the statistical comparisons due to the low numbers of animals seen in the bay in those years. The reduced proportion of juveniles in the bay in 2004 is perhaps noteworthy, as it follows two years of reduced numbers of whales and continued absence of many individuals seen frequently during the first four years of this study. If the low number of juveniles continues to be observed in future years, it could indicate that young animals are favoring other habitats. If early life experience in habitat choice influences future habitat use by individual whales as hypothesized by Kenney *et al.* (2001), then continued observations of a low number of juveniles could be interpreted as an indicator of a shift away from Cape Cod Bay by a portion of the population. Such shifts have been recorded for other habitats (e.g. the Great South Channel; Kenney 2001), and are likely linked to perturbations in the food resource. A retrospective analysis of data on the abundance and composition of the food resource in the bay compared with demographic profiles and range-wide sighting histories of whales that have been identified in the bay during the past seven years may provide insight as to the cause of the low numbers of animals seen in 2002 and 2003 as well as any shift in habitat use patterns by those animals that have not been seen in the bay since the earlier years of this study.

A timeline depicting the demographic composition of right whales identified in Cape Cod Bay in 2004 and separated into two-week periods by age and sex is presented in Table 4. All but two of the individuals seen in the first month that right whales were present in the bay were females. One of the two males was only sighted once during the season (Appendix II). By the end of March, a significant number of males had arrived and a few females were sighted less frequently, causing the sex ratio to approach parity. Through April, more males arrived, along with both mother calf pairs. During the last week of April, many whales appeared to leave the bay, although the mother calf pairs remained. Of the few whales seen in May, only one mother calf pair has been matched to date (Appendix II). Consequently, the numbers of whales in the columns in Table 4 representing the last two periods (23 Apr – 6 May and 7 – 15 May) are low or nonexistent despite several sightings during those periods (Table 2).

Spatiotemporal Distribution of Right Whales

Right whales recorded during aerial surveys of Cape Cod Bay and adjacent waters are plotted by two-week period in Figure 2. Only one right whale was seen far outside the bay, on 3 February about 12 nm east of Nauset Light (Figure 2c). The remaining sightings (n=270, Table 2) were within Cape Cod Bay (sightings immediately north of Provincetown were considered to be within the bay). Sightings recorded from vessels were not collected according to systematic survey protocols and thus were not plotted; however, the distribution of the opportunistic sightings mirrors that of the aerial survey sightings as indicated in Figure 2. As in previous years of the study, right whales were distributed primarily in the eastern portion of the bay in an arc extending from Barnstable Harbor northeast to Provincetown (Figures 2-4).

Right whales were first sighted in Cape Cod Bay on 10 February and during every subsequent survey of the bay through 10 May (Table 2). Numbers of whales increased steadily, reaching a high of 27 sightings on 14 March. The second highest number of whales (24) was seen on 24 March. This was followed by a gap of two weeks during which no surveys were conducted due to unsuitable weather conditions. The next survey was conducted on 7 April, during which 18 right whales were sighted. Surveys continued regularly through 25 April, which marked the third and final peak of sightings (21 animals). Inclement weather forced another gap in surveys (10 days); only 2 right whales were seen during the next survey on 5 May. On 10 May, the last day on which the bay was surveyed, only one right whale was sighted.

Of the 270 right whales sighted in Cape Cod Bay during aerial surveys, only four (1%) were outside the boundaries of the Critical Habitat. The sightings outside the Critical Habitat all occurred on a single day (25 April). One whale was sighted west of the Habitat boundary, while three more were seen just east of the boundary, near Peaked Hill Bar (Figure 4a). Most of the 21 whales seen that day were distributed in an area north of Provincetown, inside the Critical Habitat boundary but northeast of Race Point. This was the last day that a large number of whales were seen; the highest number of whales sighted after 25 April was four on 6 May. It is reasonable to assume that the sightings on 25 April were indicative of a departure of right whales from Cape Cod Bay, although the ten-day gap in effort following that day renders it impossible to pinpoint an exact date of departure. Few of the individual whales seen during the last surveys in May have been identified to date, but most do not match any of the animals already identified in the bay in 2004. Therefore, it seems likely that a few new whales may have arrived in the bay in late April and early May, even after the departure of the majority.

Based on results of the CCS/DMF aerial surveys, right whales were determined to have been present in Cape Cod Bay for a minimum of 90 days from 10 February through 10 May. All of the opportunistic shipboard sightings fell within this period.

Year	Date 1st survey	Date last survey right whales sighted	# 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)	29 April 2001 (2)	132 [87]	29 April 2001 (16)
2002	06 Jan 2002 (0)	15 March 2002 (3)	55 [24]	07 March 2002 (2)
2003	10 Dec 2002 (0)	30 April 2003 (8)	102 [26]	28 April 2003 (10)
2004	21 Jan 2004 (0)	10 May 2004 (1)	90 [54]	06 May 2004 (4)

* Number in parentheses is the number of right whales photographed from the airplane during that survey day. See Tables 2 and 3 for the first day whales were seen each year.

\+ Number in square brackets is the minimum number of right whales identified in Cape Cod Bay.

The period between the first and last sighting of right whales in Cape Cod Bay is defined as "residency" for the purpose of this report. During the seven years of this study, right whales were resident for the longest period during the 1999 season (see table above). Whales were resident longer in 2004 than in 2002 or 2000, although a whale was seen on the first survey of the 2000 season; the residency period for that year may have been deemed longer had surveys begun prior to 20 January. The value of 102 days indicated for 2003 is misleading because there was a period of 46 days between 10 February and 28 March during which no right whales were seen in the bay.

In many of the past years of this study, right whales have seemed to depart from the bay in a herd-like manner over the course of a few days at the end of April. It seems likely that a similar event occurred in 2004, although it was impossible to determine a precise departure period due to a gap in survey effort. It is noteworthy that a few right whales were present in the bay as late as 10 May (the last day the Bay was surveyed). This was the latest in the year that whales have been seen by the CCS/DMF survey effort in the seven years of this study. While another survey of the bay was planned prior to 15 May, it was not completed due to necessary aircraft maintenance.

At the time of this writing, analysis of data from bottom-mounted acoustic recorders, or "pop-ups", deployed in the bay is not complete (Appendix III). The "pop-ups" were in place and recording from 14 December through 31 May. When analyses of the recordings are complete, visual survey and passive acoustic data will be combined to provide a more complete timeline of right whale presence in Cape Cod Bay during the 2004 season.

Monitoring of Entangled Whales

During the 2004 field season, two entangled whales were observed in Cape Cod Bay. Both whales, # 1424 (adult male) and # 2320 (adult female), have been entangled since 2002. The first entangled whale seen was # 1424, sighted by an aerial survey on 20 and 24 March. On 24 March, observers on board R/V *Shearwater* were able to photograph the whale as well. This whale was sighted in the bay on more time on 19 April by the CCS disentanglement team (Appendix II). The second whale, # 2320, was seen twice and only by observers on board CCS research vessels on days when the aircraft was not surveying. The first sighting of # 2320 was in the vicinity of # 1424 on 19 April, and the second was on 28 April in an area immediately north of Provincetown. Based on data collected during the above sightings, it appears that both entanglements have changed since the whales were first sighted in 2002. See below for updated assessments from the CCS disentanglement team:

1424: "In 2002, entangling ropes of various sizes were documented entering and exiting the mouth of this whale in at least 16 places. At least three loose ropes trailed from both sides of the mouth ending just beyond the flukes and one more rope formed a loose loop on the whale's back running from one side of the mouth to the other. One further rope was known to exit the left side of the mouth and then encircle the body of the whale, entering the water in the vicinity of the left pectoral flipper and, apparently anchored at the other end at an unknown location. By the spring of 2004, most of these ropes were gone and the overall body condition of the whale was seemingly improved from previous years. The remaining ropes were limited to an apparently loose wrap over the anterior rostrum running from one side of the mouth to the other and the single line which still wrapped beneath the whale."

2320: "Images confirm that one rostrum wrap that was present during the early sightings in 2002 is now gone - leaving a prominent scar. The remaining wrap is seen exiting the right side of the baleen and then crossing over the whale's head. On the left side this line is involved in a tangle of lines, some of which apparently reenter the whale's

mouth with one single part of line that trails. Also visible is a weave of line running in and out of the forward baleen several times. No gear has been removed; however, far less gear was present in April 2004 than was documented in 2002 or 2003."

New data collected by the CCS/DMF surveys and the disentanglement team, as well as by Disentanglement Network members during surveys in the Great South Channel and Canadian habitats later in 2004, has allowed the disentanglement team to assess the entanglements and update their action plans for these whales. In particular, the status of # 1424 has been downgraded to a "Minor Entanglement", and the action plans for both whales involve continued monitoring and assessment.

A third right whale sighting is of note; on 12 February, the aerial survey team sighted # 2240, an adult female, which had been seen entangled in 2003 in the Southeast US, and was last seen in May 2003, having apparently shed the entangling gear but in poor condition. Based on several subsequent aerial survey and opportunistic shipboard sightings, the whale's condition has improved greatly. The sightings recorded by the CCS/DMF surveys have allowed documentation of wound healing and apparent improvement in health based on the visual criteria defined by Pettis *et al.* 2004.

Vessel Interactions

The distribution of vessels by type during the 2004 season is plotted in Figure 5. There was one instance of a large vessel passing close to a number of right whales and apparently attempting to avoid collision. On 29 February, a large ship (ca. 700') was anchored southeast of Provincetown. The aerial survey team was working a few miles to the north, completing track lines in north-to-south order, when the vessel weighed anchor and began steaming slowly to the southwest toward the Cape Cod Canal. As the waters in the path of the vessel had not been surveyed yet that day, the aircraft broke track and headed to the location of the vessel. Upon arrival at the location of the ship, the survey team immediately noticed at least two single right whales and a Surface Active Group (SAG)[*] of at least two additional whales in the immediate vicinity (< .5 nm) of the ship. The positions of these whales and the animals to the north appeared to effectively block the ship from her destination out of the anchorage. As the aerial survey team attempted to ascertain the locations of whales in the immediate area and the name of the vessel to facilitate a radio hail, they observed the vessel take evasive action to avoid the SAG, which was directly in their path. As the vessel appeared to be actively avoiding the whales that were seen, the survey team chose not to contact the vessel to avoid causing any confusion and instead circled the area to document the encounter and watch for any more whales directly in the path of the vessel. As it continued to the southwest, the vessel passed approximately 500 feet from the SAG. Despite the proximity of the vessel, the whales continued their social behavior throughout the duration of observation. At the end of the day, one of the authors (OCN) contacted the charter company that leased the vessel (M/T *Margara*) and commended the crew for an admirable job of navigating around the whales given that they had no other option but to continue in the direction

[*] A Surface Active Group (SAG) is defined as two or more animals interacting at the surface, less than one body length apart and with frequent physical contact, excluding mother calf pairs (Kraus and Hatch 2001).

they were heading. Photographs were taken of the incident, and a detailed account of the team's observations was drafted to add to the small but growing body of information on observed ship/whale encounters. The full account, including a transcript of a post-incident e-mail exchange with the vessel Captain and a photograph of vessel passing the SAG, is presented in Appendix IV. These kinds of observations, when pooled together, may provide further insight into the causative factors of fatal ship strikes of right whales. In the future, greater attention should be paid to the frequency with which large vessels use the anchorage south of Provincetown in an attempt to quantify the level of potential risk such vessels pose to right whales.

No right whales were sighted in the Cape Cod Canal in 2004, and none have been documented since the two sightings in 2002 (Brown *et al.* 2002), although photographs of two sightings of right whales in the Canal (a pair in September 1989 and a single animal in the mid-1980s) were provided to CCS in 2004. Clark (1958) reported on a right whale that remained in the Canal for about five hours in June 1957. Based on these observations, it seems plausible that right whales may enter the Canal once every few years. Per the recommendations of the Northeast Implementation Team Ship Strike Committee, it may be feasible to work with the Army Corps of Engineers (USACE) and other agencies to develop a formal plan of action to handle such events. In 2002, Corps traffic controllers were very responsive to the sightings of right whales, closing the Canal to traffic and providing a patrol vessel to ensure safety of the animals. Response to right whales in the Canal could be improved by ensuring that CCS/DMF biologists and/or USACE staff on scene collect identification photographs and behavioral observations.

Notification of Agencies and Management Measures

At the completion of each survey and cruise, the information on the number of right whales and their location that day was sent to the coordinator at the SAS office at NOAA Fisheries, Northeast Fisheries Science Center in Woods Hole. Sightings in Cape Cod Bay were reported to the USACE Cape Cod Canal Field Office at the end of each aerial survey. USACE marine traffic controllers transmitted sighting locations to vessel traffic exiting the Canal into the bay. In order to expedite the distribution of the information to the maritime community, the number and location of right whales was relayed to SAS and USACE by cell phone at the completion of each survey. During surveys in Cape Cod Bay, the USACE Field Office was contacted directly by VHF radio at the time of a sighting in close proximity to traffic exiting or entering the Cape Cod Canal. A total of 48 faxes were sent to the DMF offices in Boston and Gloucester (one fax for each aerial survey and vessel cruise in Cape Cod Bay and adjacent waters). Sightings from R/V *Shearwater* were noted, but not plotted, on the faxes. The DMF/CCS surveys are the principal source of right whale sighting information in the northeast region (north of latitude 41° N) for the NOAA Fisheries/SAS program in the winter months through March. In response to the late-season presence of right whales in Cape Cod Bay, DMF issued an advisory to the maritime community on 27 April. The advisory recommended that vessels transiting the bay reduce speed to 15 knots and post a lookout. Vessel operators were reminded that it is against the law to approach right whales within 500 yards. DMF also extended restrictions on fixed-gear fishing activities within the Critical Habitat an extra fifteen days from 30 April to 15 May.

Sightings of Other Species

In addition to right whales, five other species of cetacean, one pinniped species and one species of shark were sighted during aerial surveys and opportunistic shipboard data collection (Tables 2 and 3). The spatial distributions of balaenopterid cetaceans (minke, fin, and humpback whales) from aerial surveys are plotted in Figures 6a-c. Fin whales (*Balaenoptera physalus*, n=103) and humpback whales (*Megaptera novaeangliae*, n=102) were the most numerous of the large whales encountered in Cape Cod Bay based on aerial and opportunistic sightings combined. The numbers of humpbacks seen in or immediately adjacent to the Bay were among the highest recorded during the history of this project. Opportunistic identification photographs of humpbacks collected during vessel cruises were contributed to the Gulf of Maine humpback whale catalogue maintained at CCS by Jooke Robbins. Atlantic white-sided dolphins, *Lagenorhynchus acutus*, were the most commonly seen toothed whales in Cape Cod Bay (Tables 2 and 3).

Summary

The spatiotemporal distribution and demographic profile of right whales in Cape Cod Bay in 2004 more closely resembled observations during the first four years of this study than in 2002 or 2003. As consecutive years of systematic survey data are accumulated, years that seem anomalous may appear as part of a cyclical pattern of change in right whale presence that occurs on a decadal or longer basis and is influenced by changes in the food resource. The late season distribution of right whales distributed just north of Provincetown was reminiscent of the near-shore aggregations of feeding whales seen northeast of Provincetown in 2002 and immediately east of Cape Cod in 2003 (Brown *et al.* 2002, 2003). The sightings of large numbers of feeding whales in waters on the fringes of or immediately adjacent to the bay, particularly when food resource levels within the bay appear adequate as occurred in 2004, are indications that high-quality patches of food resource can develop close to the bay and at the periphery of the area normally surveyed. Gaps in the sighting histories of individually identified whales may indicate that some animals periodically leave the bay for short periods, perhaps to areas close to the bay but beyond detection by standard aerial surveys. It may be feasible to expand survey effort a few miles north and east of the standard survey area on a more regular basis to determine if these aggregations occur frequently. In the past, these near-shore aggregations have occurred close to or within the shipping lanes north and east of the Cape (Brown *et al.* 2002, 2003) and deserve particular attention from a management perspective. Expansion of the survey area could take place within the boundaries of the shipping lanes, which would also fill gaps in whale distribution data in these areas that are particularly critical as NOAA Fisheries begins the process of a management strategy designed to reduce the threat of ship strikes. In future years, if an aggregation is detected in the expanded survey area, directed habitat sampling at its location could allow comparison with habitat conditions in the bay and provide data to incorporate into a proposed model of competition between habitats as discussed in section 4 of this report. Assessment of the relationship between right whale distribution and the zooplanktonic food resource continues to be a primary goal of this study; further discussion of this issue is presented in the following sections of this report.

Table 1a. Aerial survey track lines flown over Cape Cod Bay, January - mid-May 2004. For location of track lines, cross-reference by track line number with Figure 1.

Track line Number	Latitude	Longitude West End	Longitude East End	Track line Length (nm)
1	42 06.5	70 10.0	70 37.9	21
2	42 05.0	70 15.8	70 36.3	15
3	42 03.5	70 17.0	70 36.8	15
4	42 02.0	70 07.7	70 35.7	21
5	42 00.5	70 07.0	70 34.2	20
6	41 59.0	70 06.6	70 34.2	21
7	41 57.5	70 06.6	70 34.2	21
8	41 56.0	70 06.3	70 31.6	19
9	41 54.5	70 06.3	70 30.9	18
10	41 53.0	70 06.1	70 30.0	18
11	41 51.5	70 06.1	70 29.5	18
12	41 50.0	70 06.1	70 30.3	18
13	41 48.5	70 06.1	70 30.2	18
14	41 47.0	70 06.1	70 28.3	17
15	41 45.5	70 11.4	70 26.5	11
Subtotal track line miles in Cape Cod Bay				271
16*	41 40.0		69 52.0	35
Total track line miles, tracks 1-16				306

* Track line 16 begins at this point, east of Chatham, continues north parallel to the eastern shore of Cape Cod approximately 3 nautical miles offshore, and joins the eastern end of track line 1.

Mileage estimates indicated above are lower than those in 1998-2003 reports and are more accurate as the previous estimates were based on survey tracks that were originally continued to shore. Since 1998, turns have been initiated ca. 1.5 nm from shore.

Cross-leg mileage (between track lines) are not listed for the standard Cape Cod Bay survey above as tracks are spaced 1.5 nm apart and the aircraft is turning during at least half of the cross-leg. Cross-leg mileage is listed for the surveys below as the track lines are spaced 3 nm apart, and more of the cross-leg is spent in level flight.

Table 1b. Aerial survey track lines flown over Stellwagen Bank and Wildcat Knoll, 8 May 2004. Cross-reference this table with Figure 1.

Track line Number	Latitude	Longitude West End	Longitude East End	Track line Length (nm)
1	42 17.0	70 10.0	69 40.0	22
2	42 14.0	70 10.0	69 40.0	22
3	42 11.0	70 10.0	69 40.0	22
4	42 08.0	70 00.0	69 40.0	15
5	42 05.0	70 00.0	69 40.0	15
Total survey with transits and cross-legs				173

Table 1c. Aerial survey track lines flown east of Cape Cod, 12 May 2004. Cross-reference this table with Figure 1.

Track line Number	Latitude	Longitude West End	Longitude East End	Track line Length (nm)
1	42 08.0	70 17.0	69 40.0	27
2	42 05.0	69 55.0	69 40.0	11
3	42 02.0	69 55.0	69 40.0	11
4	41 59.0	69 55.0	69 40.0	11
5	41 56.0	69 55.0	69 35.0	15
6	41 53.0	69 55.0	69 35.0	15
7	41 50.0	69 55.0	69 35.0	15
8	41 47.0	69 55.0	69 35.0	15
Total survey with transits and cross-legs				135

Legend of abbreviations and common names for marine mammal and shark species listed in report tables.

Species Abbreviation	Common Name
Eg	Right Whale
Ba	Minke Whale
Bp	Fin Whale
Mn	Humpback Whale
UNBA	Unidentified Balaenoptera
UNLW	Unidentified Large Whale
La	Atlantic White-Sided Dolphin
Pp	Harbor Porpoise
UNDO	Unidentified Dolphin/ Porpoise
Pv	Harbor Seal
UNSE	Unidentified Seal
Cm	Basking Shark

Table 2. Number of marine mammals and other animals seen, hours and track line miles surveyed during aerial surveillance of Cape Cod Bay and adjacent waters, January to mid-May, 2004

Survey#	Date 2004	Eg Sighted	Eg Photo'd	Ba	Bp	Mn	UNBA	UNLW	La	Pp	UNDO	UNSE	Cm	Hours Flown	Distance Flown (nm)	Tracks Completed
CCS320	21-Jan	0	0	0	0	0	0	0	0	0	0	0	0	1.4	107	1-4,16
CCS321	27-Jan	0	0	0	1	1	0	0	0	0	0	0	0	3.7	285	1-14,16*
CCS322	2-Feb	0	0	0	2	0	0	0	0	0	0	0	0	3.7	273	1-14,16*
CCS323	3-Feb	0	0	0	1	1	1	0	0	0	0	0	0	2.6	233	1-14*
CCS324	10-Feb	2	2	0	0	0	0	0	12	0	0	0	0	3.8	305	1-15,16*
CCS325	12-Feb	3	3	0	0	0	0	0	0	0	0	0	0	4.7	281	1-14,16*
CCS326	17-Feb	6	6	0	0	0	0	0	0	0	0	0	0	5.4	283	1-14,16*
CCS327	20-Feb	13	13	0	0	0	0	0	0	0	0	0	0	6.4	293	1-14,16*
CCS328	24-Feb	17	17	0	0	0	0	0	0	0	0	0	0	5.6	295	1-14,16*
CCS329	29-Feb	19	18	0	0	0	0	0	0	0	0	0	0	6.6	295	1-14,16
CCS330	1-Mar	14	14	0	0	0	0	0	0	0	0	0	0	7.2	295	1-14,16
CCS331	10-Mar	9	8	0	0	0	0	0	0	0	0	0	0	5.1	260	1-12,16+
CCS332	14-Mar	27	27	0	0	0	0	0	0	0	22	1	0	6.9	295	1-14,16
CCS333	16-Mar	14	11	0	0	0	0	0	0	0	0	0	0	2.7	100	10-15+
CCS334	20-Mar	19	19	0	0	0	0	0	0	0	0	0	0	6.5	295	1-14,16
CCS335	24-Mar	24	21	0	0	0	0	0	0	0	8	0	0	8.5	260	1-14
CCS336	7-Apr	18	18	1	2	0	0	2	0	0	0	0	0	7.4	295	1-14,16
CCS337	8-Apr	10	10	2	3	2	0	0	0	0	28	2	0	5.9	306	1-15,16
CCS338	10-Apr	10	10	0	5	0	0	0	0	0	30	0	0	4.6	306	1-15,16
CCS339	18-Apr	19	19	1	3	1	0	0	0	0	70	1	0	7.7	306	1-15,16
CCS340	21-Apr	17	15	3	11	3	1	0	0	0	26	0	0	6.7	295	1-14,16
CCS341	25-Apr	21	7	1	8	1	0	2	0	0	76	0	0	5.6	260	1-14
CCS342	5-May	2	2	5	17	55	1	1	0	0	137	0	0	4.5	306	1-15,16
CCS343	6-May	4	4	3	20	2	0	1	0	6	75	0	1	4.9	295	1-14,16
CCS345	10-May	1	1	1	12	16	0	0	0	0	12	1	2	4	286	1-14,16**
Total Cape Cod Bay		269	245	17	85	82	3	6	12	6	484	5	3	132	6811	
Adjacent Waters																
CCS323	3-Feb	1	1	0	1	1	1	0	0	0	0	0	0	1.4	45	ES
CCS344	8-May	1	1	1	7	10	0	0	0	0	221	0	0	2.7	173	SB/WK++
CCS346	12-May	0	0	1	1	10	1	0	0	14	46	1	2	2.4	135	ES
Total Adjacent Waters		2	2	2	9	21	2	0	0	14	267	1	2	6.5	353	
Total All Surveys		271	247	19	94	103	5	6	12	20	751	6	5	138.5	7164	

*Tracks in southeastern portion of Bay cut short due to sea ice coverage.
+Survey cut short due to unsuitable weather conditions.
**Track 16 cut short due to fog.
++The right whale was sighted in Cape Cod Bay on the return leg to Chatham.
SB=Stellwagen Bank; WK=Wildcat Knoll; ES=Eastern Shore of Cape Cod

Table 3. Number of opportunistic marine mammal sightings and hours at sea during vessel-based habitat sampling cruises of Cape Cod Bay, January to mid-May 2004.

Cruise	Date 2004	Eg Sighted	Eg Photo'd	Ba	Bp	Mn	La	Pp	UNDO	Pv	UNSE	Hours At Sea
SW389	4-Jan	0	0	0	0	0	0	0	0	3	1	8.0
SW391	18-Jan	0	0	0	0	0	0	0	0	0	1	7.5
SW392	28-Jan	0	0	0	0	0	0	0	0	0	1	1.8
SW394	10-Feb	2	2	0	0	0	0	0	0	0	3	7.5
SW395	13-Feb	2	2	0	0	0	0	0	0	0	0	5.0
SW396	17-Feb	6	0	0	0	0	0	0	7	0	0	8.5
SW397	24-Feb	15	1	0	0	0	0	1	0	0	1	8.3
SW399	1-Mar	8	6	0	0	0	0	5	0	1	1	10.0
SW400	5-Mar	4	2	0	0	0	0	0	0	0	2	4.5
SW401	10-Mar	5	1	0	0	0	0	0	0	0	0	6.5
SW402	23-Mar	0	0	0	0	0	0	0	0	0	0	3.0
SW403	24-Mar	9	8	0	0	0	0	0	0	0	0	8.0
SW404	30-Mar	12	8	0	0	0	0	1	0	0	3	10.3
SW405	3-Apr	3	0	0	0	0	0	0	0	0	0	4.0
SW406	4-Apr	3	0	0	0	0	15	6	0	0	4	6.0
SW407	9-Apr	2	2	0	0	0	43	5	14	0	3	8.5
SW410	18-Apr	4	3	0	2	0	0	2	14	0	2	9.5
SW413	24-Apr	8	4	0	2	0	25	0	2	1	0	8.5
SW414	27-Apr	1	0	0	0	5	46	27	2	0	2	7.0
SW415	5-May	1	0	1	12	6	110	2	0	0	0	7.5
SW417	11-May	0	0	0	2	9	0	2	0	0	0	8.5
Total		85	39	1	18	20	239	51	39	5	24	148.3

Table 4. Number of surveys, demographic composition and number of right whales identified in Cape Cod Bay (n=54) and adjacent waters (n=1) from aerial surveys and habitat sampling cruises in two-week intervals from January through mid-May 2004. The values in this table represent the minimum number of whales as photo-analysis is not complete.

(A) In Cape Cod Bay

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
Surveys											
Aerial	0	2	3	4	3	4	2	3	3	1	25
R/V Shearwater	1	2	1	3	3	2	3	2	3	1	21
Demographics											
Male				2	1	7	10	12	3		
Female			2	10	13	19	8	12	8		
Unknown Sex						1	3	3	3		
Calf							1	2	2		
Juvenile						2	3	2	1		
Adult			2	11	14	25	17	23	10		
Unknown Age				1					1		
New sightings			2	10	3	14	8	12	5		
Resightings			n/a	2	11	13	13	15	9		
Total id'd in Cape Cod Bay	0	0	2	12	14	27	21	27	14		

(B) Outside Cape Cod Bay

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
Surveys											
Aerial			1						1	1	3
R/V Shearwater											0
Demographics											
Male											
Female											
Unknown Sex											
Calf											
Juvenile											
Adult											
Unknown Age											
New sightings			1								
Resightings			n/a								
Total id'd outside Cape Cod Bay	0	0	1	0	0	0	0	0	0	0	

*This interval represents only one week.

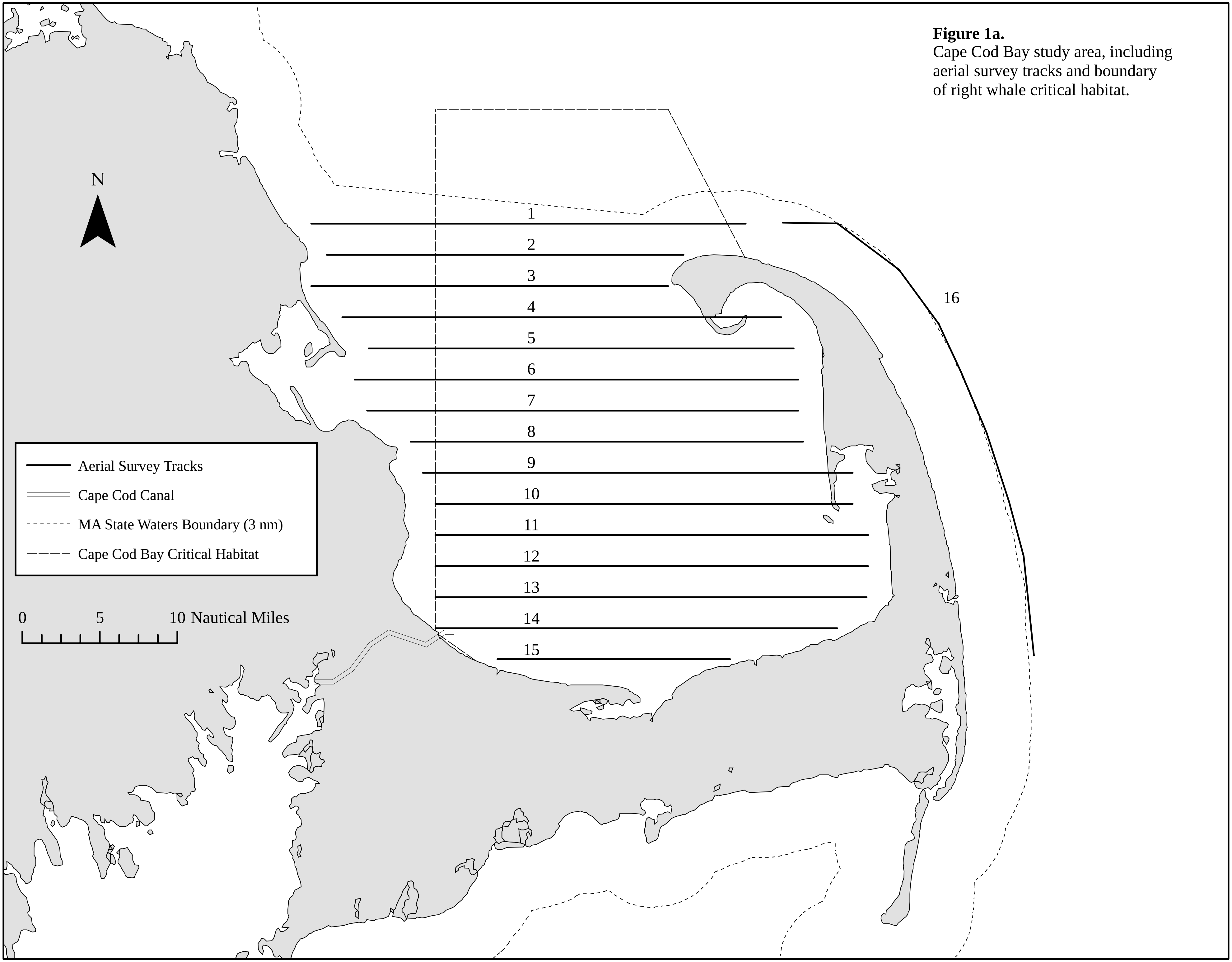
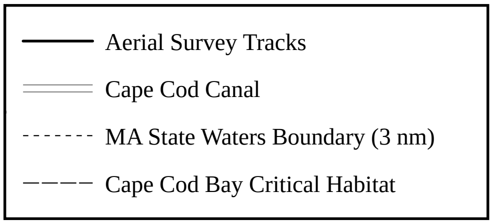


Figure 1a.
Cape Cod Bay study area, including aerial survey tracks and boundary of right whale critical habitat.



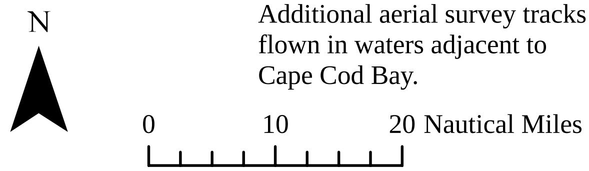


Figure 1b - c.
Additional aerial survey tracks flown in waters adjacent to Cape Cod Bay.

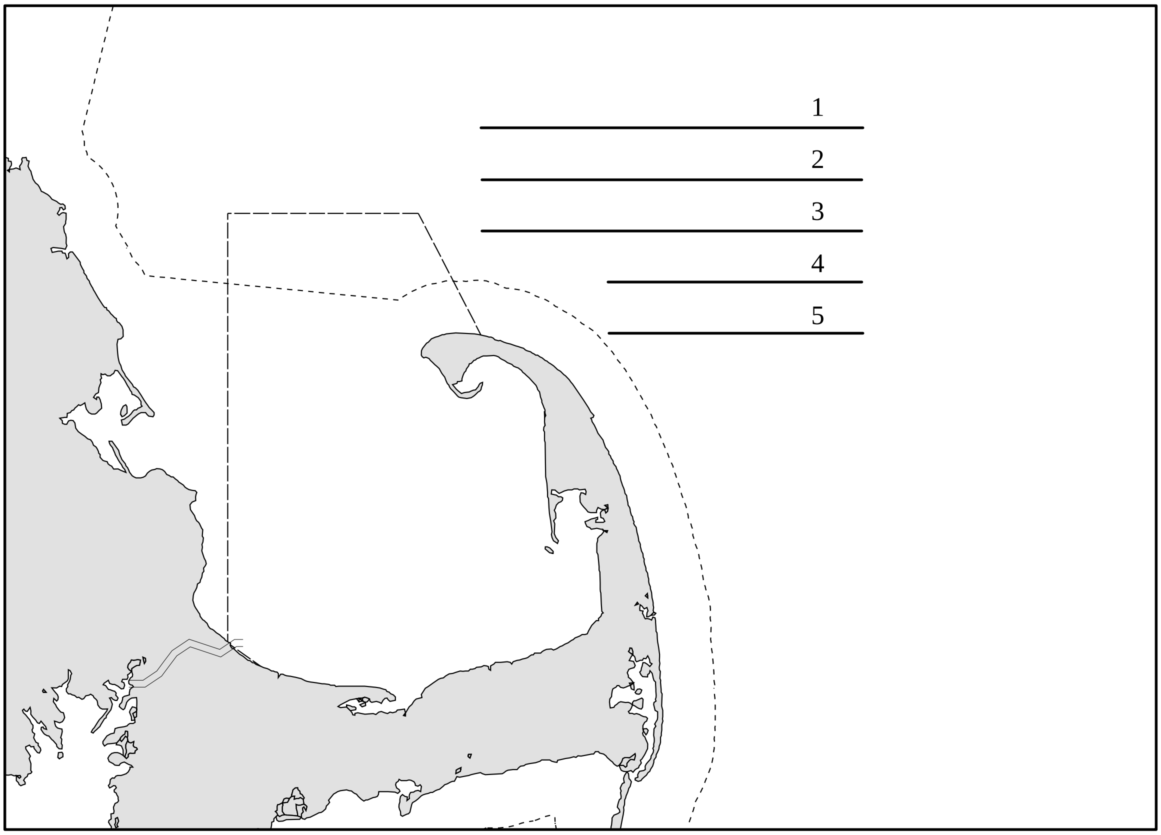


Figure 1b. Aerial survey track lines flown over Stellwagen Bank and Wildcat Knoll, 8 May 2004.

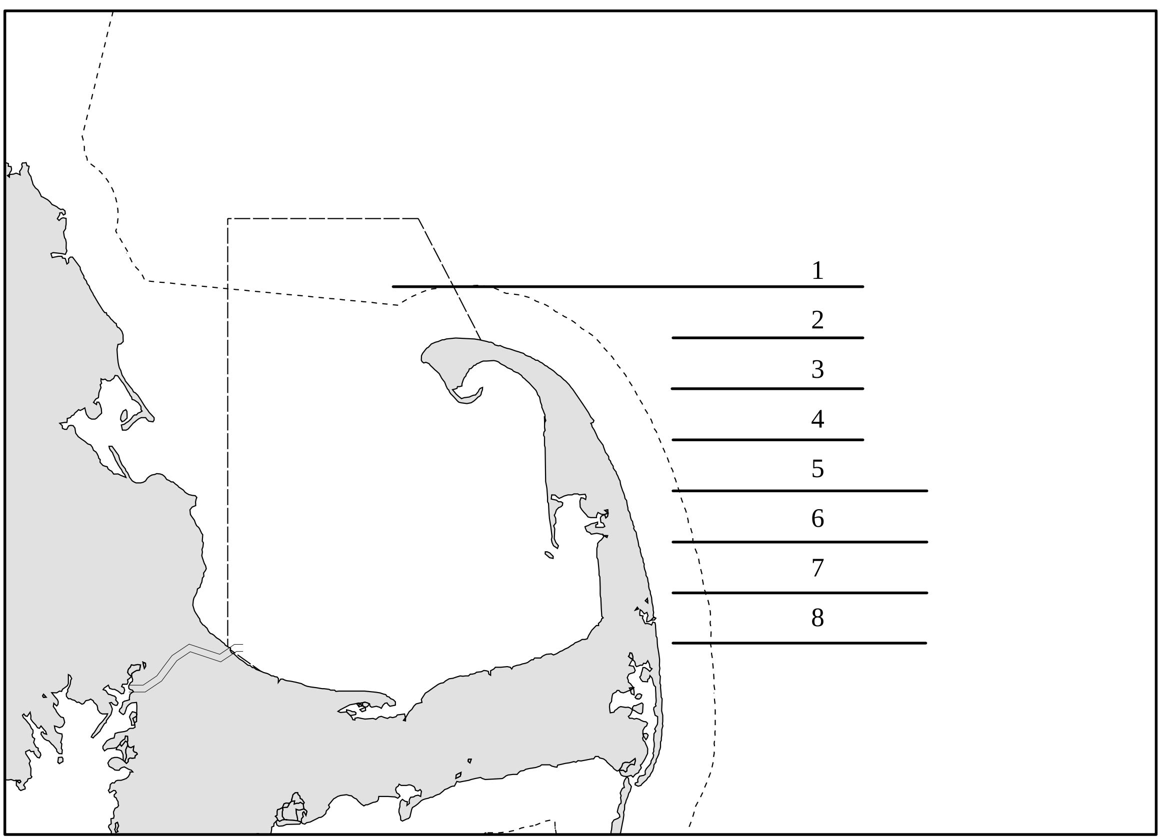


Figure 1c. Aerial survey track lines flown east of Cape Cod, 12 May 2004.

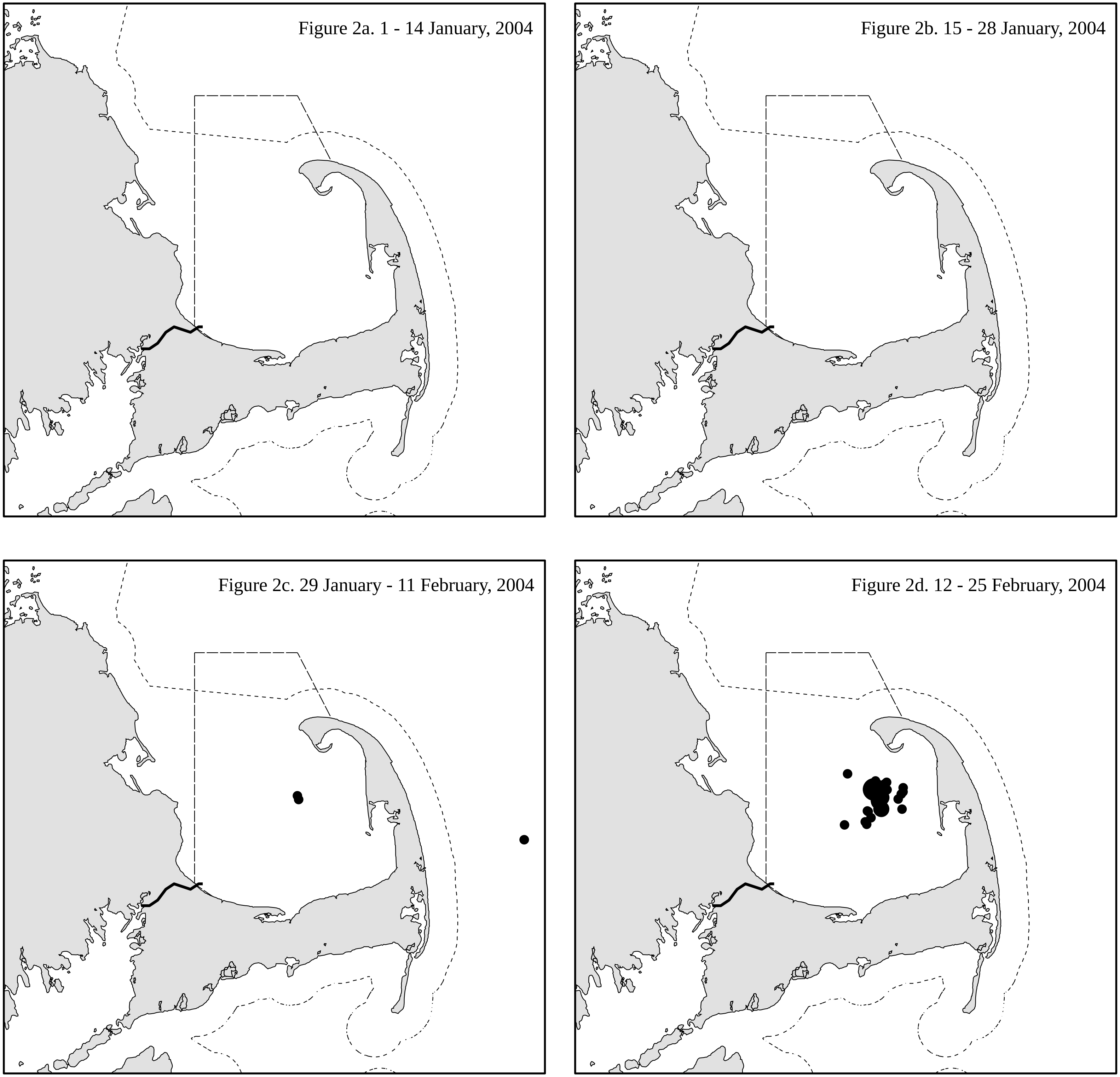


Figure 2a - d.
Sightings of right whales from 9 aerial surveys of Cape Cod Bay, 1 January - 25 February, 2004.

Right Whales

 # animals

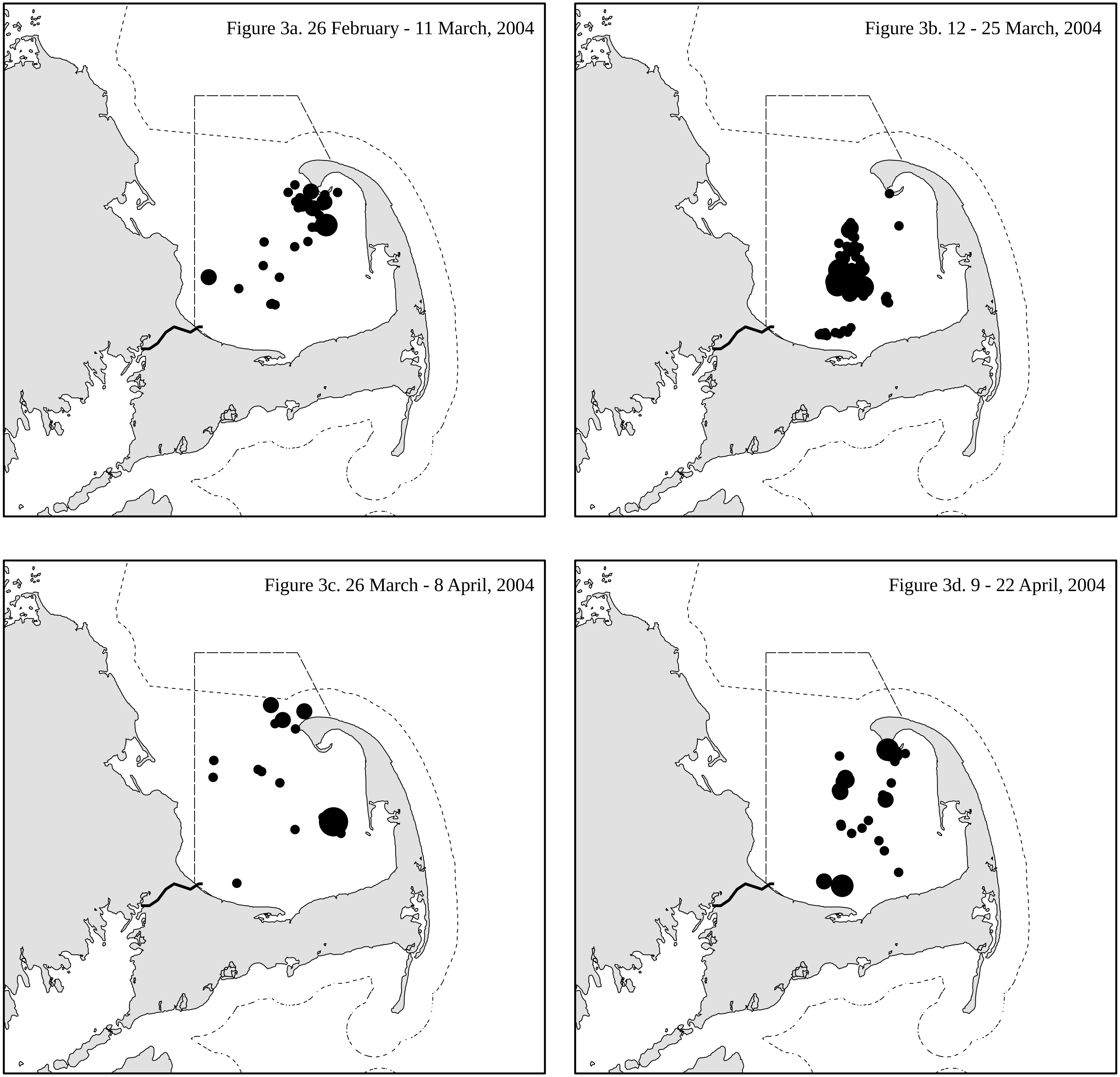
1
2
3 - 4
5 - 7
8 - 11

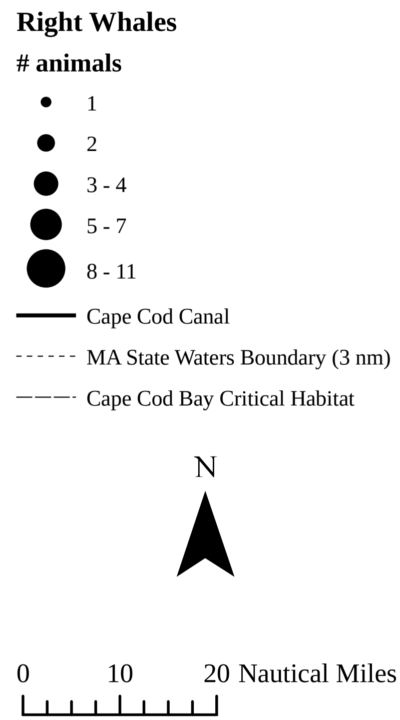
Cape Cod Canal
MA State Waters Boundary (3 nm)
Cape Cod Bay Critical Habitat

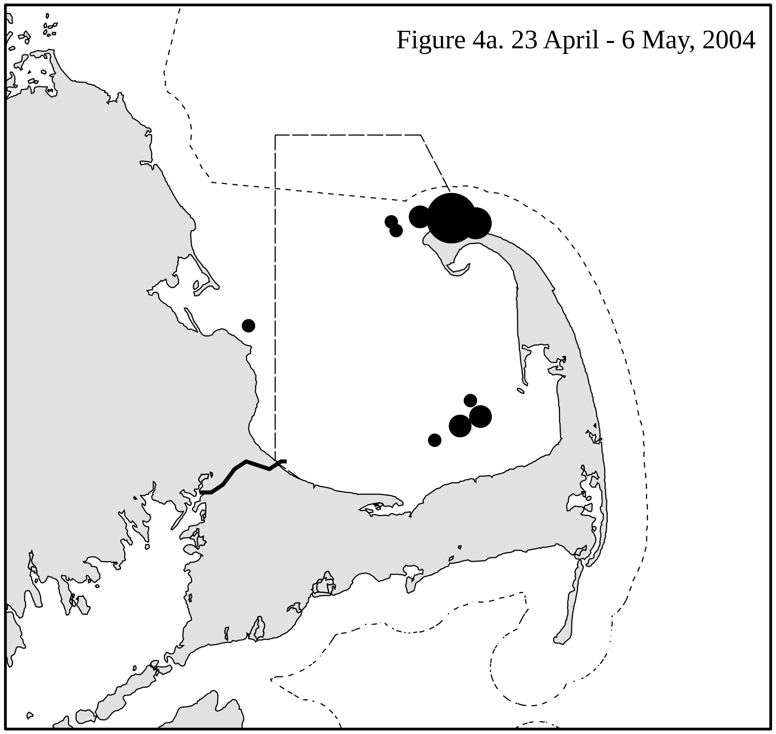
N

0 10 20 Nautical Miles

Figure 3a - d. Sightings of right whales from 12 aerial surveys of Cape Cod Bay, 26 February - 22 April, 2004.







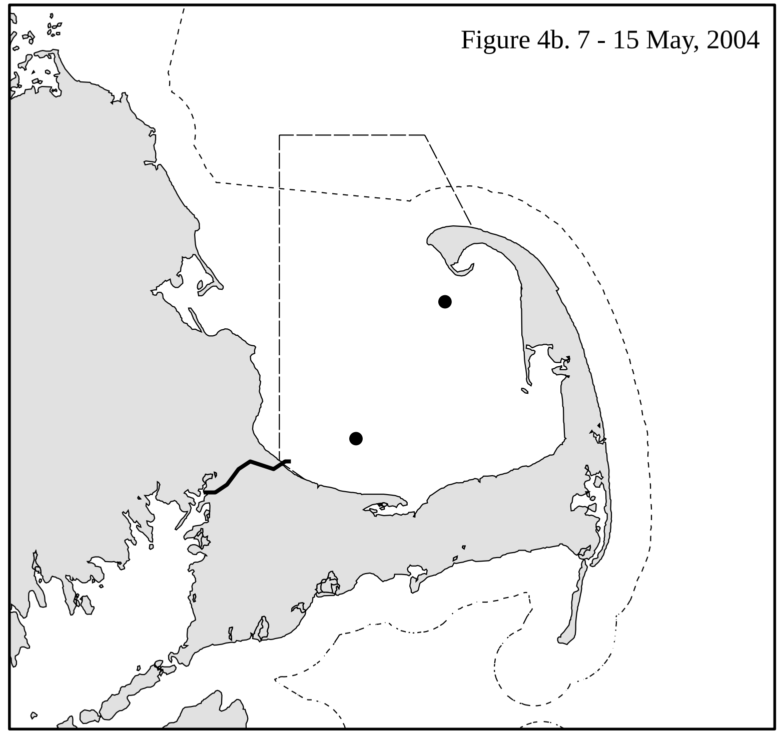
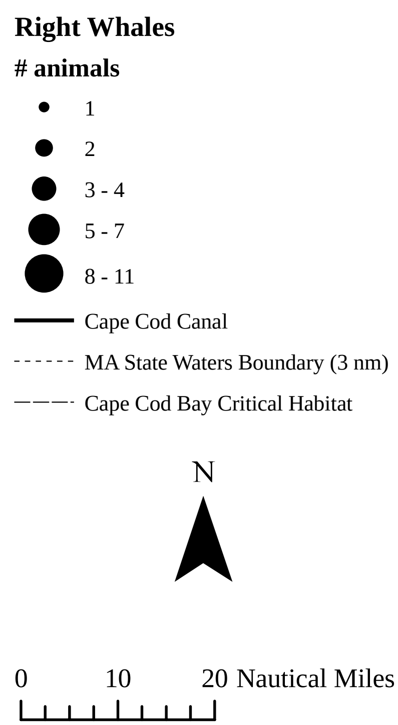


Figure 4a - b.
Sightings of right whales from 4 aerial surveys of Cape Cod Bay, 23 April - 15 May, 2004.



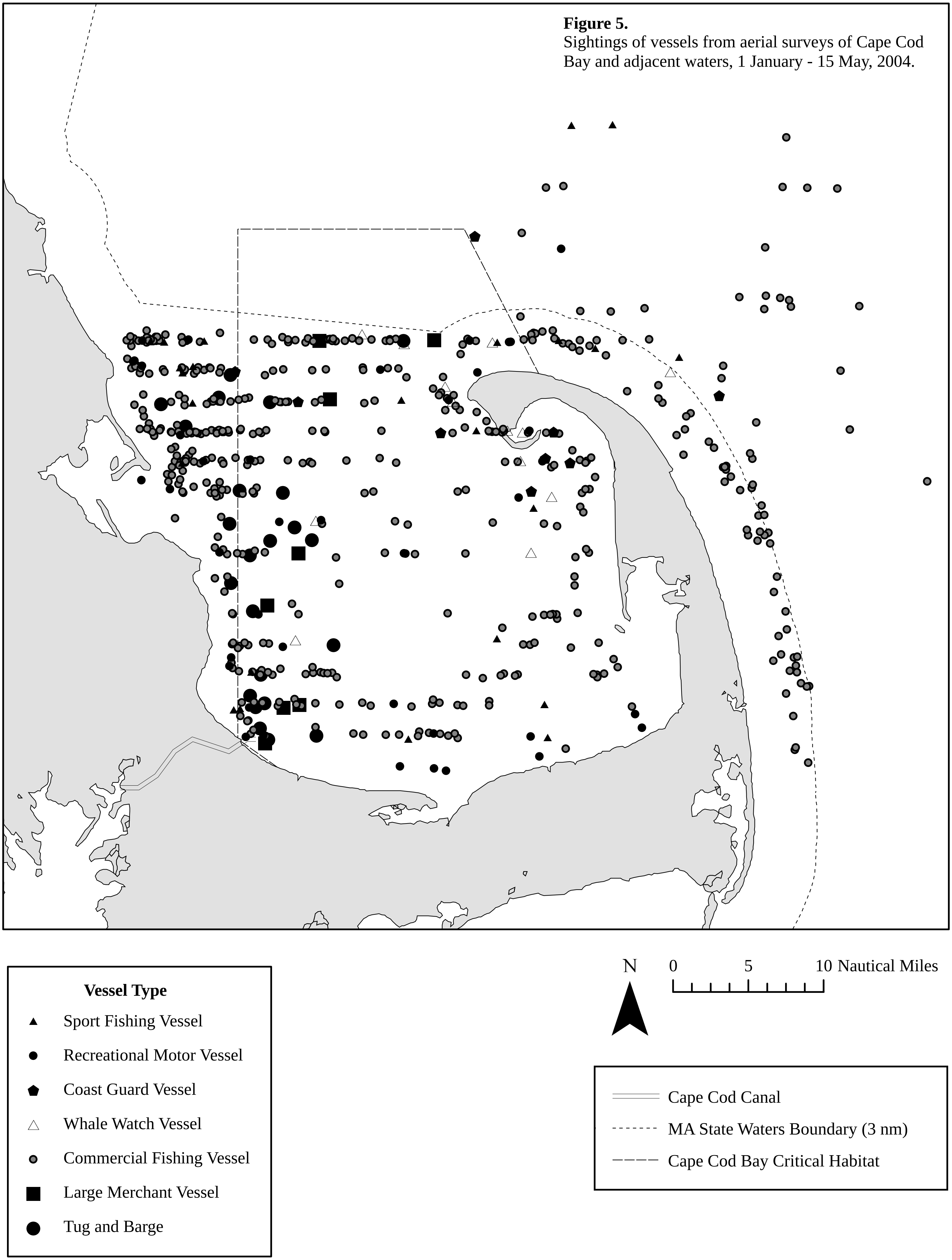
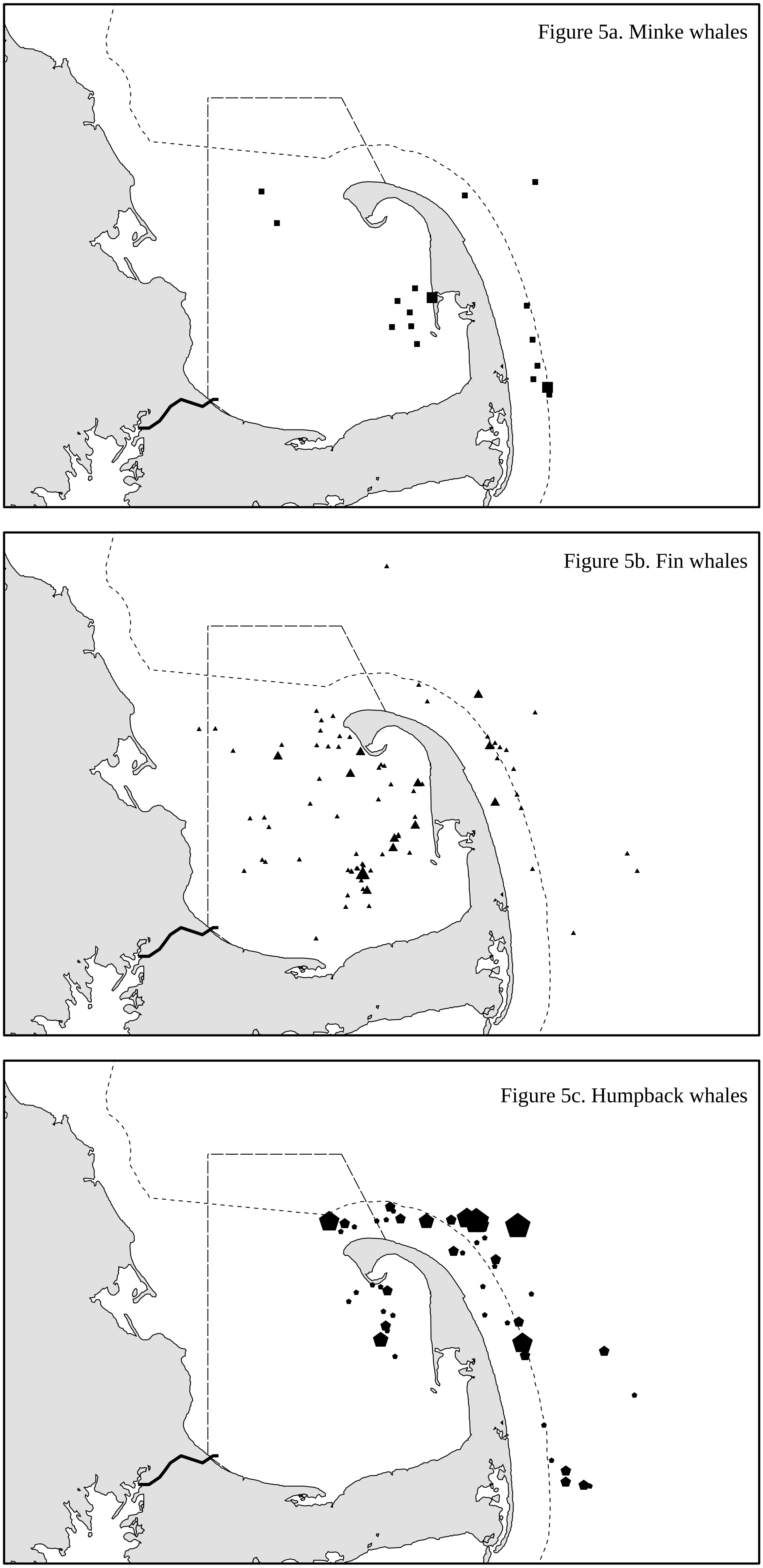
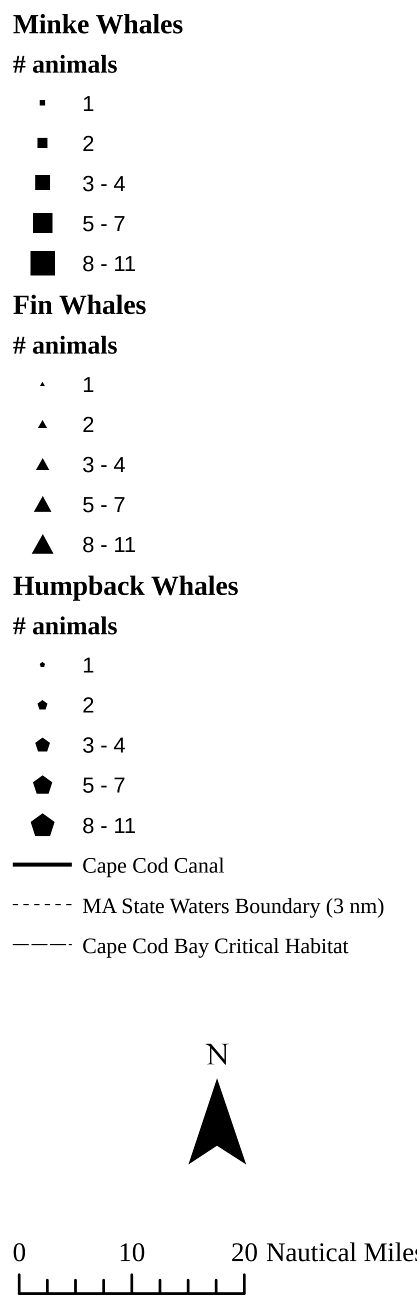


Figure 5.
Sightings of vessels from aerial surveys of Cape Cod Bay and adjacent waters, 1 January - 15 May, 2004.

Figure 6a - c.
Sightings of balaenopterid whales from aerial surveys of Cape Cod Bay and adjacent waters, 1 January - 15 May, 2004.





Appendix I

Confirmed right whale identifications in Cape Cod Bay and adjacent waters 1998-2004 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	Y2003	Y2004
1004	F	OF					G		SMF		S	SFO			FS	S	M	S	SF	M		G	G	GF	G	A
1012	F				F	M	M	SF					S				M	SMG				S	SG	MG	G	
1013	F	MF			M		SM				M					MJ		M	SM		M	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	MN	MGN	MG	S		MN		
1027	F	F		BF	BF	SA	MG	MGBF	B	MBF	SMF	B	B		MF	F	MF	MF	MGF	MAF	MF	MOF	MGF	MOGF	OB	M
1032	M	F		F	F			GF	F	GF	GF	F	F	F	F	F	F	F	MF	F	GF	OF	F	GF	GMF	
1033	M		M	B			M	B	B	B					F	M	M	MF	N	MN			N	N	N	
1036	M			B		G	G	B	MB	B	B			B											GMO	
1039	F	O						B			M	MS		M		M	M	SM	NM	MF	F	OS	SN	SM	NG	M
1042	U	GB	G		B			M	GB	B	GB		B					M	MO	MN	G			GO	G	M
1048	M	F		X				B	B	MB	G	B		B			F	OF	F		F	F	GB	G	O	M
1102	M	B	GO	B				B	G	B	B	B	B		F	F	MF	MF	F	MF			G			
1112	M	F	GF	BOF	F	MJ	MO	B	F		FM	F		M	FJ	F	M	F	GF		F	MF	GF	GF		
1113	M		F	B		O		B	B	GB	B		B		M		M		BN	N	F	MG	S	O		
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	MF	F	OM	O	M
1122	M		F					M	GB	GB	GB		GB			F	F	FO	F	F	F	G	G	F	GM	M
1130	M	GF	GF	F		M		B	B	GB	BJO	MF	MB		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	GF	GO	OJ	
1133	M		GF		B	BF	MG		B	GB	B			F	MF		M	F	F	AF	GN	M			MO	
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	G	G	G
1144	M	O	GF	F	B	BF		GBF	B	G	B			F	F	F	F	F	F		G		G		G	
1145	F		F		G	MBF			S		SF		MF				S	S				G	S	SMG		
1146	M	B	GF		M	MBF			MF	MGB	MGBF			F	F	FJ	F	MF	F	M		MF		F		
1150	M	O	MF	B	M		MF	F	B	FB	F		MFB	F	F	MF	F	FO	MF	MF	MGF	MOF	MGF	GF	GOFJ	
1151	F	OF	F	F			G	BF	SF	B	F	FS	F		F	F	FS	SF	F	F	GF	GOFS	SGF	OGS	SMFJ	S
1152	M		F	F	GJ	J	GF	M	GF	GF	GJF	F		F	SF	F	F	SFO	F	F	GF	SOF	G	GF	GFJ	
1158	F		F	F		MF		M	G	G	SGF	M	F	M	F	F	MF	S	MFS	SAFM	MGF	FS	SGF	GFS	S	
1160	F		JF	B		F	BF		N	GO			S					SF	F		O	S	SAGO	MO		
1162	M	B	F										B			F	F		F	M	OF	F	G	GB	GF	
1167	M		F	F			G	MB	B	GB	B		B	F	SF	F	SGF	F	F	F	F	AMOF	MG	OBF	G	
1170	M		F	F	MF	MGF	F	M		GF	F	F	B	F	F	F	F	FO	MF	MAF	MGF	GF	MGF	GF	F	
1207	M	A	G	G	GB			A		GB	B	F	G	F	F	J	F	SF	F	N	GF	F	G	OG	J	M
1208	F		M				MG		G	GS	SAG	N	S				S	SF			M	O	M	S	SG	
1209	F	M		M	B			B	F	F	SB	S	M		F	FJ	F	F	F	MF	GF	AOF	MGF	MOGB	MOGJ	M
1239	M		G	F				B	GB	GB	GB		GB	M	F	F	F	MFO	F	G	MF		O	G	G	
1240	F			F			F			G	SB	S	F		F	F	F	F	SF	M	MF	MO	G	SAJGOF		
1241	F			F	MF	MF	F	GF		JF	SF	F	MFB	M	F	FS	SF	M	MF	MOF	F	MF	MGS	SAGF	M	
1243	F			F		BF			G	G			SF			F	F	FS	SMF	F	F	F	SGF	MGOS	SMF	S
1245	F			F	MF	F	MFO	A	F	F	F	FM		F	OFS	SF	FS	SAMF	F	MF	F	MGF	OF		S	M
1246	F			F		G		S			SGJF										OF	GF	G	ASMG	G	
1248	F	O	G	SOF		G	F	B				F							S				S	SMGF		
1249	M			SOF	F	MG	M	MB	B	GB	B	B	BF		MF	F	MF	MFO	F	MF	MGF	MF	SGO	G	G	M
1267	F			J	F			GBF	B	BF	GFB	FS	M		MF	MF	MF	SMF	MF	MF	MGF	GOF	MSF	MGFJ		
1270	M	G		B		B				B	B	B				F				M						
1271	M			B	B			MF		GB	B	B	B			F	F	OF	F	M	GF	MGF	GF	MGB	OGF	
1276	M	GO		B	B	G			B	GB													G	G	G	
1280	U			GB		G	MB	MB	MB	B			M	M	M	M			M	M	O	AM	G	G	OG	
1281	F		G	B		SM	MA	SF		G	F		B	M	SF	F	MF	SF	F		F	OFS	SMF			S
1301	F				MF	AM		MB		BS	SF	M	B	BS		F	MF	MF	FS	SAF	MF	MGBS	SGF	MGS	SF	SM
1303	F	F			MF	F		B			GF				SF	F	MF	MF	MF	JF	GF	GFS	SAGF	MGFS	SF	
1306	M				MF		F	G	M	GF	GF	B	B	F	F	F	F	SFO	F	F	GF	MGOF	MG	MGF	F	
1307	M	O	G	O	MB			ABF	B	GB	GB		GB		F	F	MF	FO	F			F	G	MOGF	G	
1310	F				GF	B	G	MF				FJ		O				M	S	M			G	SMGO		M
1311	M				GF		M	GB		GB	B		B	SB	F	MF	F		M		G	SMG	MG	MG	G	

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1317	M				SM	MBJ		GB	B	M	SB		B			OF	F	F	MF	F	MGF	MGF	MG	F	GO	
1320	M	O	G		B		G	B	B	M	SB	B	B		F								G	G	GMJ	
1327	M			MG	M	G	M	MBF	M	MB	B	B	GB	F	MF	F	F	FO	F	F	MGF	MGOF	MGO	GF	SMGF	M
1328	M				G					B	F	B	F	MBF	F	F	M	M	F	F	M	MG	MGF	MGB	MG	M
1402	M					F		B	B	GB	GBF	B	B	F	F	F	F	SF	F		F	OF	G	GN	M	
1403	M					F		F		GB	B		B	MF		F	F	SM	F	F	GF	M	SOG	N		
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	MN	O	MOGS	SF			
1408	F					AF	F	F	F	MF	B	F		F	FMS	SF	F	AF	F	F	GOF	F	G	SGF	S	
1409	M					F		B	B	GB	B	B	B		SMF	F	MF	S				M	SG	MFJ	G	M
1411	M					SF		G		B	MB	B	B		F		F	F	MF	M		M	M			
1419	M					B		B		B	B		B	B		F	MF	M			F	G	OF	GF	MG	
1424	M		M		B	B	S	M	G	GB	GB	M	B	M	MF	F	F	SMF	F	MAF	MF	GOF	MGF	SMGO	M	M
1425	F			G		F	M		M	B	M	M		M	MFS	SGAF	MF	MF	F	A	M		SGF	M	M	M
1427	M					F	JM		GB	GB	B	B	B	MF	MF	F	MF	FO	MGF	FM	MG	S	MN	AS	J	
1428	M	F	G			MGO	M	GB		MG	F	FB	B	F	F	F	MF	SMF	F	M		MOF	SMF	GF	GO	M
1429	M			G		M		MB	GB	GB	B	B	XF		M	F	F	FO	OF			GF	G	G	GM	
1430	F					M	M	MB	MB	MG	B			SM	F	MF	MF	MNS	S	MGN	MO	MO	GNS	SON	O	
1503	F						F	M	M	MB		F		M	F	F	SFM	MF	BF	MO	MF	MOFB	MGF	MGS	SMJ	M
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	MGF	MFJ	F	M
1509	F	GB				M	M	SM		B	SJM	M	M	SMJ		M	MN	MNS	SF	M	MG	MS	SAGN	M	N	S
1511	M		G		B	G	M	MBF	B	B	B								F		M	MO	GB	GF		
1514	M						MG			MB	B	B	B				M		F	M		OF	G	G	OG	
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	SMGF	SMF		
1603	M							SGJMF	M		B	S	M		SF	F	MF	F	F	SM	GF	SMF	MGF	F		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	MGF	MF	JMF	
1609	M							SM	F	F	F		B		F	F	F	SF			JMF	GFB	MGF	MG	MGO	
1611	F							SM	SF	B	B		B			F	F	MFO	SF	MGF	MF	OFS	SGF	SF	G	S
1613	M							SJM			FM	F			S	F	F	S	BF	F	F	SAGF	MF			
1616	M							B	B	G	B	F	B	F	F	FJ	F	F	F	F	J		S	G	G	
1622	F							M	M	GBS	S	M	SM				F	MS	SMO	M	MG	M	M	SG		
1624	M							B		GB	GB				F	F			F		G	MG	G	GO	GO	
1625	M							B	GB	GB	GB		BF		F	F	F	FO	F	F	F	OGF	G	MG	M	
1627	M						G	B		GB	B		B		S				G	G			G	G	G	
1629	F						G	B	G		B	SF			G			SM	SM	S	M			SG		
1632	F							B	G	GB												O		SF	GM	
1701	F								F	F	B	B	FB		FS	F	FS	SF	OF	MF	MGF	FS	SGF	SGO	G	S
1703	F								F		F	F			SF	SF	F	SF	MF	S	SGF	MOS	SMGF		M	M
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	GF	GF	GF	S
1706	F								SMF	F	F	F	F		SMF	FJ	SF	MF	MFS	MF	MGF	ASGF	MG	MGF	MG	M
1708	M								GB	B	B			M	M			MF	F	F	MG	MGF	SMGF	GF	G	S
1709	M								M	JB	B	B	B	M	SF	F	F	F	F	SMF						
1710	F								SM				JM				G	S				GS	SMG			
1711	F								SM	GB	MB						F	SMF	F	M	SMG	MS	SG	FS	SG	
1712	M								SAM		B	B	B			F	F	F	M		MF	S	SG	F	MGB	M
1716	M			B					B	B	B		B		F	F	F	F	F	G	MF	GF	F	GB		
1802	F									MGF	MF	MF	MF	F	SMF	F	MF	MFS	F	MF	MGF	MGOFS	SGO	GF	SGF	M
1803	M									JF		F	F	S	SMF	F	F	M	OF	S	MGF	SF	MG	MGF	S	
1804	M									GO	F	F	F	F	F	F	F	F	MF	SF	MGF	AMGF	MGF	MOF	GF	
1812	F									B	B		B		SF	F	F	S	F		MGF	MOGBF		SG	G	S
1817	F									B	SB		S	S	SF	SF	FS	SF	F	S	G	MFS	SMGF	MGFS	SMF	SM
1820	M									B	B	B	B		M	F		SMF	MF	M	MF	MOF	MG	G		M

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1821	M									B	B											G		MG		
1901	M										SGF		S	SF	SF	SF	SF	SMF	SMF	F	MGOF	SOFB	SMGFO	MGF	GOF	
1909	F										SJM	MJ	B	M	SMF	F	SBF	F	MF	MF	SMOGF	GOF	G	B	SG	
1911	F										F	M				F	MF	M	MF	MF	SMGF	MF	SGF	G		S
1934	F										SMO		B	M	SF	MF	MF	M	MF	SMGF	MGF		GF	F	GM	M
1946	F										SGJF	F		M	SF	F	F	MFS	SMF	F	F	OF	MGF	GFS	SOF	
1960	M										B				F	F	F	SO	F	F	GF	G	G	MGF	GF	
1968	F										GF		B	B	S	F	F	OF	F	M	MF	MFS	SM	MFS		M
1970	F										B							S		O		S	A	MG		
1971	M										F	F		F	F	F	F	F	GF	F	GF	MSAOBF	GOF	MF	SGF	M
1980	M										B							SM		M		SMG			GM	M
1981	U										F	GF			S	F	F	SOF	FS	F	MGF	F	GF	F		
2010	M											FJ	M	M	S	F	F	SF	MF	SM	MGF	SMOBF	MGO	F		
2018	M											SF	FM	F	F	F	FS	F	F	A	F	F	GF	G	SGM	M
2027	M											MJF			F	F	F	MFO	F	M	F	MF	MGF	G		
2040	F											MFJ			F	F	F			O	G	MF	SGFB	AONF		
2048	M											F	F		F	F	MF	MF	F	F	MF	SGOB	M	MGB	AM	
2050	F											M	M	M	SM		MF	SMF	MF	MGF	MGF	MGFS	SMGOF			
2057	M											F				F	F	F	F				SG		SG	
2110	M												JM	F	F	F	F		F	F	GF	AF	GF	MG		
2114	F											S	SB		M	F	MF		F	M	GF	FB	GB	FS	S	
2123	F												F	MF	SF	FS	FS	SMFO	SMF	SMAF	MGF	MF	SMG	MGFS	S	M
2135	M												MF	MF	SF	F	F	SMOF	GF	MF	MJOGF	SMF		G		
2140	M											S	F	F	S	MF	F	SMF	F	MF	MGF	GF	SMGF	G	S	
2142	M												GF		F	F	F	F	F	MF	GF	GF	G	G		
2143	F												SF	F	F	F	F	FO	MF	F	GF	SMF	MGF	GF	M	
2145	F												MF	F	MF	F	F	MOF	MF	MF	MF	SMF	SMGF	MO		SM
2150	F												M			F							SMG	S	F	
2158	M												F	MF	F	F	MF	MF	F	SM	MF	MOF	MF	M		
2201	M													SF	SMF	F	MF	SFO	F	SF	MF	GF	M	GOF		
2209	M													SMJ	M	F	MF	SMFO	F	MAF	MGFS	MGOF	MGF	F	SM	M
2212	M													SJM	M		F	F	F	MF						
2215	M													SB	MF	F	MF	SMFO	MF	SMF	MGOF	MOF	MOGF	MGF	GM	
2223	F													F	F	F	F	FO	F	MGF	MGFS	MF	MG	MG	M	M
2240	F													SF	SF	F	F	SFO	GF	MG	OGF	MOF	SGF	SGF	S	M
2271	M													SF	F	F	F	SMOF	NF	M	MGF	AMGOF	MF	OGF	M	
2303	M														SF	SMF	MF	SF	M	SAF	MGF	GF	GF	GBO	SM	
2304	M														M	F	F	MF	F	F	MOF	MGO	MF	MG		M
2310	M														F	F	F	F	FS		F	OF	MGF	F		
2320	F														S	F	F	SF	SMF	S	GF	MOBFS	MGB	MF	GM	M
2330	F														M		F	F	F	SF	F	GF	SGMF	SBF		S
2340	M														F	F	MB	F	F		MGF	MGF	MG	G		
2350	U														F	F	MF		F		MGF		SMOG	MGFB	M	M
2406	M														A	SMF	M	F	F	MF	MGF	MGOF	MGF	G	SGM	
2425	F															SGAF	MF		F	MF	MGF	SMGF	MOG	MGF		M
2427	M															M	F	MFO	F	F	GF	MF	MOGF	FB	M	S
2430	F															F	MF	F	F	F	MGFS	MF	MF	MFB		M
2460	F															F	MF	F			GF	MOF	MGF	GF		M
2470	M															F	F	MF	F	MF	MGF	MGF	SF	MGF		M
2479	M															F	F	MF	MF	MF	MGF	MF	MF	F		
2503	F																SFM	F	F	MF	F	MF	MGF	GF		S
2510	U																M		N	MN		G	SGF	OGF		
2530	M																F	F	F	N	F	GF	GF	G	M	M
2540	M																F	F	F	F	F	MOF	MGF		M	
2602	M																	SMFOA	F	F	F	MF	MGF	F	M	
2605	F																	SF	F	MF	F	F	G	F		
2608	M																	AF	F	F	F	MF	F	GF	G	

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2611	F																	SF	F	AF	F	F	GFO	F	AGM	
2614	F																	SMF		M	GF	F	GF	F		S
2615	M																	SF	F	AF	F	OF	GF	F	G	
2617	F																	SF	SF	F	F	MF	MOF	SF		M
2630	M																	S	F	MAF	MF	GF	GF	G		
2640	U																	SF		MA	O	G	MF	GB		
2645	F																	SAMF	SMF	F	MGS	MF	MGF	MGF		
2681	M																	SF			G	O	GO	GN	M	
2701	F																		SF	SMF	F	A				
2704	M																	S	SMF	MF						
2705	M																		SF	SMF	F	F	MGF	OF		
2709	M																		SF	SF	F	MF	MGF	MGF		
2710	F																	S	SF	F	MF	F	GF	GF	GM	S
2720	U																		F	MF	F	MF	MOF	F		
2740	M																		SF	F	MF	F	MGF	SOGF	GM	
2746	F																	S	SMF	F	F	F	MF	SF		
2750	M																		SF	F	MGF	MF	MGOF	MF	M	
2753	F																		SF	F	F	GF	GF	GF	SGM	M
2760	M																		F	GFM	MOF	MF	GF		G	
2770	M																	S	F		F	S	F	G	M	M
2790	F																		F	MF	GF	OF	F	SG		
2810	M																		S	SG	G	F	G	G	G	
2820	M																			SF	F	F	GF	M		
2830	M																			AF	F	MF	MF	F		
2910	U																				M	F	GF		M	
2920	U																				SMG	MG	MGF	MOGF		
2930	U																				M			ON	G	
3010	F																					F	F	MGF		
3020	F																					O	G	GOF	M	
3030	M																					F	MG	GF		
3102	F																						SMGF	SM		
3103	F																					S	SMGF	MF	M	
3109	M																						SAN	MF	SMGF	
3110	M																					S	SMG	SAF		
3123	F																						SOF	SF	M	S
3125	M																						SGF	MF		
3130	F																						SGF	SF		M
3139	U																						SN	SMN		S
3150	M																						SMGOF	G		
3170	M																						SMGF	MF	S	
3180	F																						SMG	SGF	M	
3181	M																					S	SMF			
3190	U																					S	SGF	OGF		M
3240	F																							SAJGFO	GF	
3302	U																								SGF	SM
3308	U																								JMF	S
3317	U																							S	SMF	S
3343	U																							S	SMF	
3351	U																							S	SMFJ	S
1145ca																								M		
1246ca																								G		
1310ca																								M		
1503ca																									SM	
2145ca																										SM
2460ca																										M
01-03																							G			
02-120																								M	G	

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.

Appendix II. Sighting records of identified right whales seen in Cape Cod Bay and **adjacent waters**, January to mid-May 2004. F (female), M (male), A (adult), J (juvenile), U (unknown)
"X" denotes the sighting date in Cape Cod Bay, bold "**X**" denotes sighting date in adjacent waters. "*" denotes entangled whale.
Dates shown represent aerial surveys, including those without sightings to represent effort (surveys in **adjacent waters** shown in bold), as well as opportunistic shipboard sightings.
Dates that only represent shipboard sightings without aerial survey effort in *italics*.

Id #	Sex	Age	21-Jan	27-Jan	2-Feb	3-Feb	**3-Feb**	10-Feb	12-Feb	*13-Feb*	17-Feb	20-Feb	24-Feb	29-Feb	1-Mar	*5-Mar*	10-Mar	14-Mar	16-Mar	20-Mar	24-Mar	*30-Mar*	7-Apr	8-Apr	*9-Apr*	10-Apr	18-Apr	*19-Apr*	21-Apr	*24-Apr*	25-Apr	*28-Apr*	5-May	6-May	**8-May**	10-May	**12-May**	# days sighted
1140	F	A					**X**																															1
1027	F	A						X	X	X	X	X	X	X	X		X	X		X	X					X												13
1802	F	16						X	X						X			X		X	X									X								7
2240	F	A							X	X	X	X	X	X		X	X		X																			9
1706	F	17									X	X	X	X			X	X			X																	7
1245	F	22									X	X		X			X	X	X	X																		7
2123	F	13									X	X	X	X	X			X		X	X	X	X						X									11
1310	F	A									X		X		X		X	X		X																		6
2770	M	U										X																										1
1503	F	19										X	X		X		X				X								X	X								7
2530	M	A											X	X	X								X			X	X											6
1039	F	24											X	X	X	X	X	X			X																	7
1817	F	A											X	X	X			X	X		X																	6
1013	F	A												X	X			X	X	X	X																	6
1301	F	21												X	X		X	X	X	X					X													7
2223	F	12													X			X	X	X	X		X				X		X									8
1703	F	17																X	X	X	X																	4
2470	M	A																	X	X			X	X														4
2350	U	A																		X	X	X																3
2425	F	10																		X	X			X														3
1249	M	22																		X	X																	2
1424	M	A																		X*	X*							X*										3
1980	M	A																		X	X			X														3
2018	M	14																		X			X								X							3
2617	F	8																			X	X	X			X			X									5
1971	M	15																			X		X		X	X	X		X									6
1428	M	A																			X										X							2
2753	F	7																			X		X			X												3
1209	F	A																			X			X			X											3
1934	F	15																			X	X																2
1712	M	17																				X	X	X														3
1121	M	A																					X	X														2
2304	M	11																					X				X		X									3
1603	M	18																					X															1
1507	M	19																					X	X		X												3
2145ca	U	J																					X				X		X			X						4
2145	F	13																					X			X	X		X			X						5
3302	U	1																						X														1
1328	M	A																								X	X											2
1042	U	A																									X		X									2
1409	M	20																									X											1
2209	M	12																									X											1
1327	M	A																									X											1
1207	M	A																									X											1
1122	M	A																									X											1
1820	M	A																									X											1
2320	F	A																										X*				X*						2
2460ca	U	J																											X			X		X				3
2460	F	A																											X			X		X				3
1968	F	15																											X									1
1425	F	A																												X								1
3130	F	3																													X							1
1048	M	A																													X							1
3190	U	U																													X							1
2430	F	A																														X						1

Appendix III

Acoustic Detections of Northern Right Whales in Cape Cod Bay,

Sampled 14 December 2003 - 31 May 2004

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There is good evidence from previous studies to support the assumption that passive acoustic methods 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, and has continued every year since then in Cape Cod Bay and the Great South Channel using autonomous acoustic recorders referred to as "pop-ups". The results have been very encouraging. In all four seasons (2001-2004) and in both locales right whale sounds have been detected, and in Cape Cod Bay there has been 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 2004 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.

Starting in the fall of 2003 and through spring 2004, the Cornell Bioacoustics Research Program deployed multiple sets of pop-ups in Cape Cod Bay. The first set of three pop-ups was deployed off Race Point, off Sandwich near the "fingers" and about 8 nmi south of Wood End and 5 nmi west of Wellfleet. This configuration of three units collected data continuously from 14 December 2003 to 27 February 2004 at a sampling rate of 2000 Hz for an effective frequency range of 10 - 1000Hz. From 27 January 2004 to 17 April 2004, four pop-ups were deployed with three of the four being in the same locations as during the 14 December 2003 to 27 February 2004 period. The fourth pop-up was placed in the center of the three (close to the center of the array). These four pop-ups recorded continuously at a sampling rate of 2000Hz. Pop-up positions of this 4-elelment configuration are shown in Figure 1. On 17 April when the four pop-up array was recovered, a single pop-up was deployed at the "Wellfleet." location. This unit recorded continuously through 31 May 2004. Processing of the array data for right whale sounds and acoustic locations for the aerial survey days is in progress.

[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.

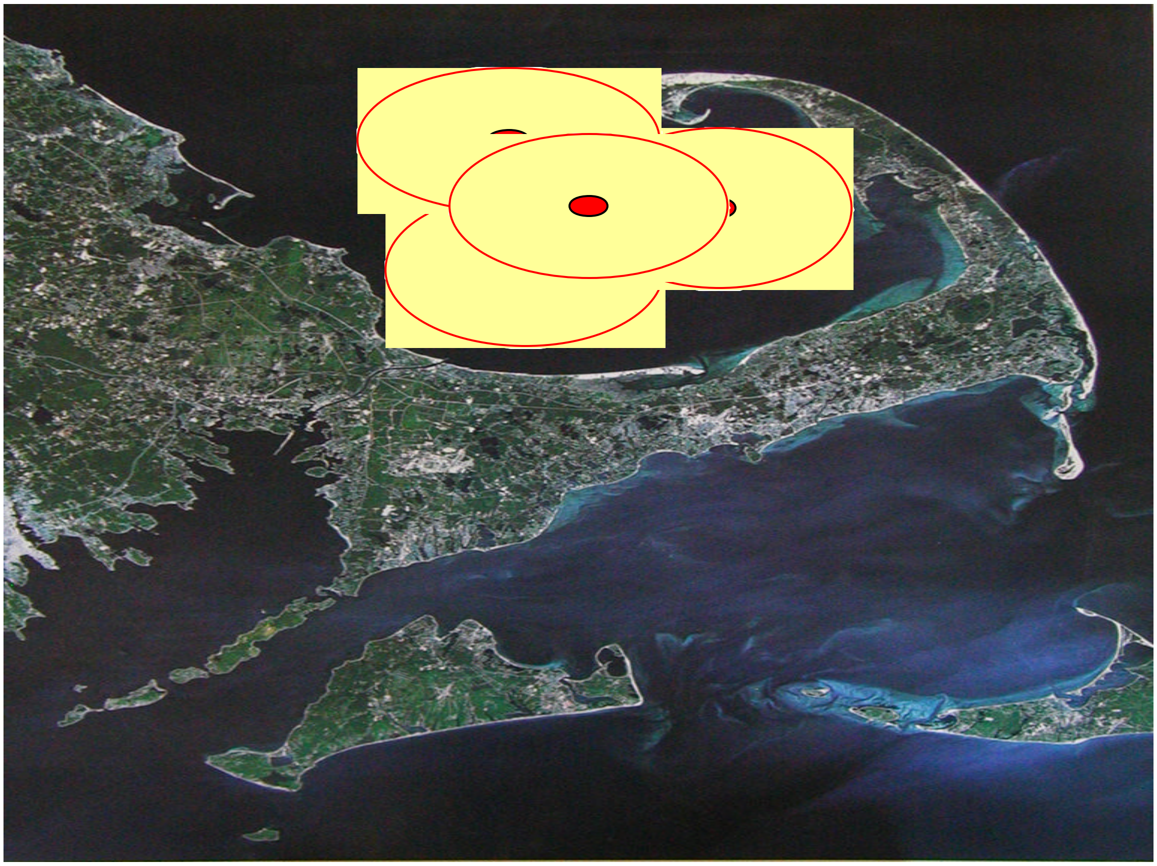

Figure 1. Positions of pop-ups deployed in Cape Cod Bay and used to detect the calls of northern right whales during the 2003-2004 season.

Appendix IV

Ship/whale interaction 29 February 2004

Time: 1140 EST
Position: 41º 57.6' N x 070º 12.5' W

On 29 February 2004, we were conducting an aerial survey (CCS329) in Cape Cod Bay. A large ship (ca. 700') was anchored southeast of Provincetown. We were photographing several right whales ~2-3 nm to the northwest when we saw that the ship had gotten underway and was steaming southwest toward the Cape Cod Canal. We flew to the location of the ship and immediately noticed at least two single right whales and a Surface Active Group (SAG) of at least two additional whales in the immediate vicinity (< .5 nm) of the ship. The positions of these whales and the animals to the north appeared to effectively "fence in" the ship from her destination out of the anchorage. We did not see a favorable course for the ship to take to avoid the area of the whales without running into shoal water. We circled the ship to ascertain her name to facilitate hailing her via marine VHF to alert her master to the whales' presence. The name on the bow was *Margara*. As we circled back toward her bow, we saw that she was headed directly toward the SAG, with the other whales further away to the north and south. Before we could hail the *Margara*, we observed her alter course to avoid the SAG. As we flew over the bow, we observed a lookout with a handheld radio. We made the assumption that the lookout was guiding the vessel through the whales and chose not to make immediate contact to avoid any confusion. We orbited the ship and photographed her proximity to the whales as she passed by the SAG (~500'). The whales continued SAG behavior as the vessel passed. We circled ahead of the ship's path for several minutes and did not sight any more right whales. We then circled in the area of the whales that the ship had passed and saw approximately the same number of animals in the same positions, including the SAG, which had apparently continued for the duration of our observations. We were overdue for a break, so we were unable to photograph the animals for identification purposes at the time. We then headed to Plymouth for the break. While on the ground, we contacted the Marine Traffic Control office at the US Army Corps of Engineers Cape Cod Canal Field Station. We provided the position of the whales and described the above incident. We also asked that they forward our appreciation of their efforts to avoid the whales, as they would be in radio contact later in the day. When we resumed the survey and returned to the area, we sighted and photographed a SAG of two whales in the same area, and a few additional whales to the north.

A Web search provided information on the vessel from the Scorpio Ship Management web site: http://www.scorpio.mc/margara/margara.html

Sent to Scorpio Ship Management via their web site (2 Mar 2004):

Greetings,

I am a researcher at the Center for Coastal Studies in Provincetown, Massachusetts, USA. On 29 February 2004, we were conducting an aerial survey for right whales in Cape Cod Bay. The M/T Margara was anchored south of Provincetown. When she got underway to the southwest toward the Cape Cod Canal, she encountered numerous right whales in her path. The master and crew did an exemplary job avoiding the whales, which are critically endangered (ca. 350 in the Northwest Atlantic). Ship strikes and entanglements are the largest known causes of mortality in the population, and the actions of the crew of M/T Margara were a model for the maritime community. Please reply with contact information for the master and crew of M/T Margara so that we may extend our appreciation.

Cheers,

Owen Nichols
Center for Coastal Studies
Provincetown, MA USA

From Master M/T *Margara* 11 March:

Dear Mr.Nichols,

I wish to thank You for Your good words in message forwarded to vessel from Charterer related to avoiding Right Whales in Cape Cod Bay on 29th February 2004. We consider taking care of nature and ecology one of the first priorities of any seaman who living from the sea and with the sea. It was our extraordinary pleasure to have opportunity to see Right Whales in their natural habitat.

Myself and whole crew wish You and all Your colleagues in The Center for Coastal Studies successful and smooth work in protecting Right Whales.

Best regards
Master MT Margara
Capt.N.Mihaljevic

Photograph of SAG (bottom left) and M/T *Margara*:

Appendix V

Pilot Project to assess if CRITTERCAM™ technology is a useful tool to examine how right whales interact with their habitat while feeding.

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Introduction

One of the leading causes of the failure to recover the North Atlantic right whale is entanglement in fixed fishing gear. It is believed that right whales become entangled when they encounter fixed fishing gear set on or near the bottom with lines through the water column to surface buoys. There is good photographic evidence that right whales can become entangled around the head, through the mouth, around the flippers, tail or body. In some instances the entangling gear is shed by the whale, in other cases, the gear can lead to serious injury and mortality of the whale. Of particular concern are right whales swimming through the water column near bottom with mouth open while feeding. In a typical set for pot fisheries, ground line is used to connect the pots. The ground line is manufactured in such a way as to float in an arc some distance above the bottom to reduce chafing and snagging on the bottom and to facilitate grappling if the vertical line and surface buoys are lost. Based on research carried out by the Division of Marine Fisheries in Massachusetts it is thought that lowering the profile of groundline by using non-floating rope in pot fisheries could represent a solution to the problem of large whale entanglement (Lyman and Allen 2003). Non-floating groundline is now required in state waters.

One of the key questions is how do right whales move in the water column and interact with the bottom while feeding in their various habitat areas. There is no direct information on how a right whale interacts with the bottom in their habitat areas, however some behaviors have been inferred. Right whales in the Bay of Fundy have been equipped with time depth recorders (TDR) and these data complemented by oceanographic data obtained by concurrent sampling in the location of the food resource have shown that right whales likely feed near the bottom (Baumgartner and Mate 2003). Tagging in the same area with a TDR equipped with a pitch and roll sensor has provided information on their pattern of swimming or body profile while near the bottom and on descent and ascent (Nowacek *et al.* 2001). Right whales are also known to come in contact with the bottom in the Bay of Fundy as demonstrated by photographic evidence of mud stuck to their head and body (New England Aquarium unpublished data). In Cape Cod Bay, most observations of feeding behavior have been obtained of whales at (skim feeding) or near (subsurface feeding) the surface (Mayo and Marx 1990, Mayo *et al.* 1999, Mayo and Bessinger 2002), right whales have rarely been seen with mud on their heads (S. Mayo pers. commn).

Collaboration with National Geographic Television

In 2002, the Center for Coastal Studies entered into a collaboration with Gregory Marshall and his team at National Geographic Television (NGT) to determine if an underwater video-imaging system called CRITTERCAM™ would be useful as a tool to film right whales feeding underwater and assess how they interact with the bottom and maneuver through in the water column. Cape Cod Bay was chosen for this pilot project because there is an extensive database on their pattern of habitat use (Brown *et al.* 2002), feeding behavior (Mayo and Marx 1990) and weekly sampling of the food resource is ongoing during the winter and spring (Mayo *et al.* 1999, Mayo and Bessinger 2002).

CRITTERCAM™, a small, streamlined, integrated video imaging and data logging system encased in an underwater housing, can be attached to an animal with a suction cup for up to 2.5 hours. Conceived by marine biologist Gregory Marshall in 1986, the concept was adopted by the National Geographic Society in 1992. Over the last 8 years, with backing by NGT, the technology has been developed into a scientific tool, which has been applied to study the underwater behavior of over 30 species of pinnipeds, sea turtles, sharks, whales and penguins to learn how marine megafauna operate in their natural habitat with minimal disturbance from human contact. (http://www.nationalgeographic.com/channel/crittercam/).

The CRITTERCAM™ unit is mounted via a pressure fitting to a harness attached to the end of a pole. There is a tube that runs from the unit to a vacuum pump that provides suction to the suction cup in the final seconds before full deployment. The unit releases from the whale by means of a corrodible link estimated to release about 2 hours after deployment.

The goal of using CRITTERCAM™ on right whales is to learn how they are interacting with the bottom, their orientation in the water column while feeding and what are they actually doing with their mouths during feeding bouts. There is an interest in learning about these right whale behaviors to better inform efforts between right whale biologists and fishermen to modify fishing gear to reduce the risk of entanglement.

Sea Trials

The first attempt to attach CRITTERCAM™ to a right whale took place in March 2002. Right whales were few in number in Cape Cod Bay that year and the weather proved suitable for only one day of work on the water. A few approaches were made, but there was no successful attachment of the unit to a right whale. However, progress was made on the attachment technique and in 2004 we used a vessel operated by Dr. Michael Moore (Woods Hole Oceanographic Institution) equipped with a 40 foot-long cantilevered pole that had proved successful at obtaining blubber thickness measurements using ultrasound from over a hundred right whales (Moore *et al*. 2001).

The CCS, WHOI and NGT teams assembled for one week, 23-25 March 2004. Dr. Moore's boat was equipped with the CRITTERCAM™ and we were able to get 2.5 days on the water with right whales in Cape Cod Bay. The sea state conditions the first morning were excellent (Beaufort 1), however sea conditions were greater than Beaufort 2 and up to Beaufort 4 for the rest of the trials. The methods of documenting the right whales using photo identification and the technique for close approach were similar to those explained in Brown *et al.* (2002) and Moore *et al.* (2001).

A total of 23 right whales were approached for photo-identification. We attempted to attach the CRITTERCAM™ to six different right whales. There were two successful attachments but the duration of the two attachments was disappointing, lasting only about a minute before the suction cup released and the CRITTERCAM™ drifted off the back of the right whale. All attempts were recorded on videotape; digital still images were obtained of the attachment site (Figures 1 and 2) and orientation of the CRITTERCAM™ on the whale (Figure 3). After each attempt, the reasons for failure were discussed and modifications were made to the attachment system.

Assessment

Although CRITTERCAM™ units have been successfully attached to several other species of whales; there were clearly problems with attachment on right whales, in part, due to their behavior, and in part due to technical problems. Although right whales spend a lot of time near the surface in Cape Cod Bay, they are often feeding and their backs are underwater and unavailable for attachment thus reducing the number of opportunities for deploying the unit. Additionally, the time window for this project was narrow, only one week, thus boat operations were conducted in sea states higher (greater than Beaufort 2) than is desirable for controlled close approaches required to maintain sustained pressure with a long cantilever pole. On the technical side, the vacuum pump hose failed to disengage during several attachment attempts, pulling the tag off after initial contact. After the first day the vacuum hose was removed from the unit and the attachment relied on suction from the suction cup. The suggestion was made to the NGT team that they consult with Nowacek and coworkers for future efforts to obtain different kinds of suction cups that have been used successfully to attach other tags to right whales for several hours at a time (Nowacek *et al*. 2001).

The underwater video footage obtained from the CRITTERCAM™, although short in duration, demonstrated that it is possible to use the CRITTERCAM™ to view right whale behavior underwater. In the video footage obtained, it was possible to see the back of the right whale, and with an ideal attachment location it would be possible to see if the mouth was open.

Next steps

The plan for this project is to attempt to attach the critter cam on right whales in August 2004 in the Bay of Fundy. The behavior patterns of right whales in the Bay of Fundy are characterized by deep feeding dives interspersed with long surface resting intervals, longer than typically seen in Cape Cod Bay. The researchers will attempt to slowly idle up to a resting whale at the surface and place the camera on the back approximately above the flippers using a counter balanced 20 foot long hand held pole from the bow of an inflatable. This technique was used successfully with bowhead whales in the Arctic. The hand held pole should permit greater flexibility of attachment location and allow for holding the tag on the whale during the final seconds of the attachment to give the vacuum pump time to effect adequate suction, if the boat can get close enough. It has also been suggested that different types of suction cups be used so that the hose and vacuum pump can be dispensed with since it appeared that this complication affected the success of deployments during the Cape Cod Bay trials. The report of the Bay of Fundy trials will be available from NGT.

Acknowledgements:

We are indebted to the Moore family of Ram Island, Marion MA, who housed and fed the teams from CCS and National Geographic Television and provided logistical support for the duration of the project, 22-26 March 2004. A special thank you to Dr. Michael Moore for the provision of his boat (*Hannah T*) and expertise on this project. Photographic identification data were collected by Marilyn Marx (NEAq) and Cyndi Browning (CCS). Regina Campbell-Malone (WHOI) kept a written record of the photographic and CRITTERCAM™ data. The National Geographic team was made up of principal investigator Gregory Marshall and engineer Mehdi Bakhtiari. Kyler Abernathy and Patrick Green carried out the fieldwork in Cape Cod Bay in 2004. This work was supported by a grant from the Division of Marine Fisheries to the Center for Coastal Studies. Substantial in kind support was provided by Dr. Michael Moore and family.

Figure 1. Attachment attempt on the back of a right whale. The pole is extended off the bow of the boat; ideal placement is above the right flipper about four feet behind the blowholes. The yellow hose snaked along the pole is connected between the CRITTERCAM™ and a vacuum pump to create suction.

Figure 2. Attachment of CRITTERCAM™ to the back of a right whale. This location is somewhat further back on the whale than what is thought to be the ideal location to view the head and mouth of the whale.

Figure 3. CRITTERCAM™ attached to the back of a right whale. About one minute of underwater video footage was obtained.

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SECTION 2: MONITORING THE HABITAT OF THE NORTH ATLANTIC RIGHT WHALE IN CAPE COD BAY – 2004

Introduction

This section addresses 2004 habitat sampling results in the context of Objective IV of the CCS/DMF surveillance and monitoring program. Objective IV describes the importance of zooplankton data collection from weekly vessel cruises in advancing understanding of the habitat characteristics to which right whales respond. These data have been useful for many years in aiding management agencies when making decisions (e.g. amendments to seasonal gear restrictions or the issuance of vessel speed advisories) that directly affect right whales in the Cape Cod Bay Right Whale Critical Habitat area. Constantly evolving zooplankton data collection continues to further the understanding of how the planktonic food resource affects the spatiotemporal distribution of right whales. In addition to meeting the criteria of Objective IV, an additional goal of the 2004 season was to continue the innovative technique developed in 2003: rapid assessment and interpretation of the habitat for the prediction of right whale distribution, aggregation and residency. This goal was achieved through the dissemination of detailed electronic reports immediately following each cruise.

Methods

The R/V *Shearwater* is equipped with oceanographic and food resource sampling equipment including a CTD (Conductivity, Temperature, Depth) profiler with attached PAR meter (incident light sensor) and fluorescence probe, plankton nets, and a vertical plankton pump. The equipment available has been refined to allow an accurate assessment of the resource in the vertical and horizontal planes.

Zooplankton samples were collected at fixed stations and in the vicinity of whales both horizontally or obliquely using standard 333-micrometer (µm) mesh conical nets 30cm or 60cm in diameter and fitted with a General Oceanics helical flow meter. This net collection technique has been employed since 1984 and therefore is the most useful comparative measure of the conditions that support the feeding activities of right whales. Vertical zooplankton samples were obtained from a pump sampler deployed in the CTD frame. These samples were filtered through a 333 µm mesh and the volume of the water sample was recorded using a 1" water meter. Field samples were kept in seawater on ice on board the vessel, preserved in isopropyl alcohol and settled overnight in graduated cylinders in the lab. Samples were counted within 12-24 hours of collection and the results of the zooplankton observations were expressed in organisms per cubic meter (organisms/m^3).

Phytoplankton samples were collected either by bucket dip or with the vertical pump system at fixed stations and in the vicinity of right whales. Fifty milliliter (ml) samples were preserved with the addition of 5 drops of Lugol's solution, tubes were capped and inverted to mix the fixative and settled upright for a minimum of 5 days inside a covered cooler. After settling, the top 45 ml were decanted with a syringe and a 0.1 ml subsample was placed on to a Thomas #9853-N 10 counting slide. Specimens above 15 µm were noted using 100x and 400x of a compound microscope. A minimum of 100 organisms were identified and counted except in cases where phytoplankton were very sparse. In these cases, three to four slides were counted. The phytoplankton samples were enumerated to the lowest taxon and the density calculated and expressed in organisms per liter (organisms/L).

CTD casts, recording one data line per half-second from all sensors, were made at all fixed stations, and at special stations in the vicinity of right whales. Data from the CTD were downloaded to a computer and represented graphically using the Seasoft graphics programs.

Results and Discussion

The supporting data for this report, including detailed counts of zooplankton and phytoplankton to the lowest taxon (minimums of 47 and 145 taxa respectively) for each plankton sample, multi-variable data from all CTD casts and associated detailed data on weather, general right whale behavior, and opportunistic sightings of fixed and floating fishing gear are kept in raw computer files at the Center for Coastal Studies. These data are available upon request, however for brevity much of this information is summarized in this report in appendix form. These Appendices are as follows:

- Appendix I: System Data Record with Inter-annual Comparisons- 2004
  Various figures of 2004 phyto- and zooplankton densities, caloric densities, species composition, and interannual trends using numerous spatiotemporal treatments. Some figures follow formatting from 2003 and are updated to include 2004. All figures stand alone, are self-explanatory, and contribute to the characterization of the environment that in the winter and spring of 2004 supported the more than 60 individual right whales reported in Section 1 of this report.
- Appendix II: System Assessment and Prediction- 2004
  Three examples (SW391- January 18, SW401- March 10, and SW417-May 11) of the zooplankton assessments and predictions, with their accompanying graphs and interpretations, that were sent out via an email distribution list to interested academic, governmental, scientific, and management parties shortly after each cruise. This is the second year of this distribution list, and the number of subscribed individuals has grown to 46. For 2005, we plan on continuing the dissemination of this information in a comparable format, with additional information affecting whale occurrence in Cape Cod Bay (see Section 4 of this report), such as near real-time GIS plots of whale occurrence from CCS aerial surveys with mean zooplankton densities from recent cruises. Additionally, we will develop methods to include data from Cornell University's Bioacoustics Laboratory, which has developed real-time automatic buoys that record and upload right whale calls in Cape Cod Bay.

The 2004 right whale habitat field season began on January 4, and continued through May 11 with a total of 21 cruises in Cape Cod Bay. There were no additional cruises to areas other than the bay. Much of January and March was characterized by extreme winter weather, with sudden squalls, cold temperatures, and ice buildup in Provincetown Harbor and/or Cape Cod Bay prematurely ending two cruises, and preventing the completion of two additional cruises that would have brought the cruise total to 23. However, cruises did depart with temporal regularity, with the longest interval between cruises only 12 days.

The total number of zooplankton and phytoplankton samples collected during 2004 was slightly higher than in 2003, even though the number of cruises was the same. In 2004, 726 plankton samples were collected (Table 1) from surface tows, oblique tows, and vertical pumps casts. This rise in samples is primarily a result of an increase in vertical pump casts (due to an exceptionally widespread, durable, and concentrated mid to deep water zooplankton resource) and the continuation of oblique tows at every station, a protocol begun in early March 2003. The 2004 season was the first to establish a set of eight "regular" stations for collection of biological and oceanographic data on every cruise (weather permitting). This is an increase in the number of stations visited per cruise from 2003, and represents more thorough geographic coverage of Cape Cod Bay. This change in technique allows the collection of a more robust data set that better aids managers in predicting right whale occurrence and density in Cape Cod Bay. Additionally, oceanographic data was collected at every station through the use of a CTD depth profiler, totaling 136 casts, again more than in 2003. No transects were performed in 2004.

Zooplankton

A look at the general trends in zooplankton densities at all depths shows a rich production throughout the duration of the season. Compared to the previous four years, the surface layer of 2004 displayed the expected temporal variation, surpassing densities from 2000-2003 during the first two weeks of January, at the beginning and end of March, and near the end of the season from mid-April to mid-May (Figure 1, note this figure is reproduced in color in Appendix I). Lack of previous years' oblique tows prevents comparative examination, however the 2004 mid-water (0-19m) oblique resource displayed a consistently high density (mean daily values generally over 5,000 organisms per cubic meter), with a season peak at the end of March. Samples taken from vertical pump casts identified an extraordinary resource, which from mid February to mid March maintained densities more than three times those seen during 2000-2003. These peak densities were generally found in the 28- 32m range, with a secondary peak at 8-14m.

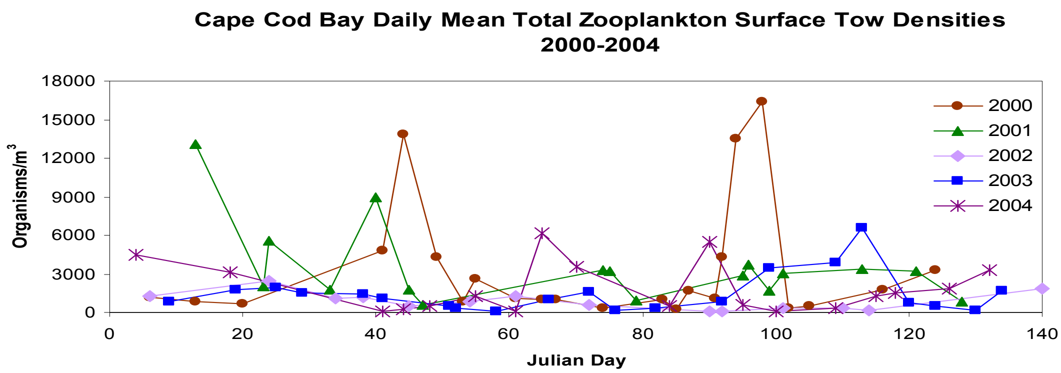


Figure 1. Daily mean surface layer zooplankton densities in Cape Cod Bay 2000-2004.

- Surface Tows: Unless noted otherwise, all graphs in this report displaying surface tow data reflect zooplankton samples collected at the eight stations visited on every cruise, regardless of right whale presence or absence. These stations are often referred to as "regular" stations. This analytical technique allows for more standardized comparisons of the zooplankton in Cape Cod Bay. However, Figure 2 below shows data from three surface tows performed not at these regular stations, but at other locations where right whales were present and either behaving socially, engaged in long dives, or observed surface skim feeding. This figure clearly shows how knowledge of zooplankton densities can often be used to explain right whale behavior.

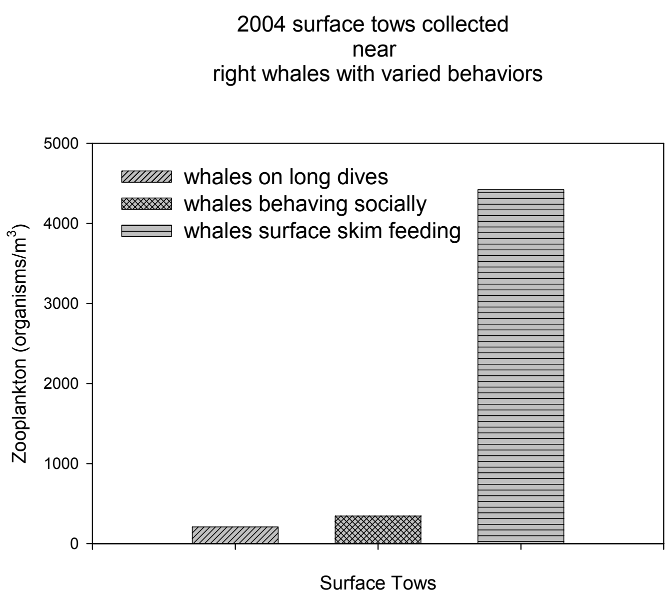


Figure 2. Three surface tows collected near right whales with varied behavior: surface skim feeding, acting as part of a social group, or engaged in long dives.

The species composition of the surface layer in 2004 was somewhat unusual compared to the prior 5 years (see Figures 4-8 in Appendix I). Although January's composition matched that seen in previous years, February saw an early, strong surge in the percentage of the *Pseudocalanus* complex (*Pseudocalanus* spp., *Paracalanus* *parvus, Clausocalanus* sp.,) with a monthly mean composition of 80% (2003 was 36%). March also recorded high numbers of the *Pseudocalanus* complex (96%) relative to any other copepod species. The percentage of this species complex during these two months was higher than in any other year from 1999-2003. The month of April showed a sharp decline in the *Pseudocalanus* complex and a rapid rise in the percentage of *Calanus finmarchicus* (76%). Data from previous years show a more gradual transition to dominance of *Calanus finmarchicus*. In May the dominance trend continued; *Calanus finmarchicus* accounted for an incredible 99% of all copepods in the surface layer and showcased the absence of the usual 15%-20% of either *Pseudocalanus* complex or *Temora longicornis*.

- Oblique Tows: As mentioned above in reference to surface tows, the oblique data discussed and represented graphically in this report are collected from the eight regular stations in Cape Cod Bay. Additional oblique tows were also performed in other locations with right whales present, but those results are not included in these summary analyses. The consistent collection of oblique (0-19m) samples is a relatively new addition (first used in mid 2003) that provides broader information on the dynamic environment of right whales. Thus, extensive interannual comparative examination, like that done with surface tows, is not possible. It is apparent, however, that the first signal of the influx of *Calanus finmarchicus* was detected from the oblique tows as early as 15 days prior to its appearance in the surface layer. Whether or not this is a significant, consistent trend is not known at this time. Additionally, it can be seen from Figures 2 and 3 in Appendix I, that in 2004 the presence of right whales overlapped well with periods when the *Pseudocalanus* complex was dominant. This indicates that the primary food resource for the whales this year was *Pseudocalanus* complex. Although the densities of *Calanus finmarchicus* increased to high numbers while whales were resident in the bay, and even though densities remained high through the end of the sampling season (May 11), the number of right whales declined dramatically during this time.

- Vertical Profiles (pump samples): The pump system on the R/V *Shearwater* was used to collect 108 phytoplankton and 214 zooplankton samples at targeted depths throughout the water column is 2004. Samples were not collected consistently from particular stations, but instead were chosen individually on every cruise for specific reasons often associated with right whale occurrence and behavior. The primary function of the pump collection system is to isolate the depth(s) where zooplankton densities are highest and where whales are likely diving to feed. Evidence of this correlation is clearly shown in Figures 3 and 4 below, displaying the vertical zooplankton profiles on two days where right whales were on long dive patterns and presumed to be feeding at depth.

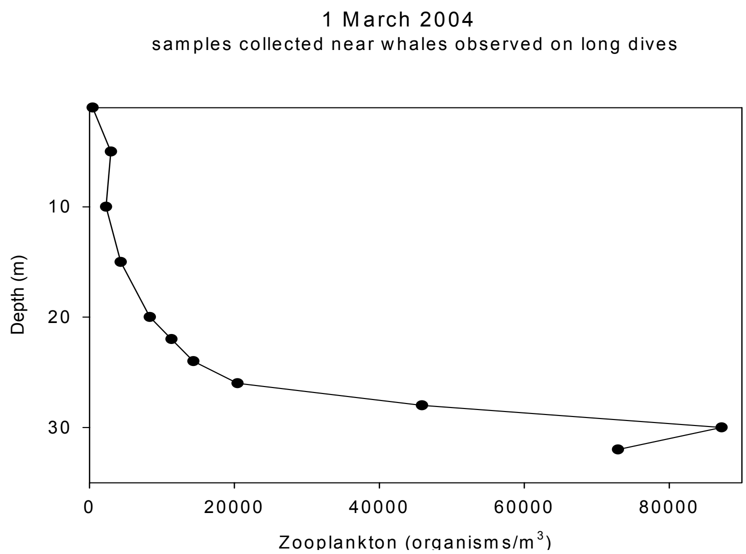


Figure 3. Results from a vertical cast at Station A near long diving right whales on March 1.

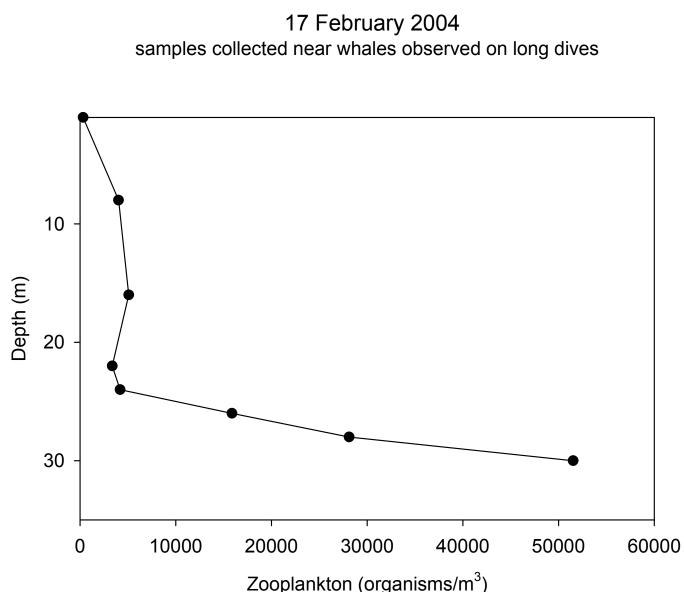


Figure 4. Results from a February 17 vertical cast at Station A with long diving right whales.

Comparative analysis of the 2004 vertical data with 2000-2003 data, when grouped and sorted by depth, shows exceptionally high densities in tow strata from 8-20m and from 28-32m during the period between February 17- March 1, 2004. These depth ranges supported densities that at times reached nearly 90,0000 organisms/m^3, values that are approximately triple those seen at any time from 2000-2003. It is important to note that these record high numbers were not maintained consistently throughout the bay, but were only seen in an area northeast of station 6M where right whales where present and on long dives. A secondary peak of zooplankton densities in the water column occurred from

March 30- April 18, further south and west in Cape Cod Bay, at stations 6M and 7S. Here high densities were limited to the upper 15 m and only reached a maximum of 22,311 organisms/m^3. Again, right whales were observed by CCS' aerial and vessel-based teams closely associated with this area. Finally, samples collected from the upper 10m at stations 6M and 5N during the last cruise of the season, on May 11 when no right whales were sighted, reached densities of nearly 15,000 organisms/m^3. Clearly the vertical pump sampling technique yields information useful in explaining and predicting whale occurrence.

Phytoplankton

Studies of phytoplankton density and composition have been ongoing at the Center for Coastal Studies since 1999. The detailed taxonomic identification has been performed consistently by Dr. Anne Hampton (professor: Castleton State College, retired). The data used to produce the graphs in Appendix I were collected from surface bucket dips and through the use of the vertical pump system. Phytoplankton surface samples were collected at every station, while vertical samples were collected opportunistically at selected depths (generally chosen to target the chlorophyll maximum and thermocline depths).

Phytoplankton in Cape Cod Bay undergo a bimodal annual cycle characterized by increases in abundance (blooms) in late winter/early spring, and in the fall. Most commonly the blooms are a result of burgeoning diatom populations. However, in some years the spring bloom is a result of the flagellate *Phaeocystis pouchetii*. Species composition in the summer months is often dominated by dinoflagellates, and overall phytoplankton abundance generally declines. The 2004 season (242 total samples collected) registered a large bloom of *Phaeocystis pouchetii* for two weeks (April 9 to 24) that was weakest in the top 10m and increased with depth. This bloom was the largest seen during any of the past four years (Figure 18 in Appendix I). Interestingly, comparison of *Phaeocystis pouchetii* densities and total zooplankton densities by depth suggests an inverse relationship, with zooplankton densities decreasing as *P. pouchetii* densities increase (Figures 5 and 6). From only one year of analysis, we cannot draw any conclusions or make statements of significance regarding this observation.

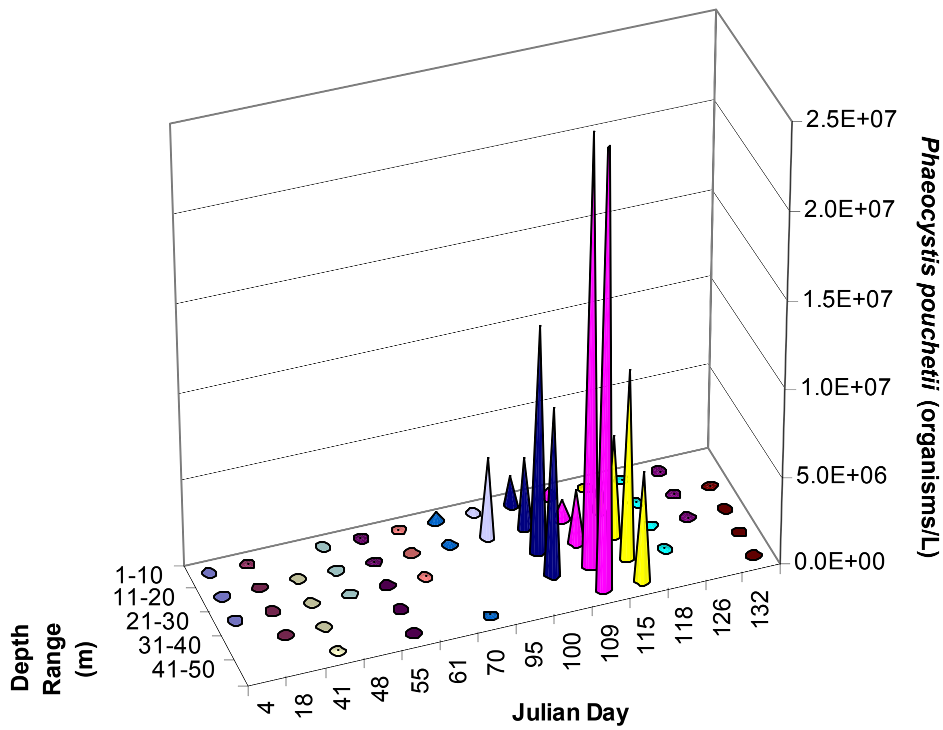


Figure 5. 2004 mean daily *Phaeocystis pouchetii* densities by depth.

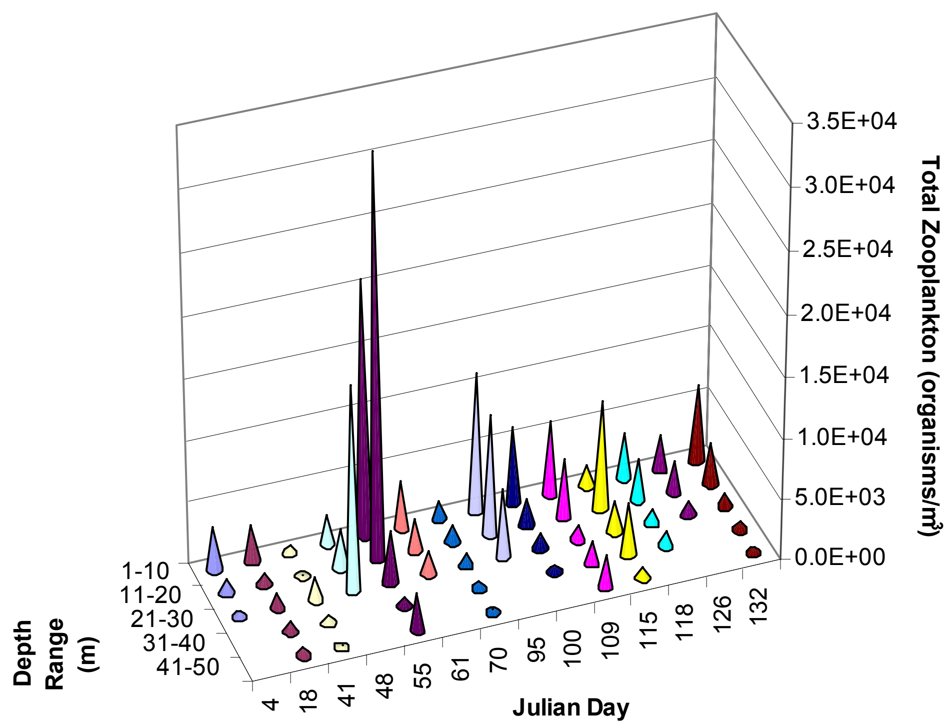


Figure 6. 2004 mean daily total zooplankton densities by depth.

Oceanography

All chlorophyll, temperature, salinity and fluorescence data from the CTD casts during 2004 are archived in CCS electronic files, but have not yet been analyzed in treatments similar to past years. All oceanographic data files are available upon request.

Summary

The 2004 plankton data discussed above continue to demonstrate to utility of monitoring zooplankton trends as predictors of right whale occurrence in Cape Cod Bay. The Center for Coastal Studies' database of plankton information from the past twenty years allows for a uniquely valuable opportunity to compare interannual patterns and learn more about this right whale feeding habitat. As more knowledge is gained, and new methods are evolved to refine our ability to predict whale distribution, managers will be better equipped to make regulatory decisions aimed at reducing anthropogenic mortality of right whales in Cape Cod Bay. Additionally, as mentioned in Section 1 of this report, the ability to investigate habitats adjacent to Cape Cod Bay, through directed sampling, would further understanding of right whale distribution patterns in the southern Gulf of Maine and could ultimately enhance the protection of this species.

CTD CASTS							PLANKTON SAMPLES: Zooplankton (Phytoplankton)					
Cruise	Date	On Station	Off Station	Transects	Vertical Casts	Total Casts	On Station Surface Tows (Bucket Samples)	Off Station Suface Tows (Bucket Samples)	Vertical Samples	Transect Samples	Oblique Tows	Total
SW389	4-Jan	8	.	.	.	8	8 (8)	.	7 (3)	.	7	2 (2)
SW391	18-Jan	8	.	.	.	8	8 (8)	.	16 (7)	.	8	15 (9)
SW392	28-Jan	1	.	.	.	1	1 (1)	.	.	.	1	7 (7)
SW394	10-Feb	6	1	.	.	7	6 (6)	1 (1)	6 (5)	.	7	27 (15)
SW395	13-Feb	.	1	.	.	1	.	1 (1)	10 (6)	.	1	19 (12)
SW396	17-Feb	6	2	.	.	8	6 (5)	2 (2)	18 (10)	.	8	22 (14)
SW397	24-Feb	7	1	.	.	8	7 (7)	1 (1)	22 (12)	.	8	30 (20)
SW399	1-Mar	8	1	.	.	9	8 (8)	1 (1)	18 (9)	.	9	25 (15)
SW400	5-Mar	2	1	.	.	3	2 (2)	1 (1)	9 (4)	.	3	23 (13)
SW401	10-Mar	7	.	.	.	7	7 (7)	.	6 (3)	.	7	18 (8)
SW402	23-Mar	3	.	.	.	3	3 (3)	.	.	.	3	14 (7)
SW403	24-Mar	5	1	.	.	6	5 (5)	1 (1)	.	.	6	46 (18)
SW404	30-Mar	8	1	.	.	9	8 (8)	1 (1)	7 (3)	.	8	28 (12)
SW405	3-Apr	4	.	.	.	4	4 (4)	.	.	.	4	5 (2)
SW406	4-Apr	4	.	.	.	4	4 (4)	.	8 (3)	.	4	24 (11)
SW407	9-Apr	8	.	.	.	8	8 (8)	.	13 (7)	.	8	11 (5)
SW410	18-Apr	8	1	.	.	9	8 (8)	1 (0)	21 (13)	.	9	3 (3)
SW413	24-Apr	8	2	.	.	10	8 (8)	2 (2)	8 (6)	.	10	20 (10)
SW414	27-Apr	4	3	.	.	7	4 (4)	3 (3)	18 (9)	.	7	23 (9)
SW415	5-May	8	.	.	.	8	8 (8)	.	7 (4)	.	8	11 (6)
SW417	11-May	8	.	.	.	8	8 (8)	.	20 (4)	.	8	30 (14)
					Totals	**136**	**121 (120)**	**15 (14)**	**214 (108)**	**0**	**134**	**484 (242)**

Table 1. **2004 Cape Cod Bay Habitat Cruises and Collected Samples.**

Appendix I

System Data Record with Inter-annual Comparisons – 2004

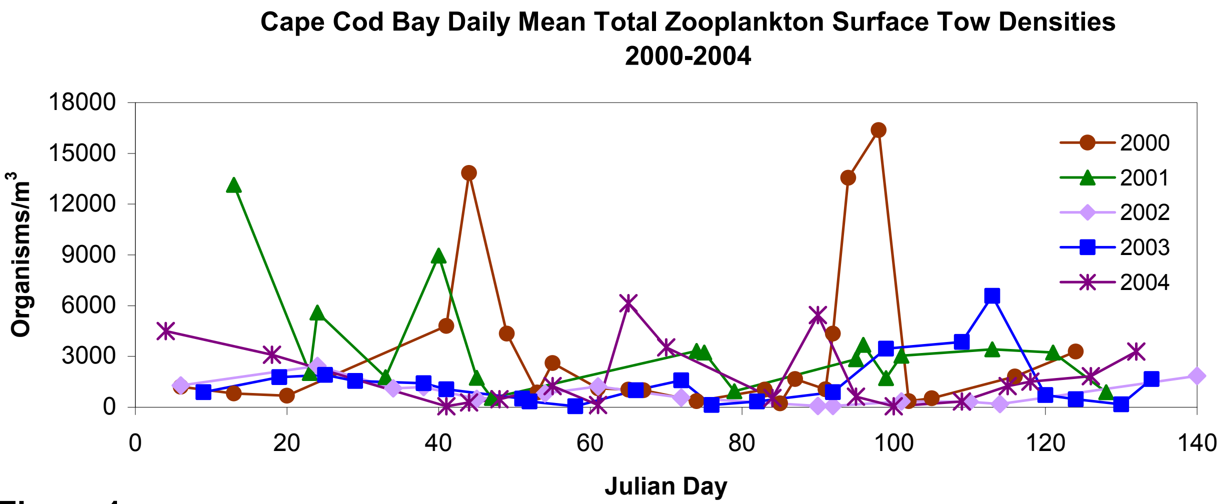


Figure 1

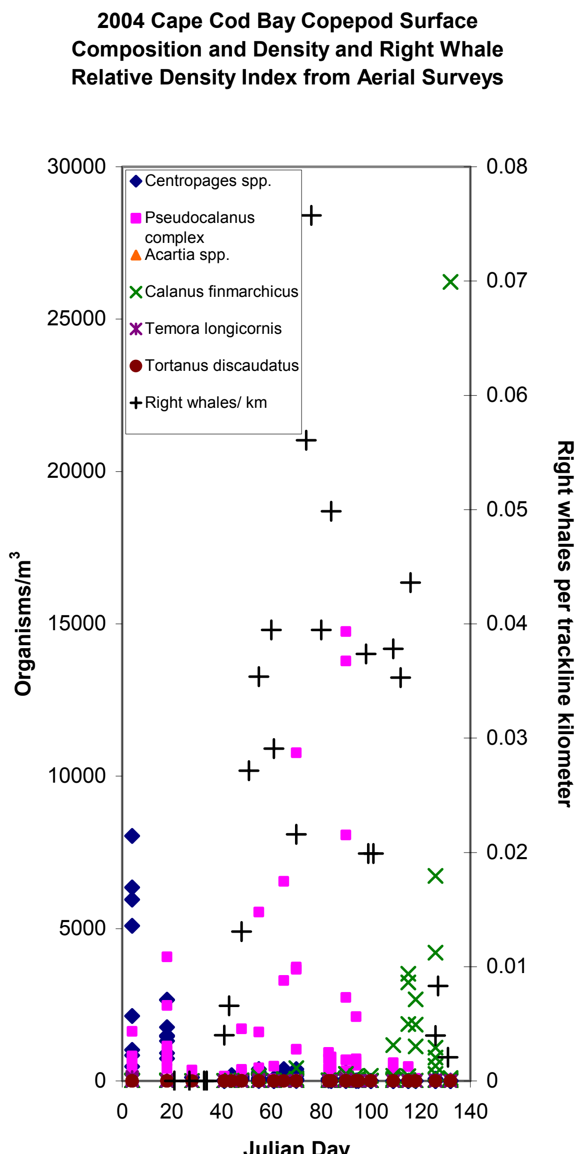


Figure 2

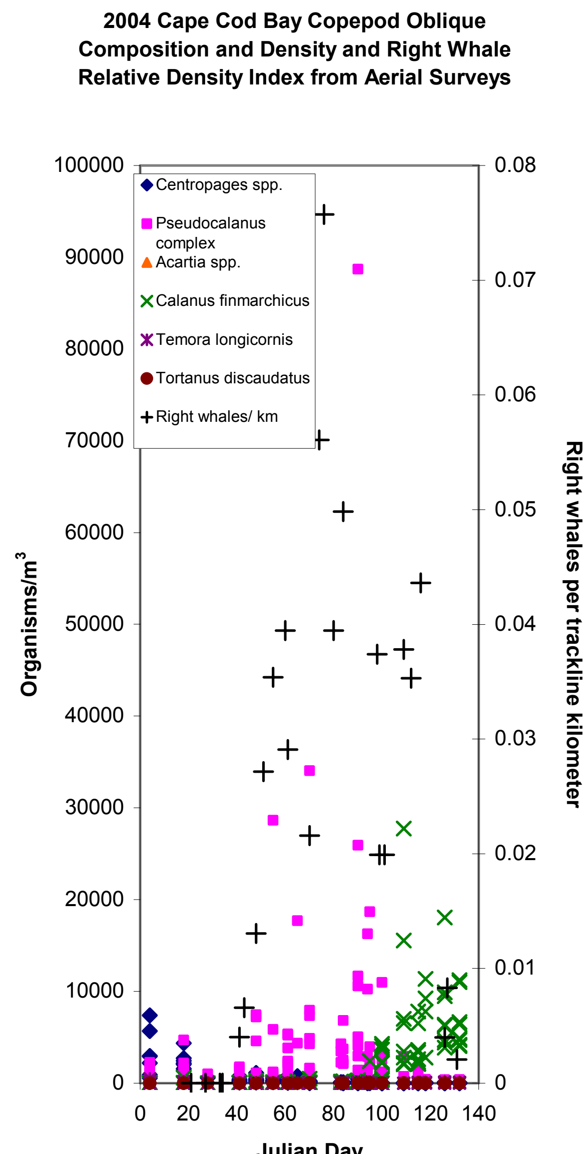


Figure 3

Cape Cod Bay surface layer copepod composition averaged for the month of January, 1999-2004.

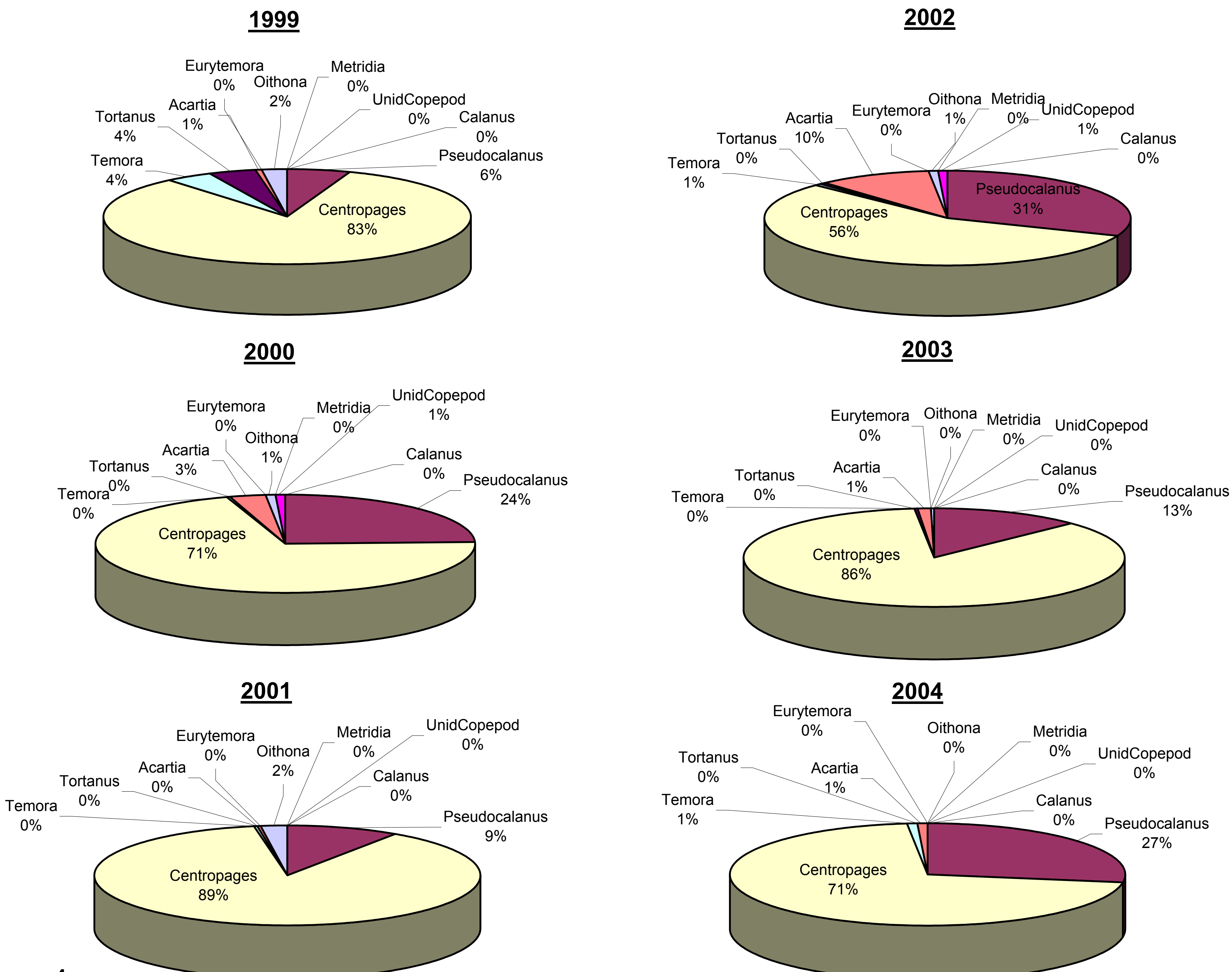


Figure 4

Cape Cod Bay surface layer copepod composition averaged for the month of February, 1999-2004.

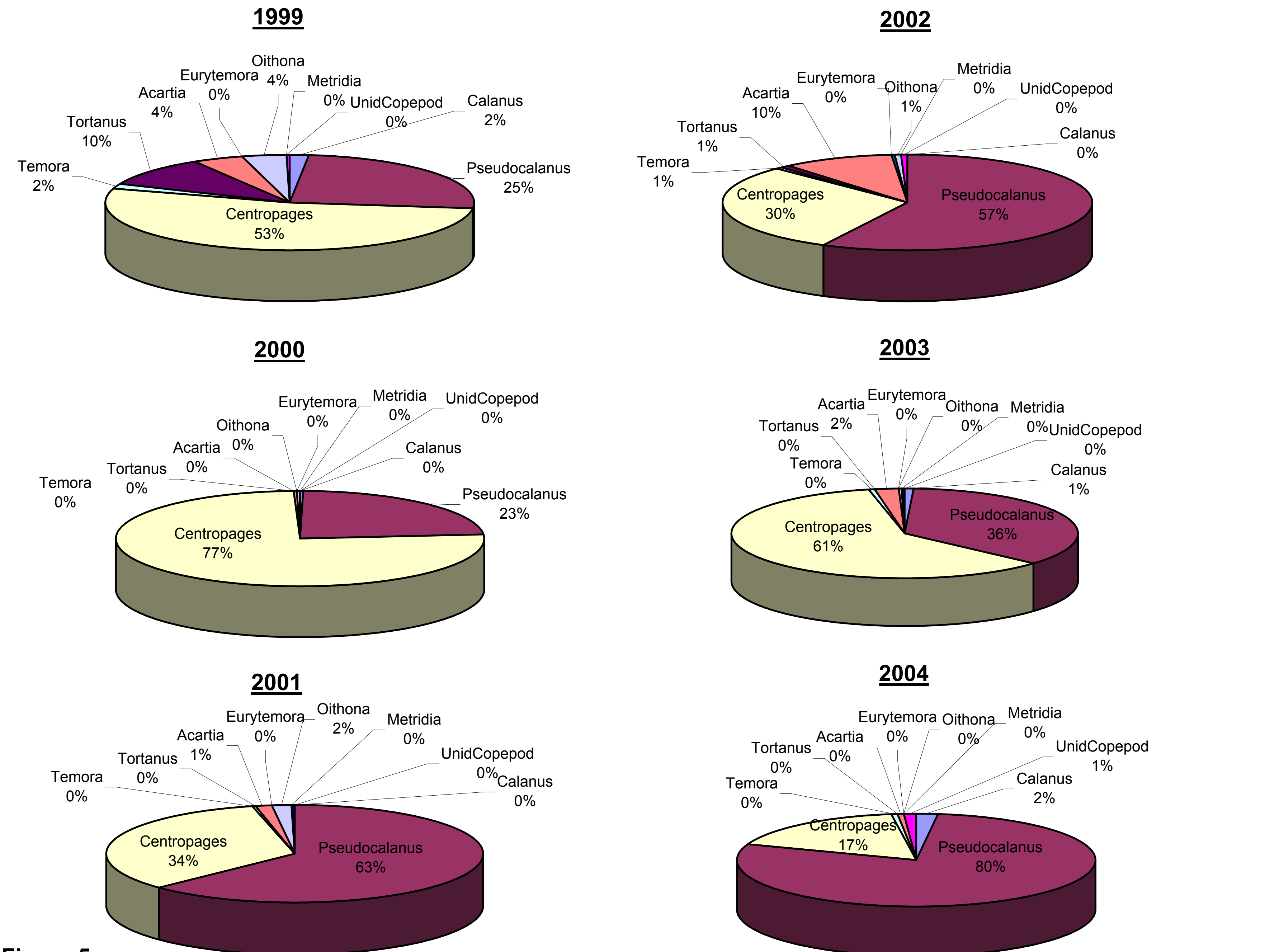
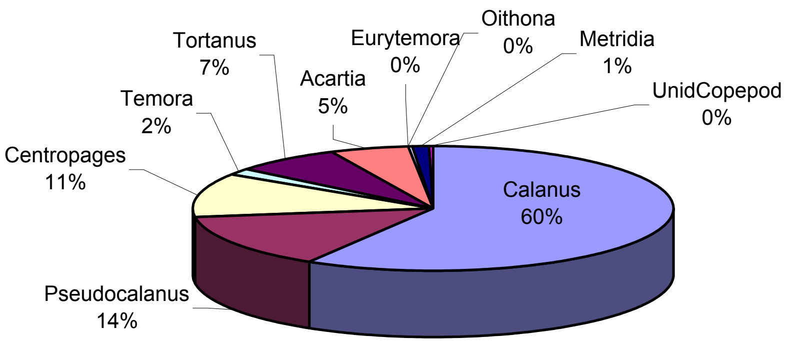


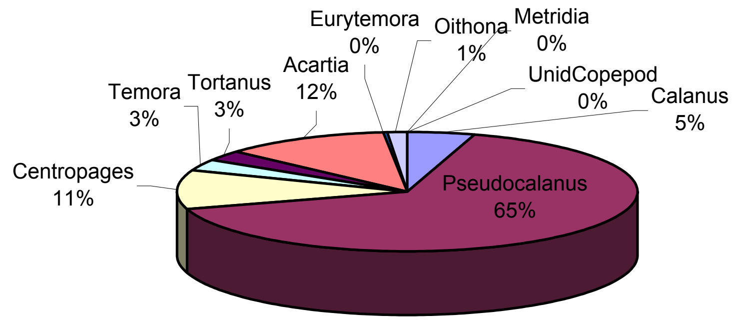
Figure 5

Cape Cod Bay surface layer copepod composition averaged for the month of March, 1999-2004.

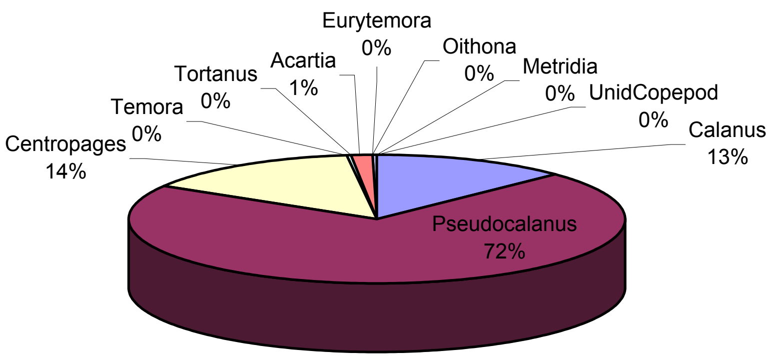
1999



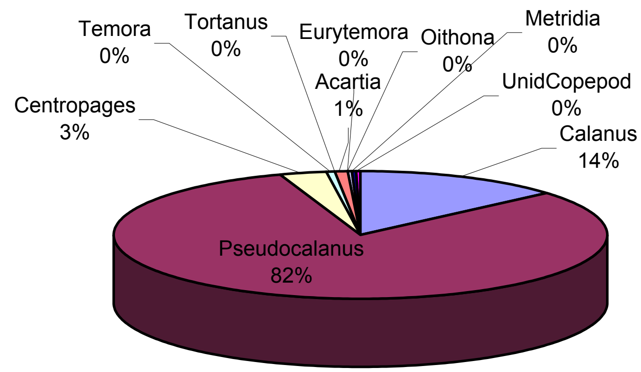
2002



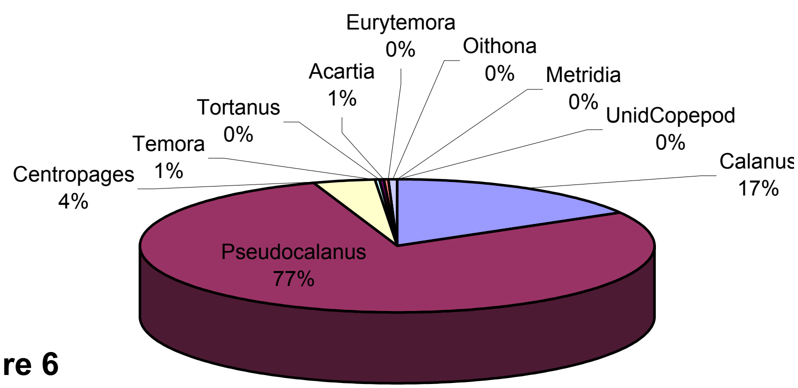
2000



2003



2001



2004

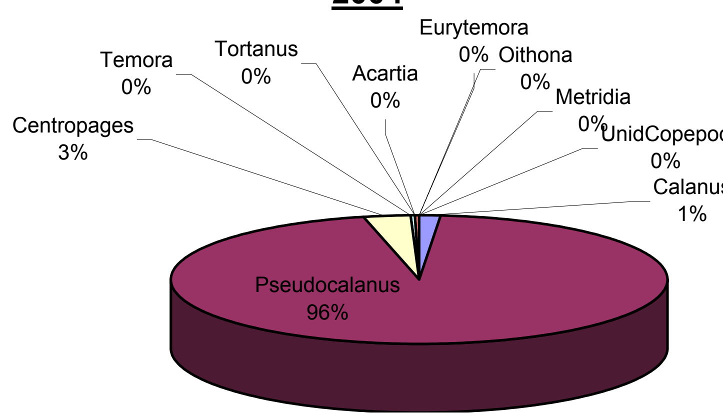


Figure 6

Cape Cod Bay surface layer copepod composition averaged for the month of April, 1999-2004.

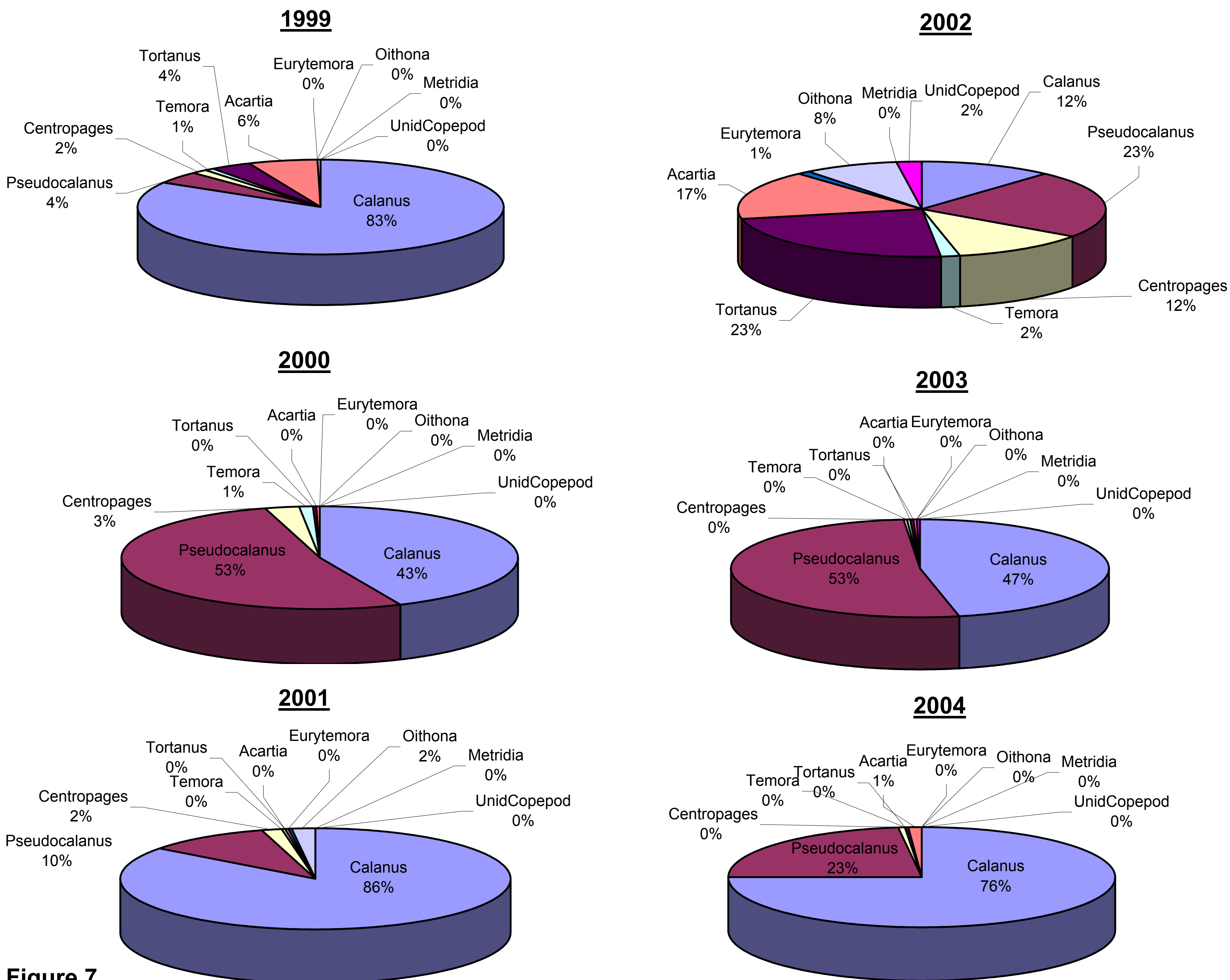


Figure 7

Cape Cod Bay surface layer copepod composition averaged for May 1-15, 1999-2004.

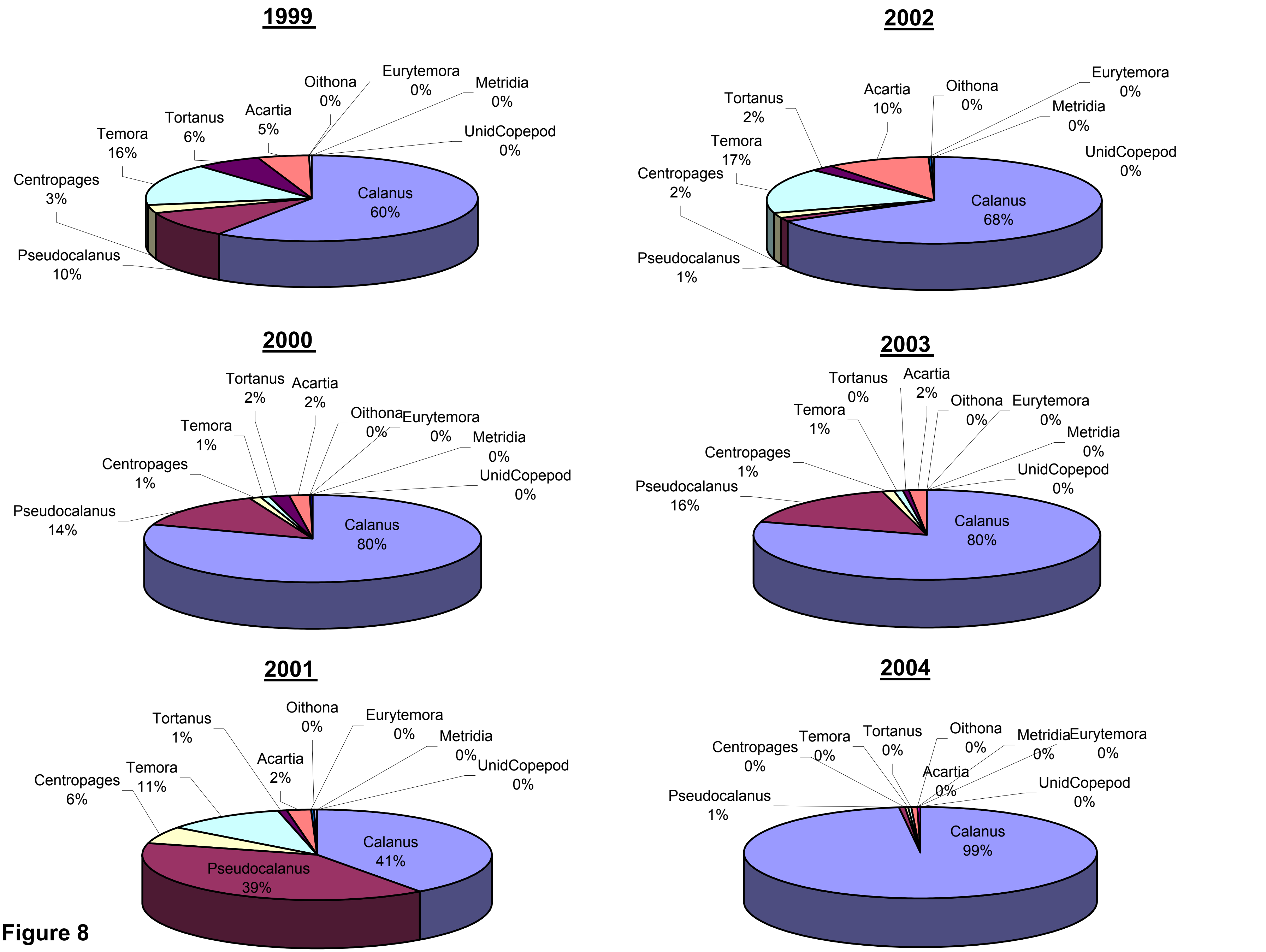


Figure 8

Cape Cod Bay 2004 Average Zooplankton Density Graphs for early and late-stage *Centropages* spp.

Surface Samples **Oblique Samples**

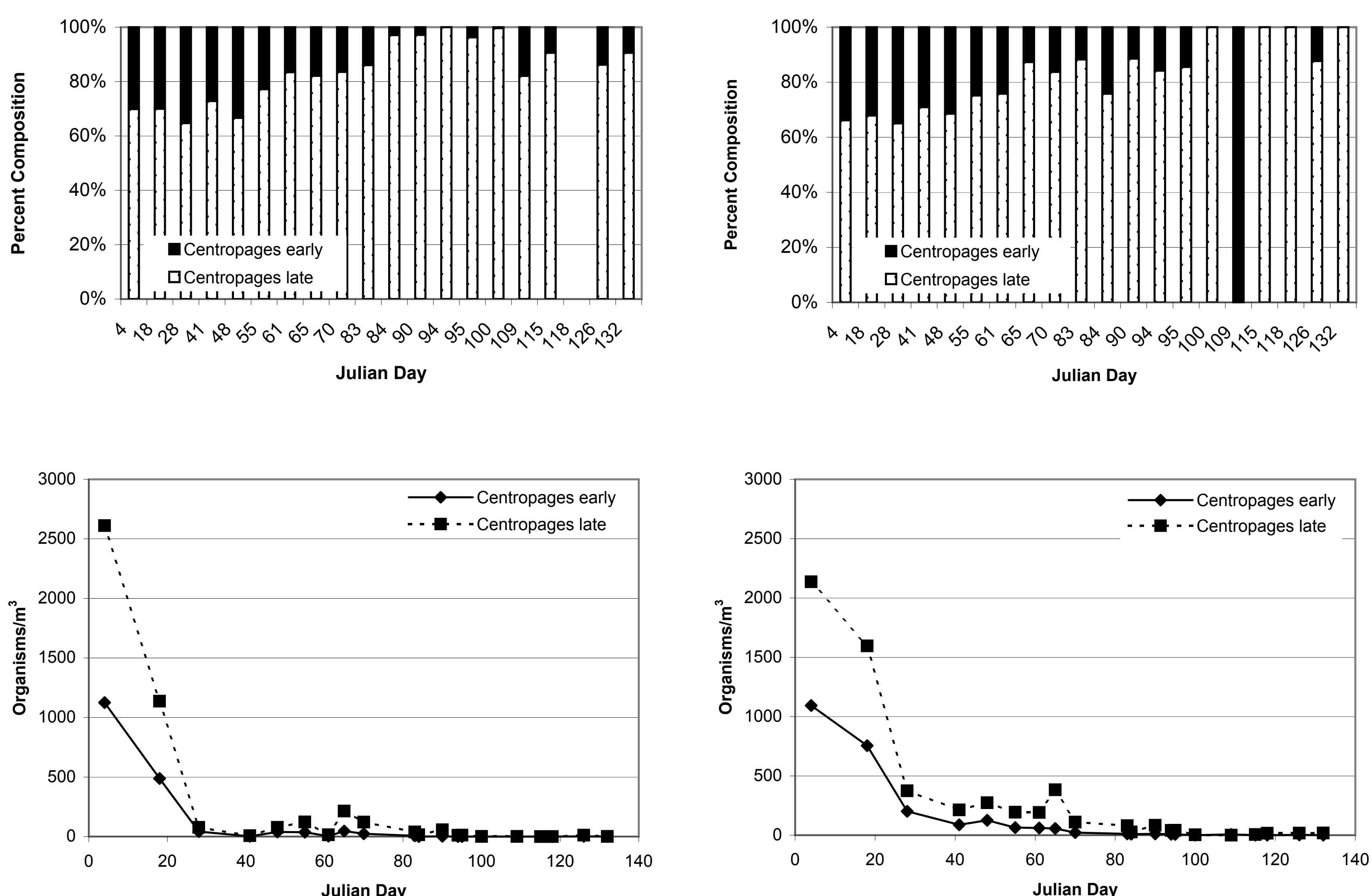
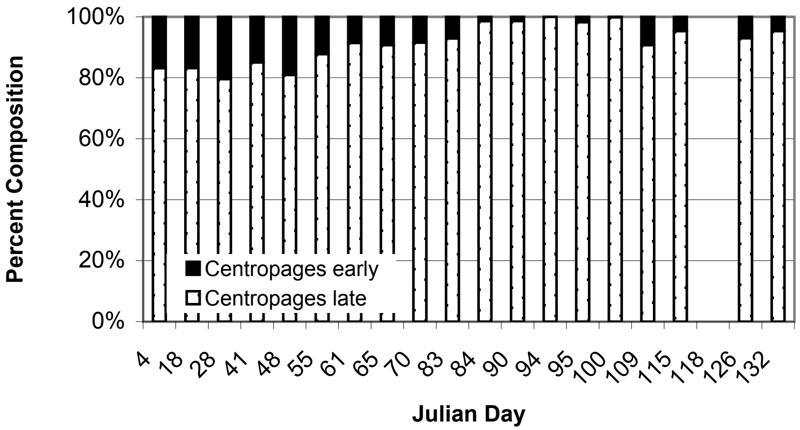
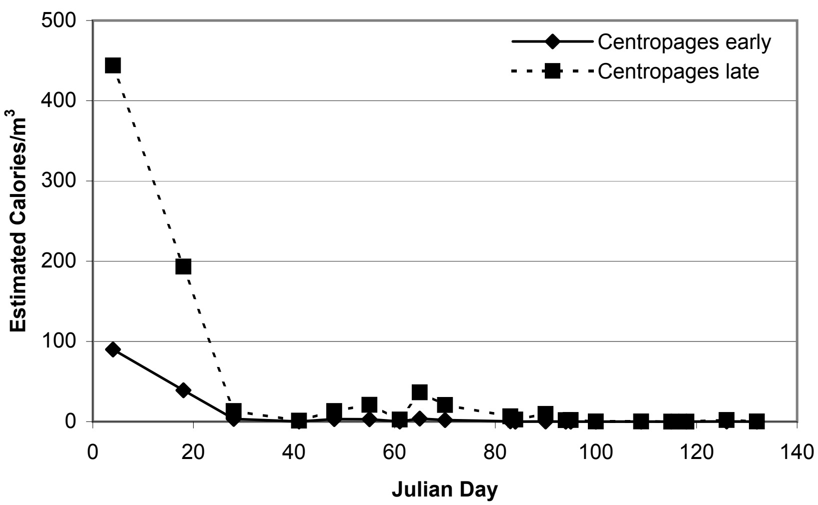


Figure 9

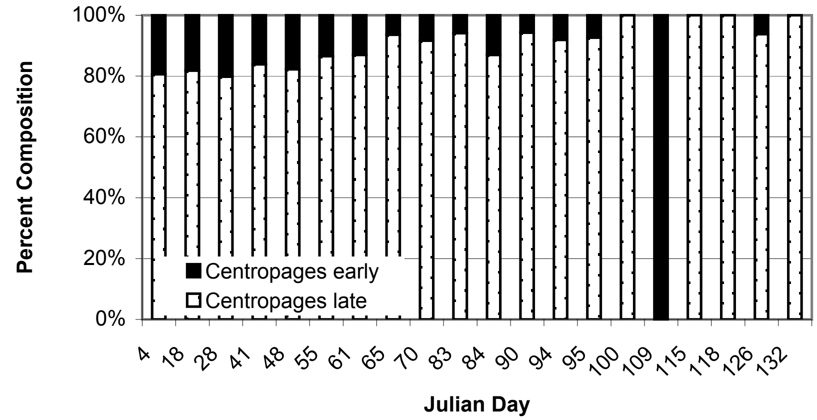
Cape Cod Bay 2004 Estimated Caloric Density Graphs for early and late-stage *Centropages* spp.

Surface Samples





Oblique Samples



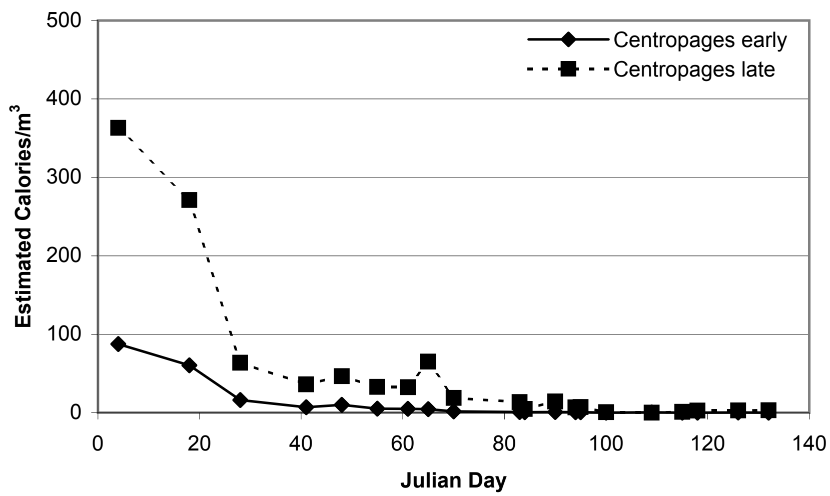
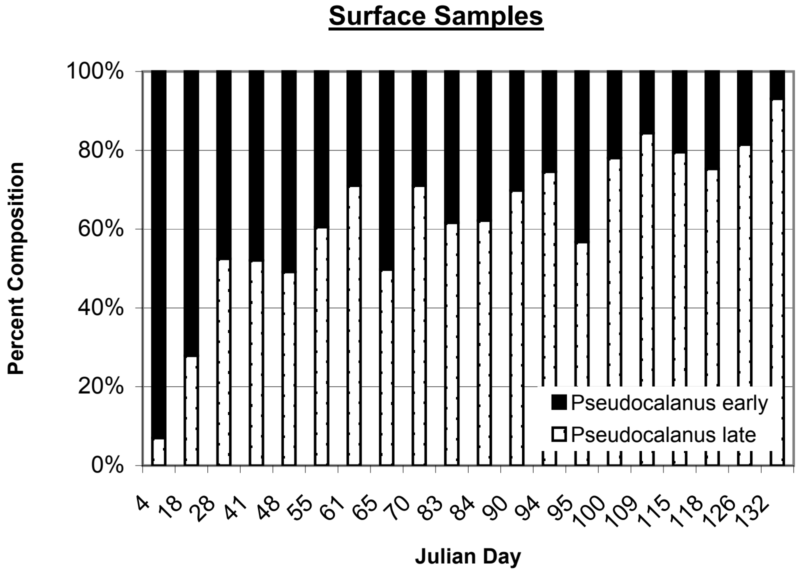
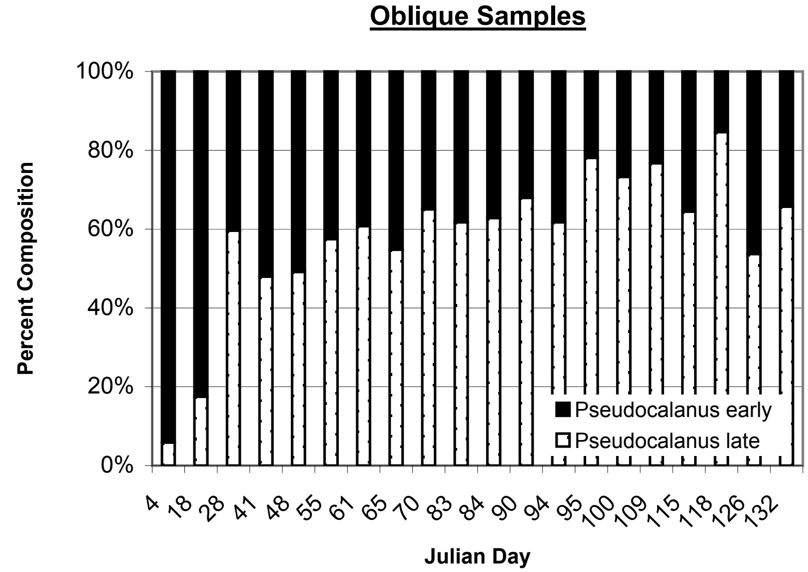
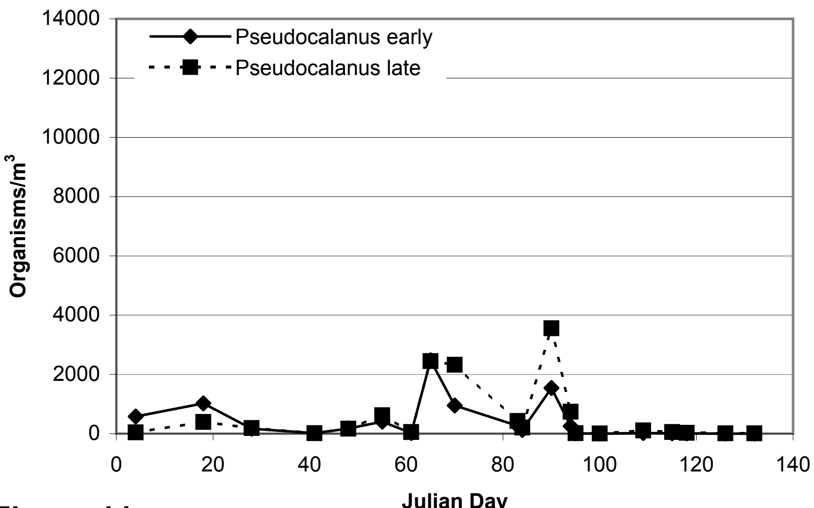


Figure 10

Cape Cod Bay 2004 Average Zooplankton Density Graphs for early and late-stage *Pseudocalanus* spp.







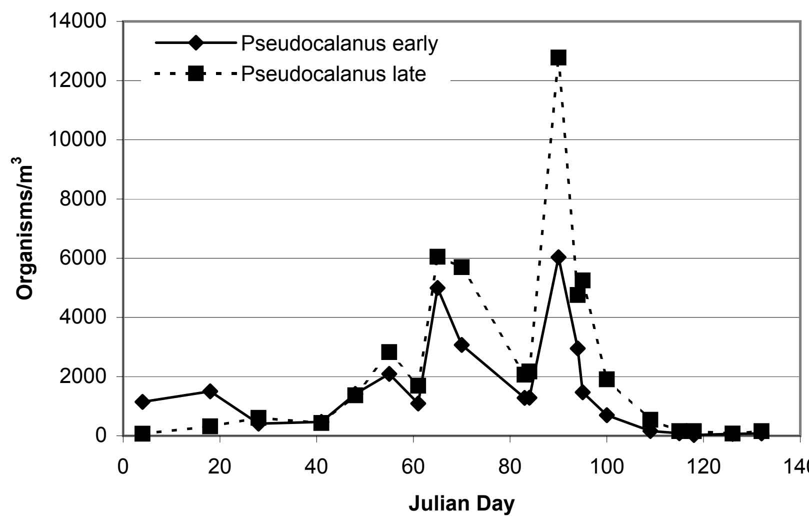


Figure 11

Cape Cod Bay 2004 Estimated Caloric Density Graphs for early and late-stage *Pseudocalanus* spp.

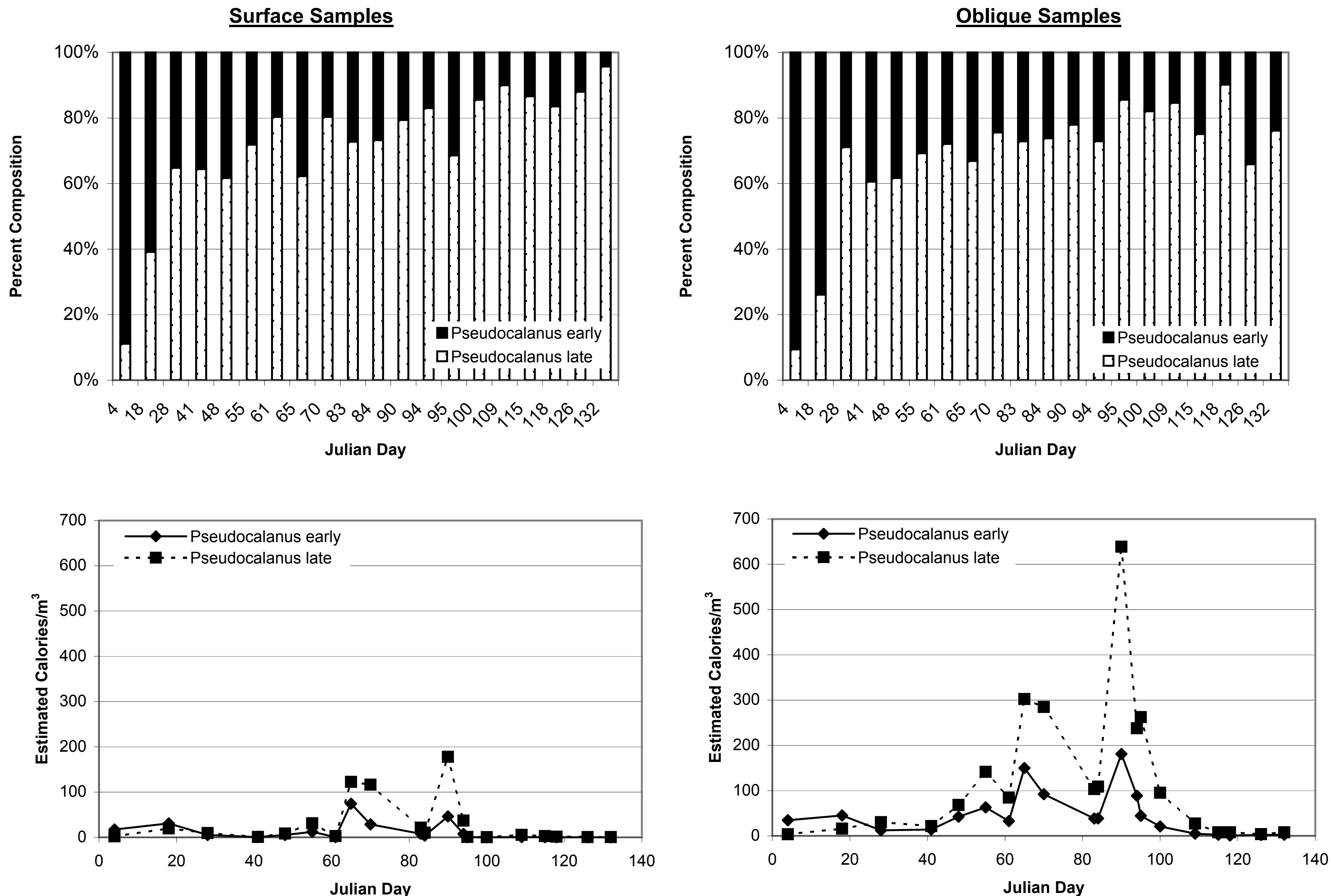
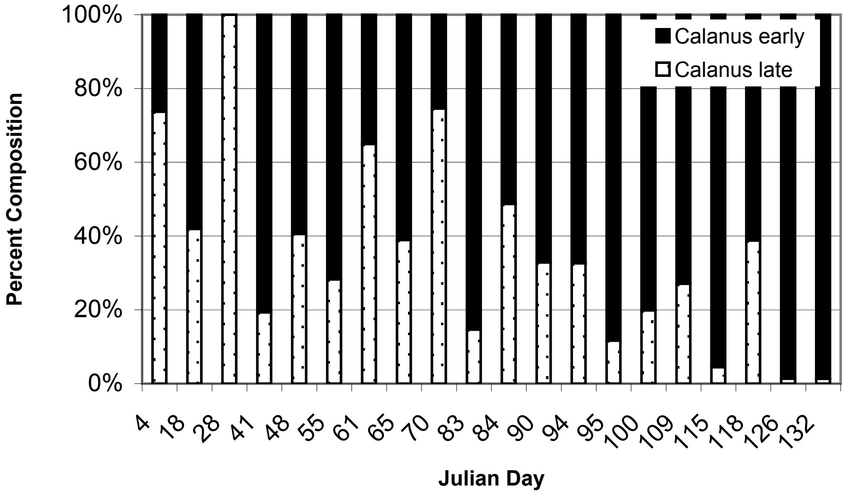


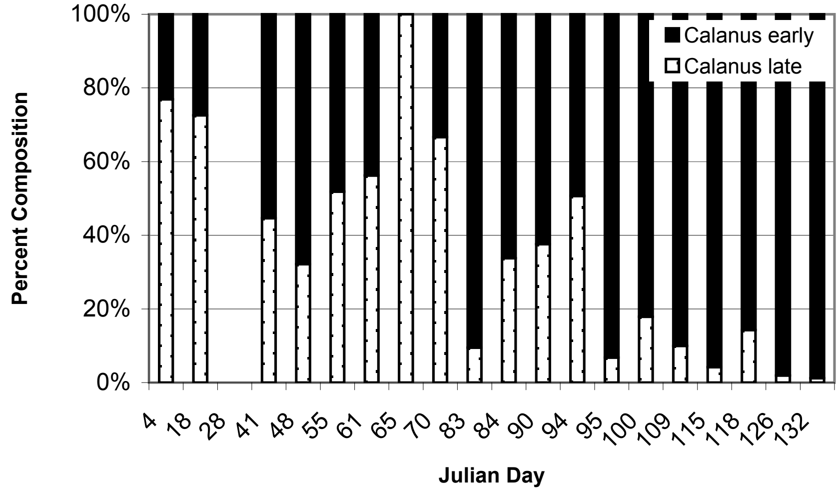
Figure 12

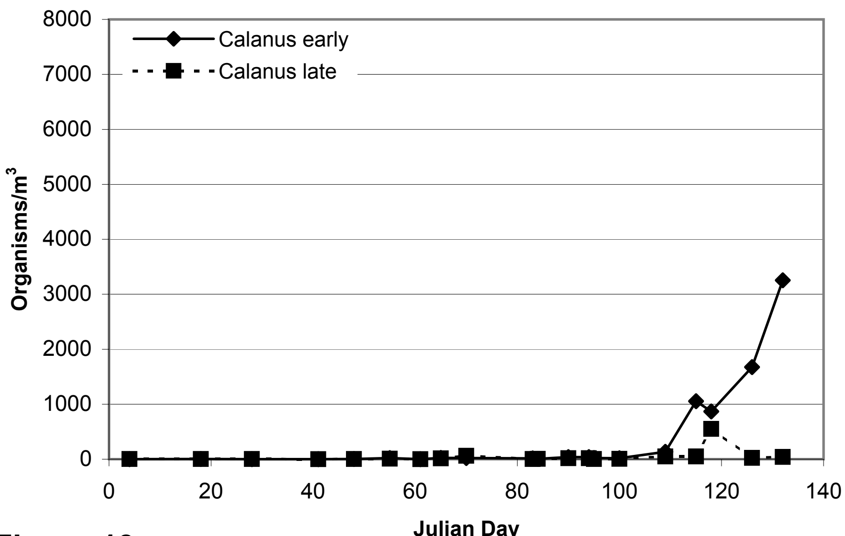
Cape Cod Bay 2004 Average Zooplankton Density Graphs for early (I-IV) and late stage (V-VI) *Calanus finmarchicus*

Surface Samples



Oblique Samples





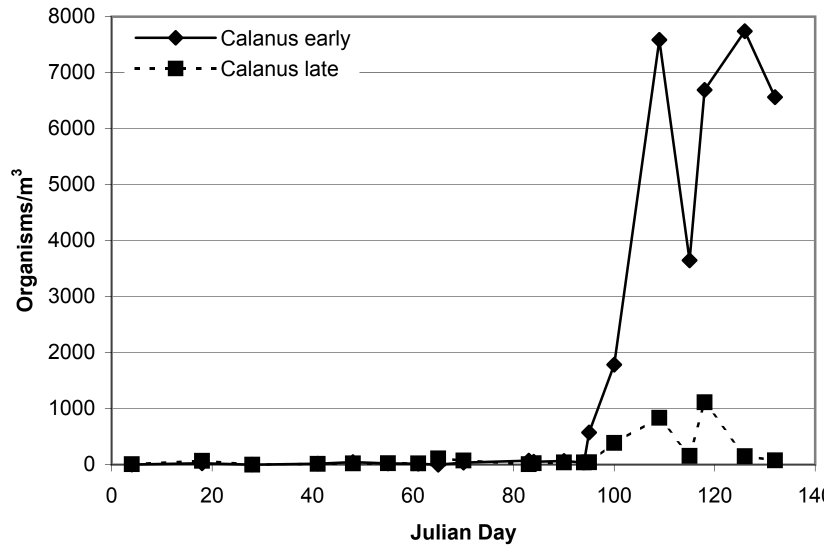


Figure 13

Cape Cod Bay 2004 Estimated Caloric Density Graphs for early stage (I-IV) and late stage (V-VI) *Calanus finmarchicus*

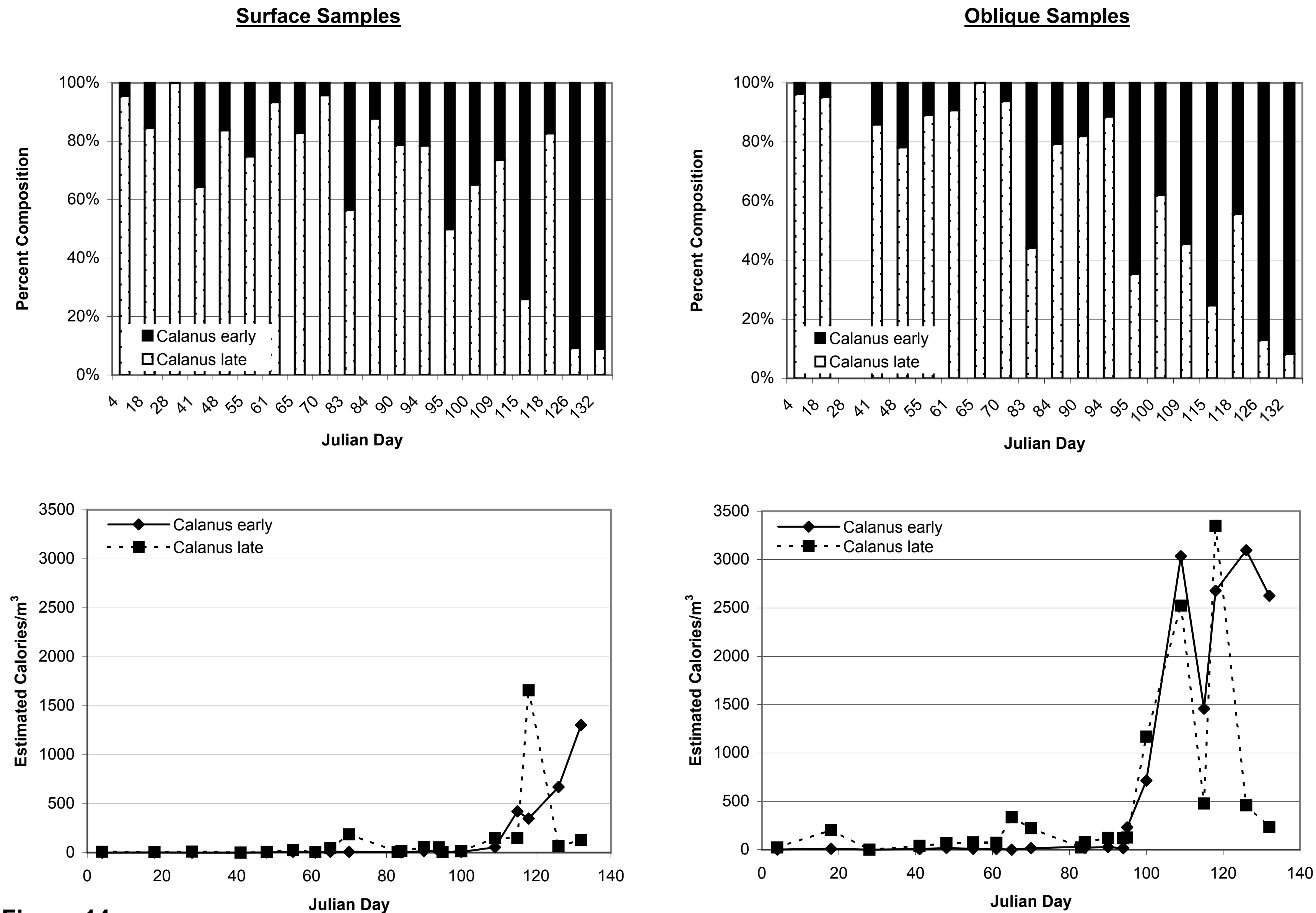


Figure 14

Cape Cod Bay 2004 Mean Daily Density Graphs for individual stage *Calanus finmarchicus*

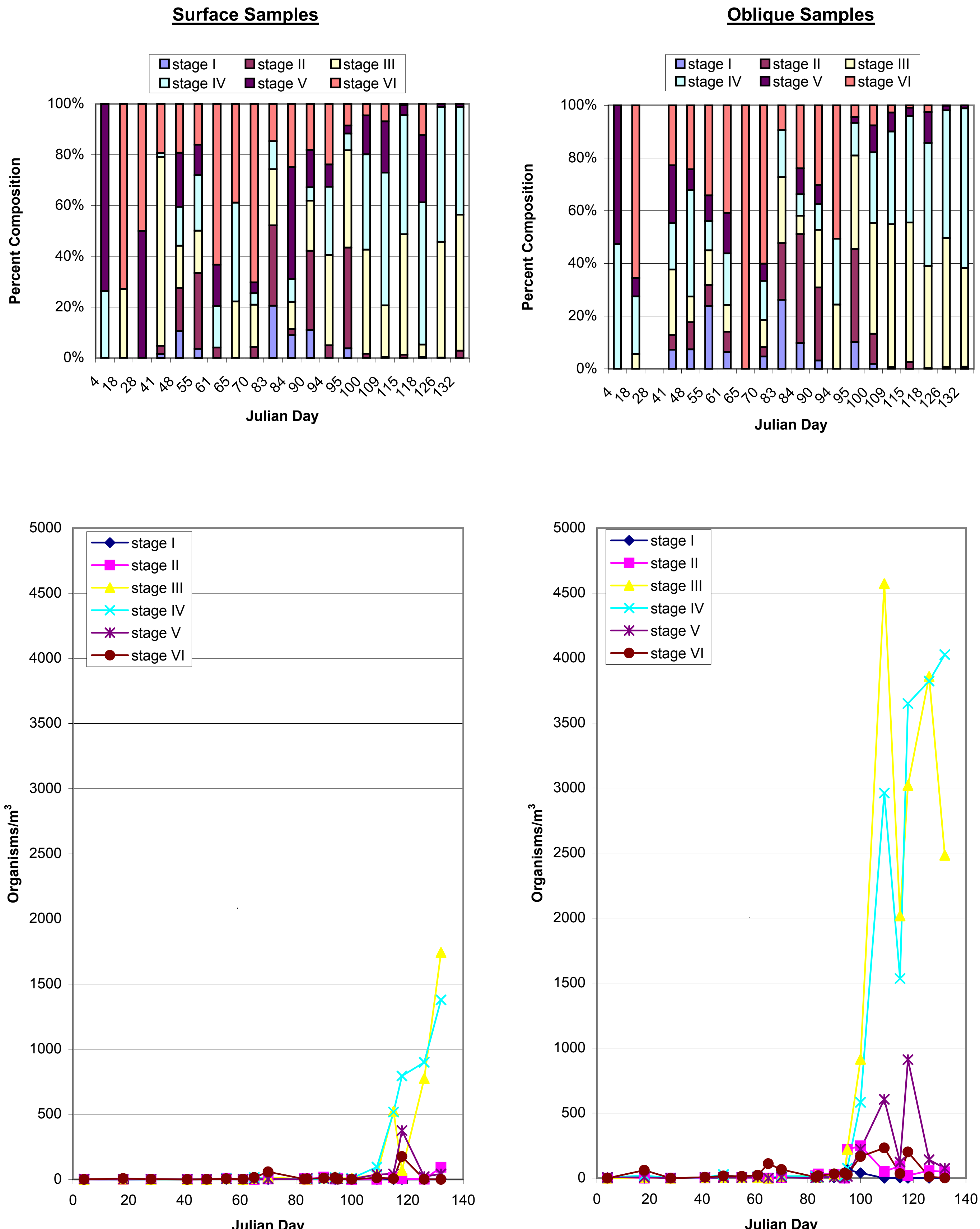
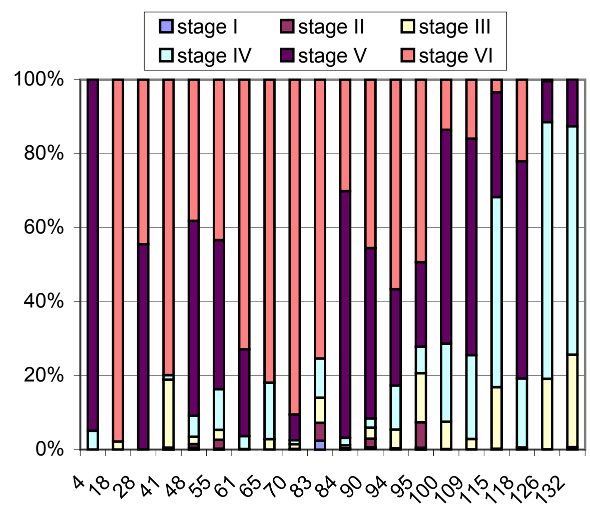


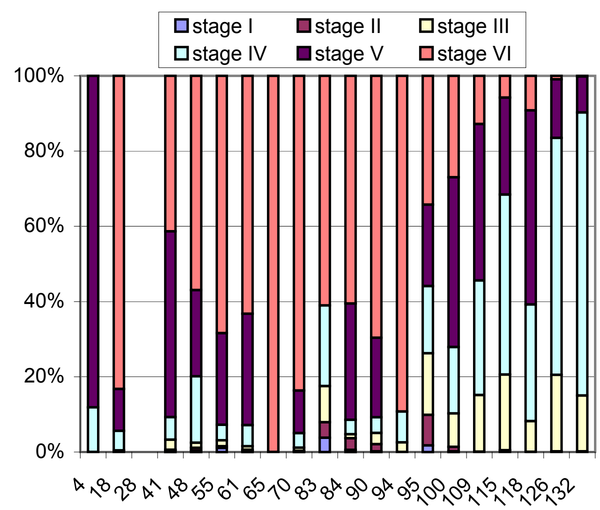
Figure 15

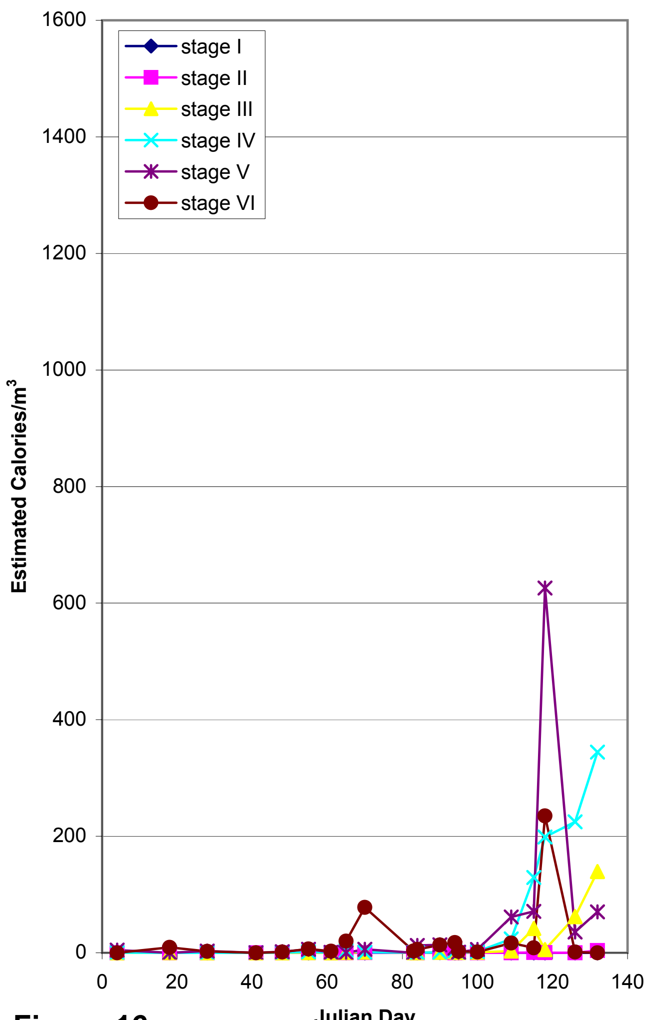
Cape Cod Bay 2004 Mean Daily Estimated Caloric Density Graphs for individual stage *Calanus finmarchicus*

Surface Samples



Oblique Samples





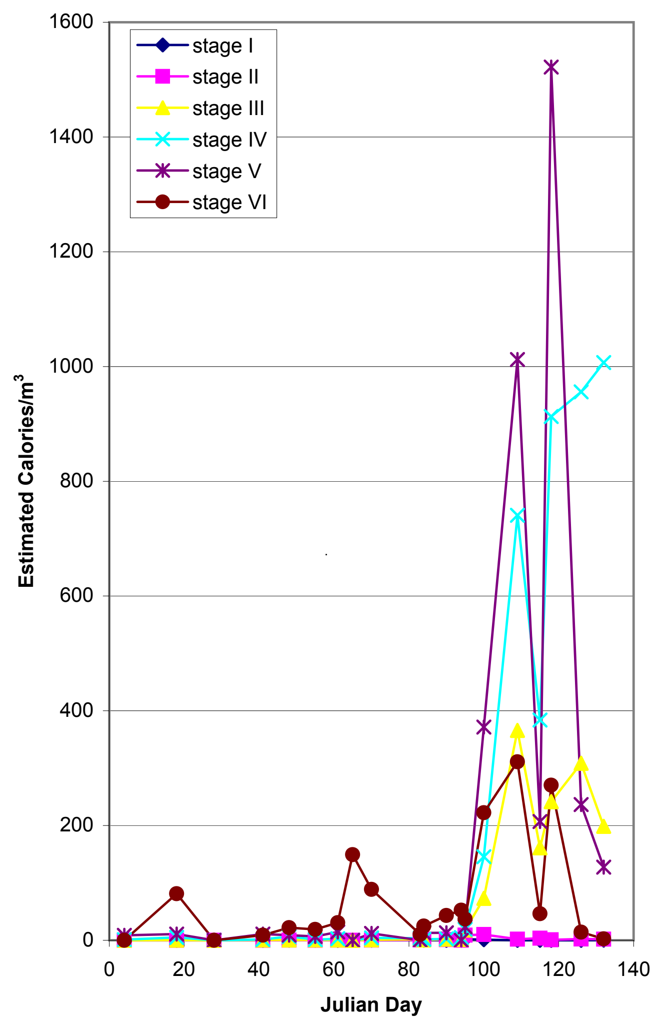
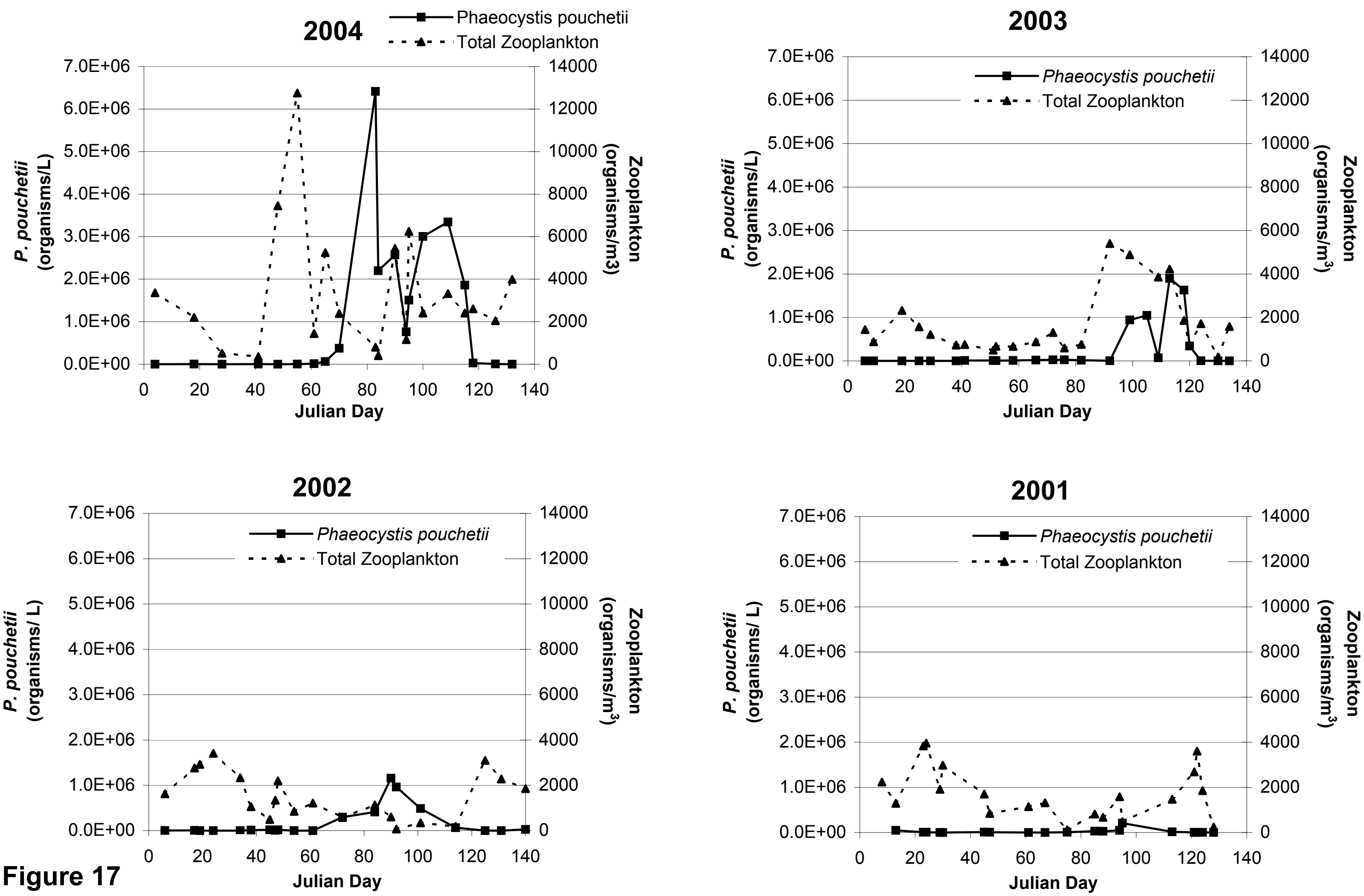


Figure 16



2004
Phaeocystis pouchetii
Total Zooplankton
P. pouchetii (organisms/L)
Zooplankton (organisms/m3)
Julian Day
2003
Phaeocystis pouchetii
Total Zooplankton
P. pouchetii (organisms/L)
Zooplankton (organisms/m3)
Julian Day
2002
Phaeocystis pouchetii
Total Zooplankton
P. pouchetii (organisms/ L)
Zooplankton (organisms/m3)
Julian Day
2001
Phaeocystis pouchetii
Total Zooplankton
P. pouchetii (organisms/ L)
Zooplankton (organisms/m3)
Julian Day

Figure 17

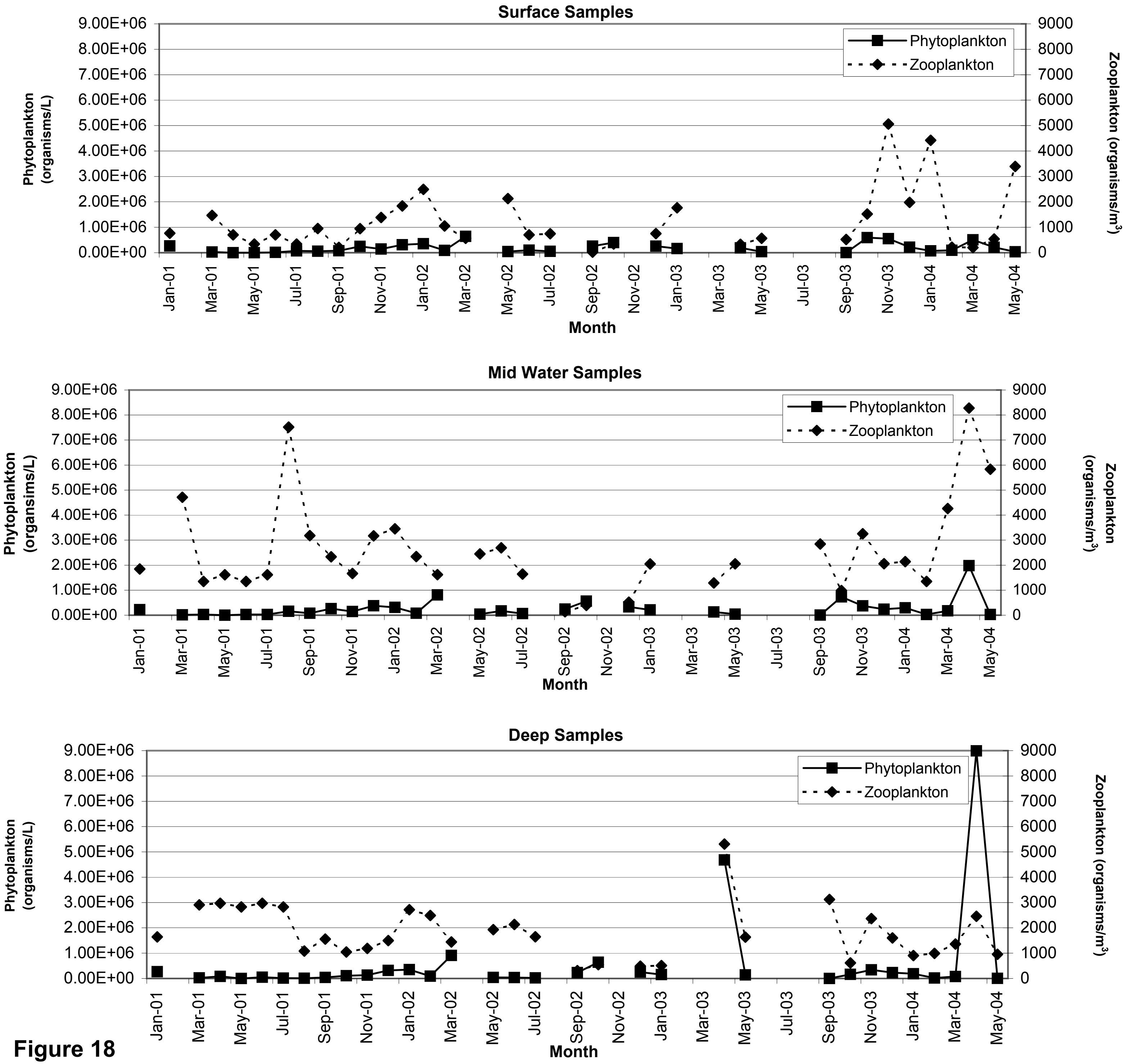

Surface Samples
Phytoplankton
Zooplankton
Phytoplankton (organisms/L)
Zooplankton (organisms/m3)
Month
Mid Water Samples
Phytoplankton
Zooplankton
Phytoplankton (organsims/L)
Zooplankton (organisms/m3)
Month
Deep Samples
Phytoplankton
Zooplankton
Phytoplankton (organisms/L)
Zooplankton (organisms/m3)
Month

Figure 18

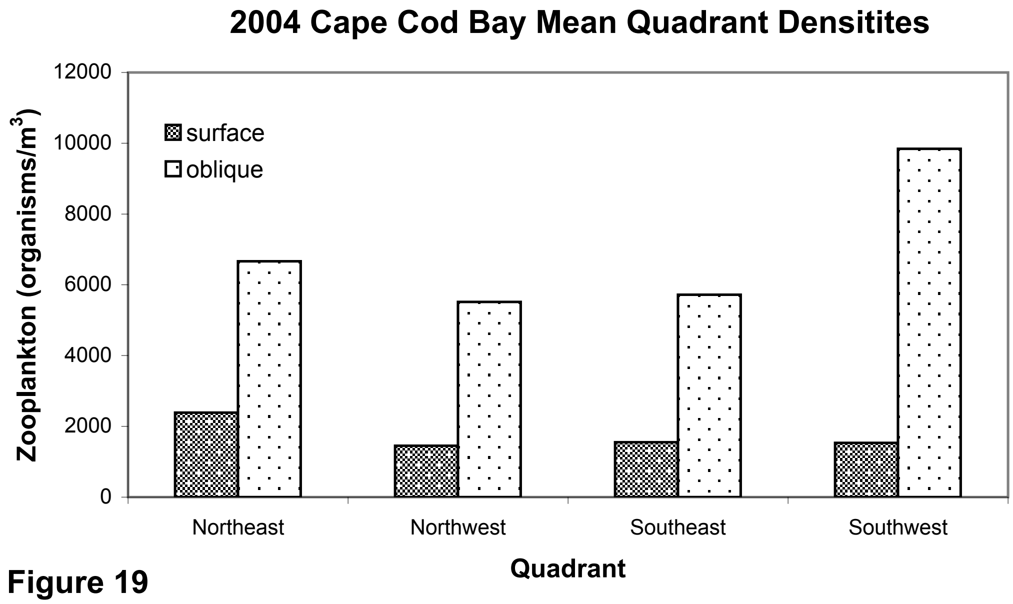


Figure 19

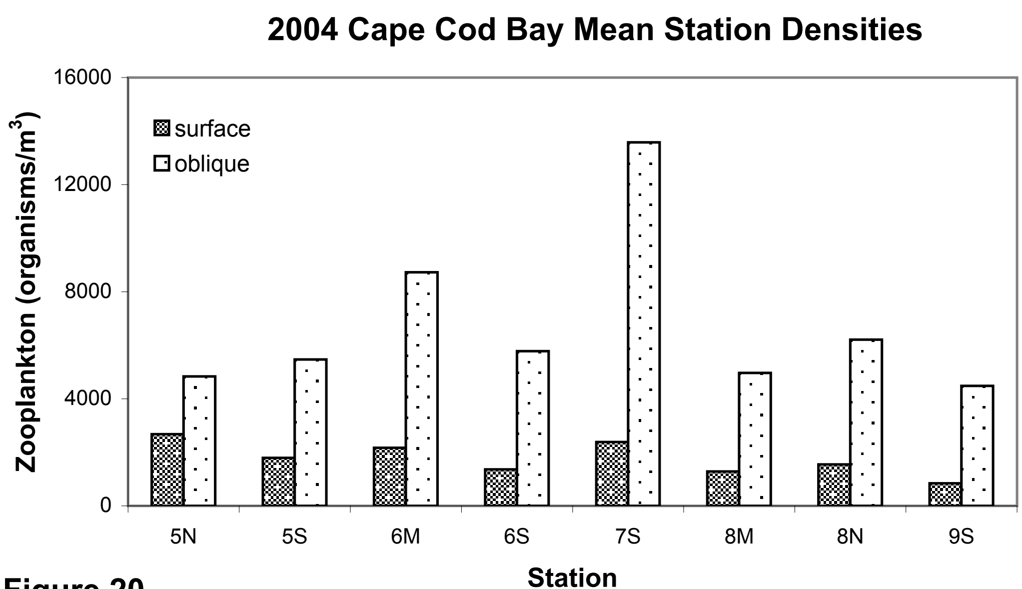


Figure 20

Appendix II

System Assessment and Prediction:
Examples from early, mid and late-season 2004

Interpretation of Zooplankton: SW391
Cruise Date: 18 January 2004
Julian Day: 18

This second cruise of the winter of 2004 successfully sampled stations in all four quadrants of Cape Cod Bay, after a long period of inclement weather. Changes since JD 4 are apparent in the collections and suggest a pattern of zooplankton abundance that gives some direction to our assessment.

Surface layer Assessment

The surface zooplankton densities dropped slightly since cruise SW389 but remain generally close to the estimated threshold of right whale feeding. Although the early-winter copepod, *Centropages* remains dominant, a decline in abundance was seen generally throughout the bay. A distinct increase in *Pseudocalanus*, the mid-winter taxon, has started and suggests the potential for the development of a rich zooplankton resource during the usual peak period of whale presence in the bay. The surface of Cape Cod Bay continues to appear suitable for right whale feeding, particularly in the northwestern quadrant, although for substantial residency the observed decline in *Centropages* biomass must be filled in by continuing increases in *Pseudocalanus*.

Oblique (surface – 19m) Assessment

Samples from shallow oblique tows demonstrated a pattern similar to the surface collections with patches of elevated densities appearing in the northwest and southeastern quadrants. Composition of the oblique samples mirrored those of the surface with the exception that late stage (C5 and adult) *Calanus* was represented in small but significant numbers in the northwest quadrant, proportionally increasing the settled volume and caloric densities.

General

The zooplankton resource continues to be marginally higher than the predicted feeding threshold and, should these conditions continue, with localized areas of amplification resulting from advective patch formation, right whale presence and feeding is likely. It appears that such amplification would be, as usually the case, essential to the development of areas of right whale aggregation and residency. The somewhat less patchy zooplankton profile from this cruise contrasts with a slightly richer and more patchy condition found during cruise SW389 (JD 4). It seems likely that, as the composition of the zooplankton continues to go through the seasonal flux the conditions that induce aggregation of the whales will improve on the first indications of a strong early- season *Pseudocalanus* signal. Nevertheless in the short term the less patchy and slightly less rich bay-wide zooplankton resource and caloric density suggests a modest decline in the likelihood of whale aggregation and surface feeding.

Comparisons

The average surface collections from 18 January 2004, cruise SW391 are here compared with those from 19 January 2003, cruise SW 308.

2003 bay-wide zpl density: **1461 orgs/m^3**   2004 avg. zpl density: **3104 orgs/m^3**

Comparison Assessment

The above comparison of the two years continues to support the view in the assessment of SW 389 (JD 4) that Cape Cod Bay is much more favorable in 2004 than in 2003 during the same time period. Composition during both years is similar with the exception of the early *Calanus* signal.

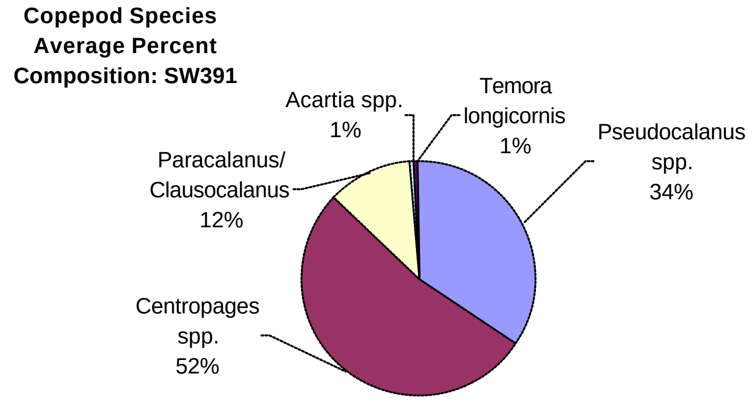
Interpreted likelihood (1-10) of:

Aggregation: moderate (6)
Residency: moderate (5)
Near-Surface feeding: moderate (6)
Feeding in the water column: moderate (6)
Trends in above: slow decrease in all measures
Quadrant Quality/Attractiveness: NE (5); SE (5); SW (4); NW (7)

Surface Zooplankton Assessment: SW391 (1/18/2004) Julian Day 18

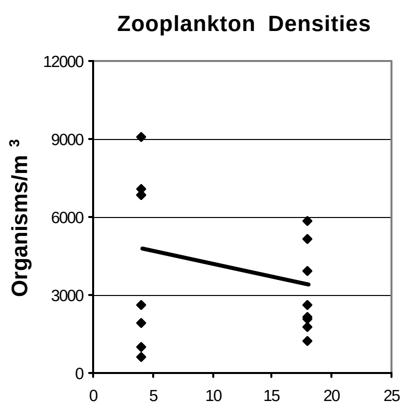
MEASURES:

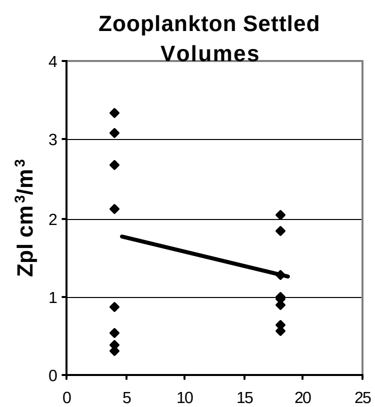
Technique	Station	Total Zpl/m³	Settled Vol/m³	Total Calories/m³	Total Dry Wt./m³
Surface Tow	5N	2611.53	0.96	263.11	0.05
Surface Tow	6M	2138.90	1.00	236.48	0.04
Surface Tow	8N	5183.44	2.05	516.09	0.09
Surface Tow	8M	5838.14	1.85	434.55	0.07
Surface Tow	6S	3934.92	1.27	433.36	0.08
Surface Tow	5S	2085.73	0.89	227.54	0.04
Surface Tow	9S	1785.34	0.64	174.09	0.03
Surface Tow	7S	1251.03	0.55	125.48	0.02
Cruise Average:		**3103.63**	**1.15**	**301.34**	**0.05**
Previous Cruise Avg:		**4491.58**	**1.67**	**564.99**	**0.11**

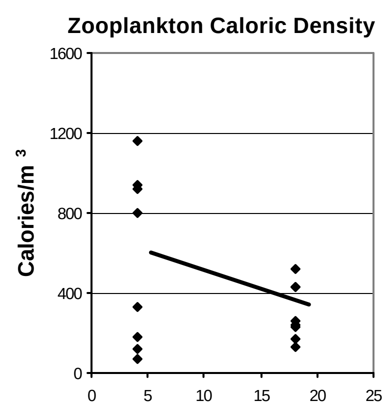


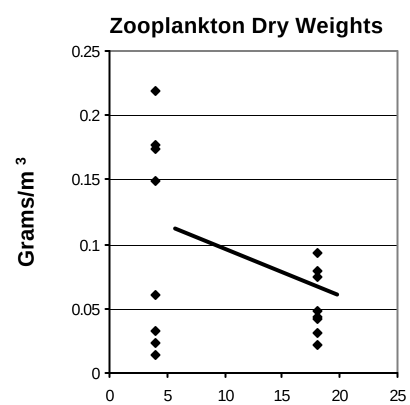
2004 SEASONAL TRENDS: x-axis values are expressed as Julian days in all graphs

Entire Cape Cod Bay:

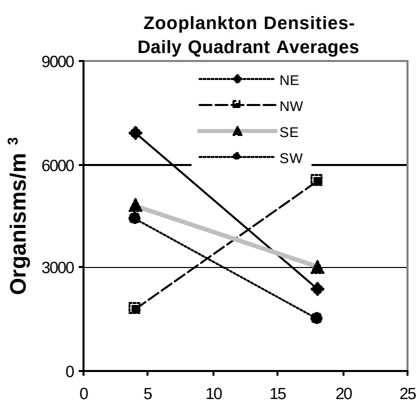


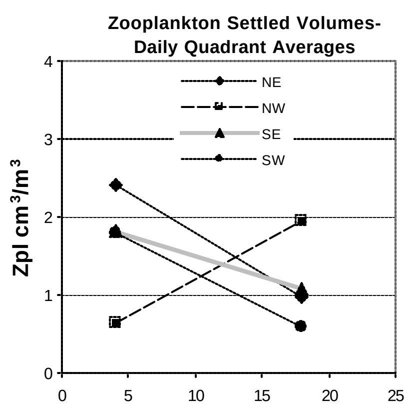


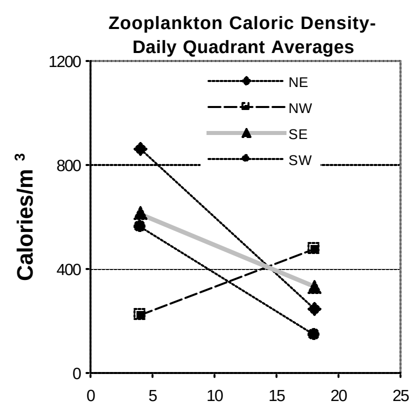


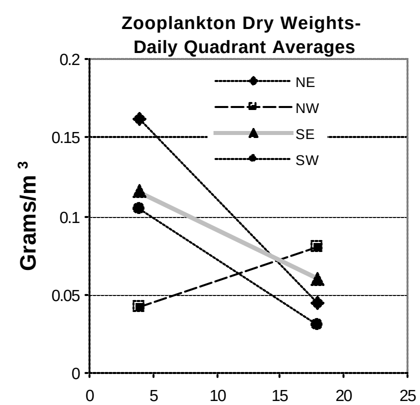


Geographic Quadrants:







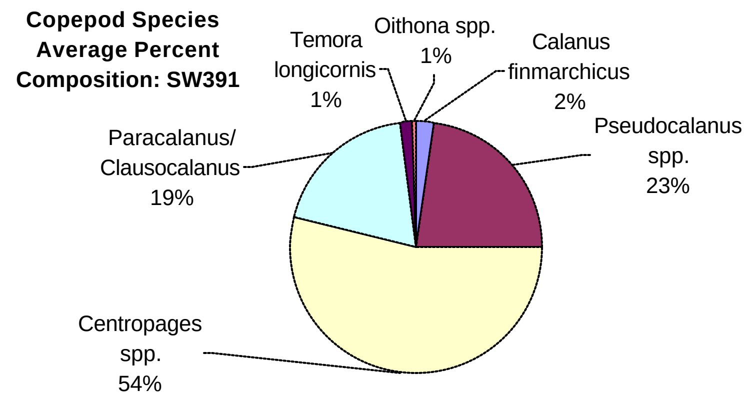


Oblique Zooplankton Assessment: SW391 (1/18/2004) Julian Day 18

Right whales sighted during SW391: 0 ***Right whales sighted during recent aerial survey: no surveys flown due to weather conditions***

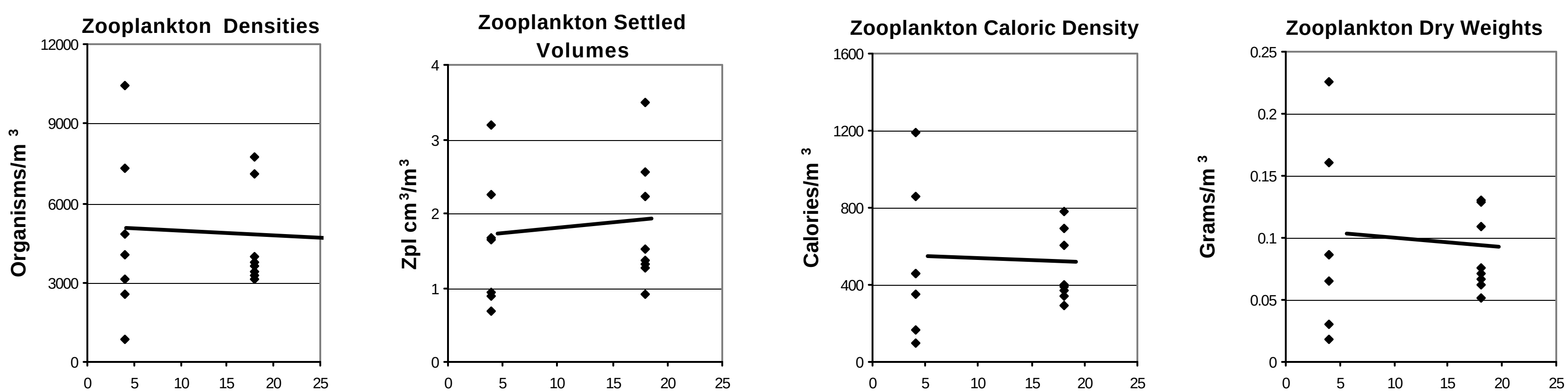
MEASURES:

Technique	Station	Total Zpl/m³	Settled Vol/m³	Total Calories/m³	Total Dry Wt./m³
Oblique Tow	5N	3957.69	1.36	373.60	0.07
Oblique Tow	6M	3629.63	1.32	390.11	0.07
Oblique Tow	8N	3417.76	3.49	775.65	0.13
Oblique Tow	8M	7757.74	2.55	600.52	0.11
Oblique Tow	6S	7068.00	2.23	694.27	0.13
Oblique Tow	5S	3280.48	1.26	336.71	0.06
Oblique Tow	9S	3099.78	0.91	287.94	0.05
Oblique Tow	7S	3750.19	1.52	401.52	0.08
Cruise Average:		**4495.16**	**1.83**	**482.54**	**0.09**
Previous Cruise Avg:		**4743.38**	**1.61**	**511.81**	**0.10**

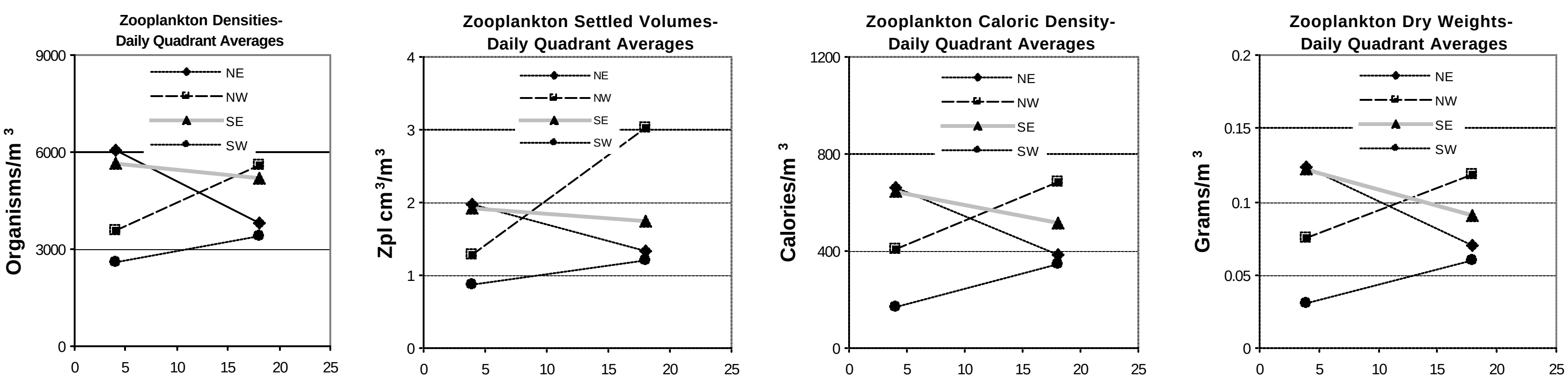


2004 SEASONAL TRENDS: x-axis values are expressed as Julian days in all graphs

Entire Cape Cod Bay:



Geographic Quadrants:



Interpretation of Zooplankton Resources: SW401
Cruise Date: 10 March 2004
Julian Day: 70
Zooplankton Samples Enumerated: 20

Surface and oblique samples were taken over the entire area of Cape Cod Bay in order to represent the characteristics of the system as a whole. Substantial changes in the characteristics of the zooplankton distribution were reflected in changed distribution of right whales as observed by DMF/CCS aircraft and by observers aboard R/V *Shearwater*. The previously predicted movement of whales to the south and southwest was mirrored in the generally enriched zooplankton biomass of those areas, an enrichment we have been identifying for the last 10 days.

Surface samples during this day of overcast conditions expectedly showed patches of moderate to high zooplankton biomass. Samples from oblique tows suggest an increased enrichment of the subsurface of the southern half of the bay. While poor weather conditions precluded vertical pump sampling in the south portion of the bay in the area of whale aggregation, the elevated zooplankton concentrations in all oblique collections from that area suggest a high mid-water biomass. These oblique samples show that much of the bay is rich in zooplankton and that the movement of whales within the southern and eastern portions of the bay will likely be controlled by localized patch formation on scales of tens to thousands of meters. The most dense oblique sample (at station 7S, in the south-central bay) reflected a calculated zooplankton particle concentration approximately one order of magnitude greater than our estimated feeding threshold for right whales. Because the oblique sampling technique estimates an integrated zooplankton density from 19 meters depth to the surface, it is likely that layers of very high zooplankton biomass and caloric density within the upper mid-water are controlling the observed distribution of the whales.

The collections both at the surface and with vertical pump techniques in the western and northern parts of the bay continue to indicate that at those locations there is both a low available zooplankton biomass and little likelihood of aggregation or residency by right whales. The vertical zooplankton profile in the northwestern portion of the bay (station 8N) defines a food resource substantially below the estimated feeding threshold at all depths. However, the species diversity, as on cruise SW399, was very high at station 8N.

Surface Layer Assessment

The measures of surface zooplankton richness appear to have increased throughout much of Cape Cod Bay, with particularly high values recorded in an area where right whales were observed along the southern margin. Generally, the strong subsurface resource influencing the whales earlier in the season (J.D. 45-60) appears to be moving into the upper water column probably resulting in decreased or absent engybenthic layers. This movement appears influenced by light intensity.

The first indications of the influx of the late winter/early spring *Calanus* resource were detected at station 5N. On the attached cruise data assessment instrument we report the species composition at 5N because of the importance of the *Calanus* resource in supporting the spring occurrence of right whales. In that respect, it is not yet possible to predict the impact of the switch over from a *Pseudocalanus* dominated system to one with dominance by *Calanus;* however this first indication of the rise in *Calanus* is typical of the period around the second week of March and may be expected to precede the usual spreading of the resource.

<u>Oblique (surface – 19m) Assessment</u>

Oblique samples collected on this cruise show a perfusion of mid-water resource dominated by *Pseudocalanus* both in the area of whale aggregation and throughout the bay. As in the surface samples, the biomass at station 5N was dominated by Pseudocalanus and a complex of *Paracalanus* and *Clausocalanus* but with the first strong signal of *Calanus.* The *Calanus* resource both at 5N at the surface and at depth was dominated by adult females.

<u>Water Column Assessment</u>

Sampling of the water column using the discreet depth sampler was undertaken only at station 8N, in the northwestern quadrant of the bay. The samples there reveal a low resource from top to bottom, with no clear zooplankton enrichment in the engybenthos. The very low concentration of the resource along with the low biomass from surface to bottom continues to suggest that feeding and aggregation in the northwestern bay is unlikely.

<u>General:</u>

The Cape Cod Bay system appears capable of supporting whales for some time, contingent on the further development of the *Calanus* resource. A decline in the richness of the smaller calanoid taxa, *Pseudocalanus, Paracalanus* and *Clausocalanus* that have been supporting the whales for the past month is likely. With a decline in those taxa the principal influence on right whale aggregation and residency will be *Calanus*. Present conditions favor the smooth transition to a *Calanus* – dominated biomass. Following on the observations of previous years, particularly those preceding 2000, an increase in the assessment measures, particularly in estimated caloric density, in areas of the southeastern and northeastern quadrants of the bay is suggested. Thus the bay continues to be favorable to right whale aggregation, residency and feeding. Further, the continued rise in the layers of the *Pseudocalanus* resource suggests that whales will display surface-feeding behavior (skimming) increasingly placing whales at risk of ship strike. Conversely, the threat of entanglement by fishing gear in the lower portion of the water column will continue to decrease.

<u>Interpreted likelihood (1-10) of:</u>

Aggregation: high (8)
Residency: high (7)
Near-Surface feeding: medium (6)
Feeding in the water column: high(7)
Feeding in the engybenthic layer: low (3)
Trends: increase in surface and oblique food measures; spreading of *Calanus*; movement of the resource throughout the eastern and southern bay and enrichment due to small -scale physical processes
Quadrant quality/attractiveness: NE (7); SE (8); SW (7), NW (2)

<u>Comparisons:</u>

March 13, 2003, SW319 bay-wide avg. surface zpl density: **<u>1303 orgs/m^3</u>**

March 10, 2004, SW401 bay-wide avg. surface zpl density: **<u>3529 orgs/m^3</u>**

March 13, 2003, SW319 bay-wide avg. oblique zpl density: **<u>1740 orgs/m^3</u>**

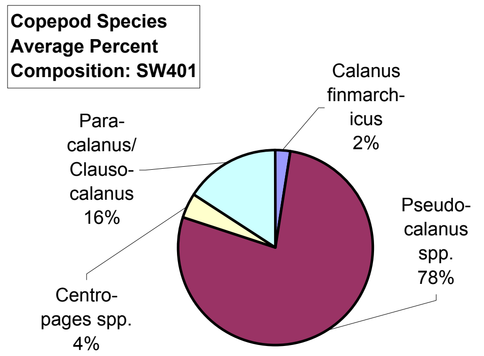
March 10, 2004, SW401 bay-wide avg. oblique zpl density: **<u>9141 orgs/m^3</u>**

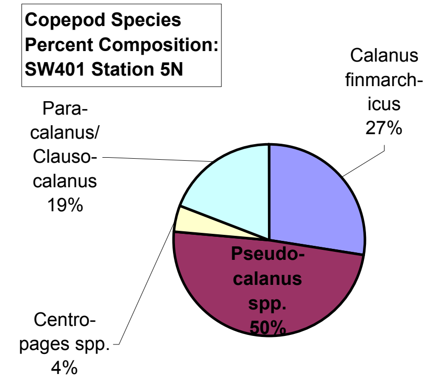
Surface Zooplankton Assessment: SW401 (3/10/2004) Julian Day 70

DMF-funded CCS aerial right whale sightings: at least 9 whales on 3/10 *SW401 vessel sightings: same whales as seen from plane*

MEASURES:

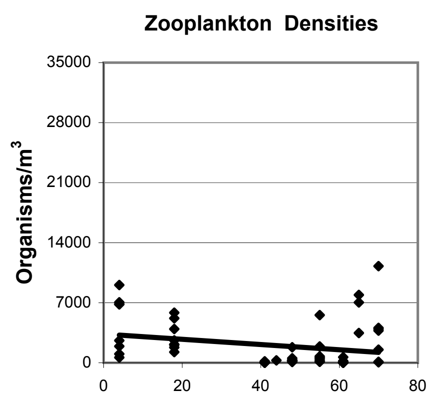
Technique	Station	Total Zpl/m^3	Settled Vol/m^3	Total Calories/m^3	Total Dry Wt./m^3
Surface Tow	6M	4063.56	1.61	236.25	4.42E-02
Surface Tow	5N	1526.38	1.67	417.38	6.81E-02
Surface Tow	8N	51.29	0.14	3.43	5.77E-04
Surface Tow	8M	107.17	0.14	9.09	1.69E-03
Surface Tow	5S	3750.16	1.52	176.79	3.24E-02
Surface Tow	6S	3933.34	1.43	212.12	3.85E-02
Surface Tow	7S	11275.62	3.85	612.62	1.14E-01
Cruise Average:		**3529.65**	**1.48**	**238.24**	**4.27E-02**
Previous Cruise Avg:		**124.07**	**0.14**	**8.93**	**1.64E-03**

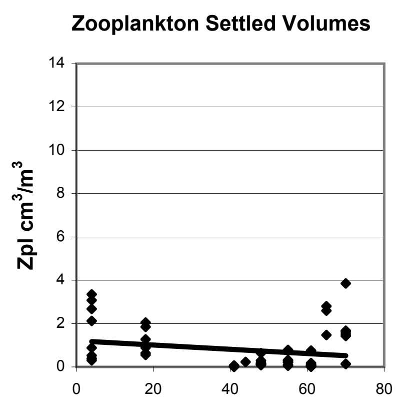


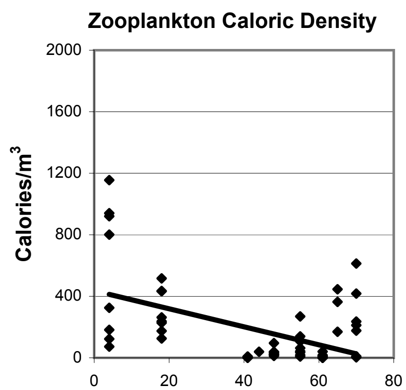


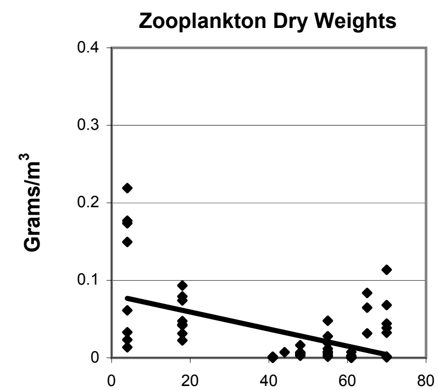
2004 SEASONAL TRENDS: x-axis values are expressed as Julian days in all graphs

Entire Cape Cod Bay:

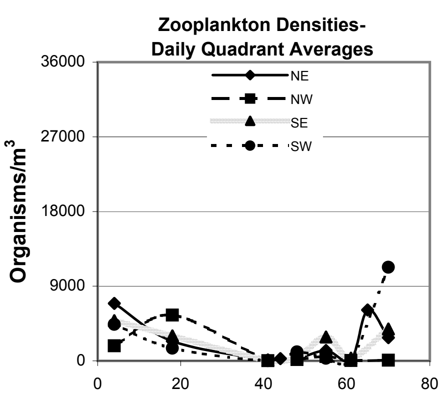


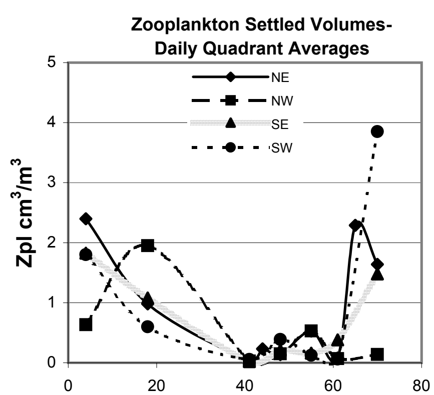


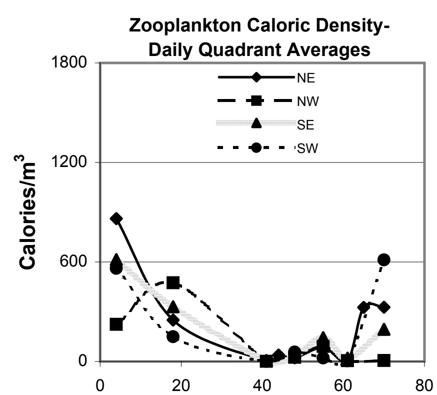


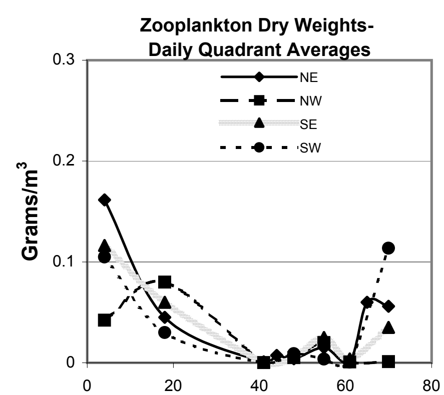


Geographic Quadrants:







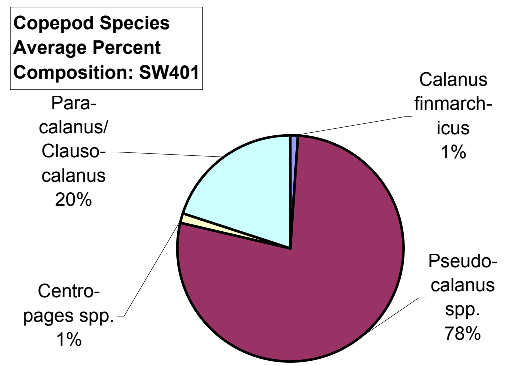


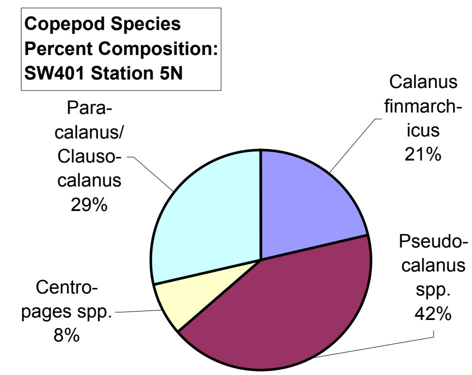
Oblique Zooplankton Assessment: SW401 (3/10/2004) Julian Day 70

DMF-funded CCS aerial right whale sightings: at least 9 whales on 3/10 *SW401 vessel sightings: same whales as seen from plane*

MEASURES:

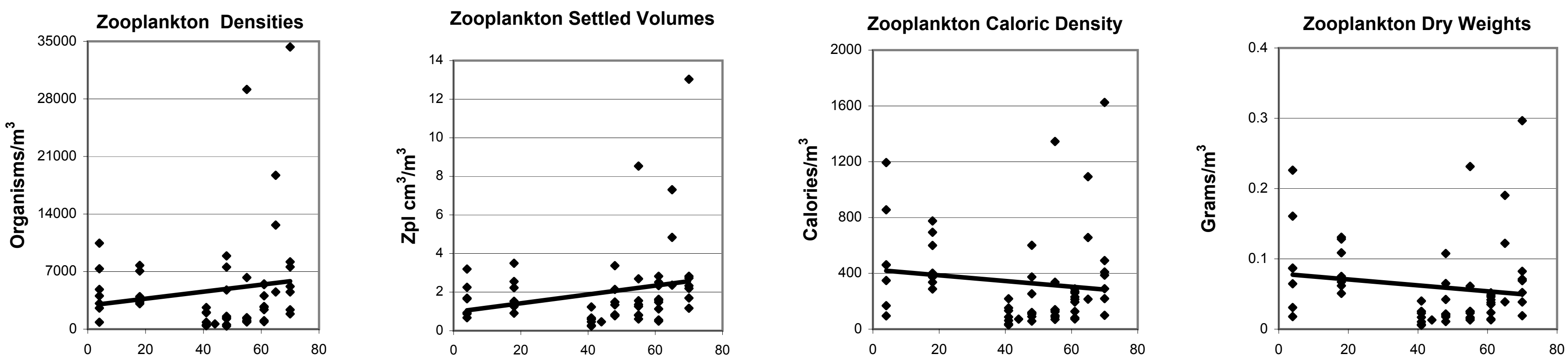
Technique	Station	Total Zpl/m^3	Settled Vol/m^3	Total Calories/m^3	Total Dry Wt./m^3
Oblique Tow	6M	8189.63	2.73	409.20	7.12E-02
Oblique Tow	5N	2350.65	2.33	491.45	8.23E-02
Oblique Tow	8N	1859.63	1.16	99.18	1.91E-02
Oblique Tow	8M	5198.91	2.19	289.95	5.21E-02
Oblique Tow	5S	4521.59	1.69	219.44	3.86E-02
Oblique Tow	6S	7561.56	2.82	387.29	6.89E-02
Oblique Tow	7S	34306.85	13.03	1624.99	2.97E-01
Cruise Average:		**9141.26**	**3.71**	**503.07**	**8.98E-02**
Previous Cruise Avg:		**3051.06**	**1.62**	**193.63**	**3.47E-02**



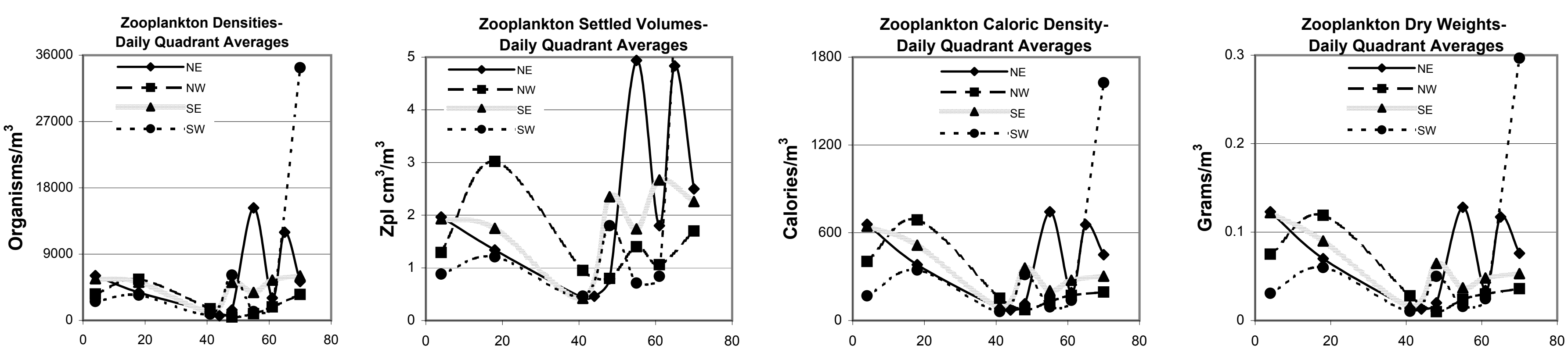


2004 SEASONAL TRENDS: x-axis values are expressed as Julian days in all graphs

Entire Cape Cod Bay:



Geographic Quadrants:



Interpretation of Zooplankton Resources: SW417
Cruise Date: 11 May 2004
Julian Day: 132
Zooplankton Samples Enumerated: 36

Cruise SW417 was completed in calm sea conditions with all standard quadrant stations and three vertical pump collections counted to characterize the conditions throughout the bay. Visibility during the cruise was excellent and no right whales were sighted, however the DMF/CCS aircraft survey on 10 May sighted one whale. Efforts on this cruise, at the end of the period of right whale activity in Cape Cod Bay that began in late December, were directed at describing the persistent food resource that has been observed in Cape Cod Bay over the last 15 days.

<u>Surface Layer Assessment</u>

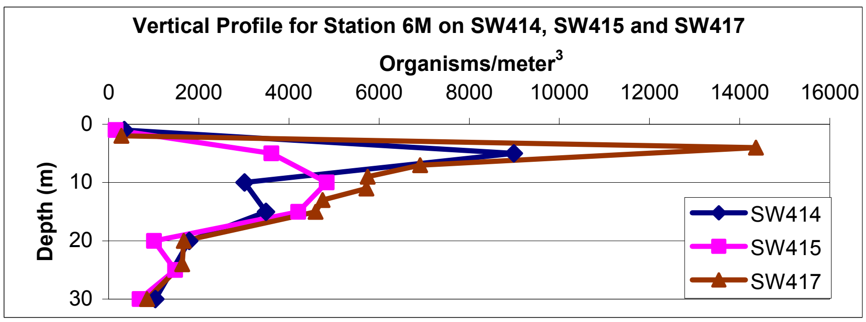
The surface resource in Cape Cod Bay remains generally more speciose and lower with respect to all assessment measures than seen in previous collections. The dramatic exception to the low surface biomass was seen at station 5N in the northeastern portion of Cape Cod Bay. While the high resource estimate at 5N results in a high mean zooplankton value for the bay, the general conditions at the surface in the bay are poor and will not support surface feeding by right whales. At station 5N the resource was located within the upper 4 meters of the water column and was composed of an exceptionally dense concentration of nearly pure *Calanus finmarchicus,* principally C4. Thus, while the surface layer at all other stations in Cape Cod Bay were far below the estimated thresholds for all measures, the food resource at station 5N was both rich and acceptable for right whale feeding.

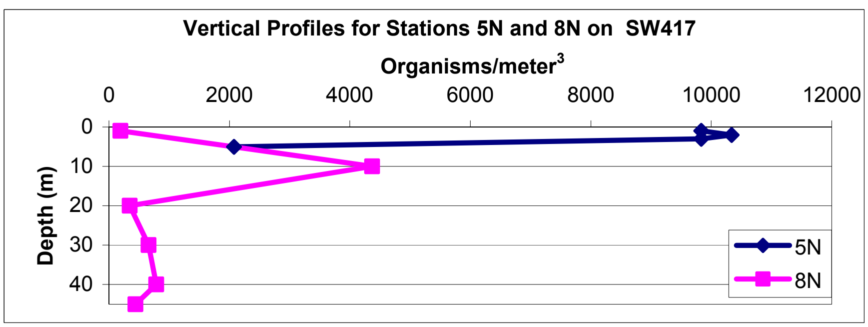
<u>Oblique (surface – 19m) Assessment</u>

The 0-19 m oblique collections from quadrant stations remain similar to the collections from JD 118 and 126, suggesting a system that for the time being is stable with respect to the quality of the food resource that controls right whale activity in the bay. The bay system as characterized from the oblique sampling remains high and above estimated thresholds in all measures with *Calanus finmarchicus* (principally stage C4) dominant throughout the bay. The high oblique sample measures are useful indicators when evaluated with an understanding that they are integrative of the upper water column that is impoverished at the surface at most stations. The oblique samples then are suggestive, as they have been for more than 3 weeks, of a strong upper-water column layer of *Calanus finmarchicus* that surpasses the density calculated for the oblique samples.

Water Column Assessment

Collections using the vertical pumping device were conducted at stations 8N (NW quadrant), 6M (NE quadrant) and at 5N where high surface zooplankton densities were recorded and sampling of the upper water column was undertaken (see figures). The water column samples generally suggest a rich resource that is found from a few meters below the surface to a depth of 10 meters through out much of the bay. The continued strength of the *Calanus finmarchicus* signal at the depth of the layer continues to present to any right whales a rich environment that will release subsurface feeding behavior. The distribution of the resource at 5N demonstrates a typical condition observed in the bay with a sharply formed high density layer at 1 meter below the surface and a distinct decline in density below 3 meters depth.





General

Cape Cod Bay remains a food-rich habitat with zooplankton concentrations and composition continuing to make the system acceptable to aggregation and feeding by right whales. Though the observed late-season enrichment of the bay by a strong *Calanus finmarchicus* resource is unusual when compared to previous years of study, the potential that whales may continue to visit the area to feed and nurse continues to be high. Although other traditional habitats where right whales are found during mid- to late May are, doubtless, more attractive to the species, the conditions in Cape Cod Bay will likely continue to be attractive to some individual whales and of concern to managers. Break-up of the resource is likely to occur with the next strong storm surge but until then we anticipate that the bay will continue to be attractive to whales straying from their traditional late-spring habitats in the Great South Channel and the Provincetown Slope.

Conservation Note

Although the slow departure of the whales from the bay presents less risk to the species, it is likely that right whales will occasionally enter Cape Cod Bay and, encountering dense *Calanus finmarchicus* resources still available through much of the bay, reside in the area for days. During such times feeding will predominate.

Comparisons:

May 10, 2003, SW336 bay-wide avg. surface zpl density: **179 orgs/m^3**
May 11, 2004, SW417 bay-wide avg. surface zpl density: **3288 orgs/m^3**

May 10, 2003, SW336 bay-wide avg. oblique zpl density: **1863 orgs/m^3**
May 11, 2004, SW417 bay-wide avg. oblique zpl density: **7106 orgs/m^3**

Interpreted likelihood (1-10) of:

Aggregation: high (7)
Residency: medium (4)
Near-Surface feeding: medium (4)
Feeding in the water column: high (8)
Feeding in the engybenthic layer: low (1)
Trends: The *Calanus finmarchicus* resource will remain strong and at or beneath the seasonal thermocline; density of the resource in the eastern bay will persist; depending on advective processes there may be a slow decline in zooplankton biomass throughout the bay
Quadrant quality/attractiveness: NE (7); SE (6); SW (5), NW (4)

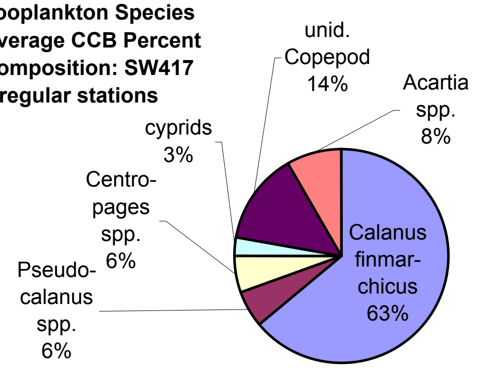
Surface Zooplankton Assessment: SW417 (5/11/2004) Julian Day 132

DMF-funded CCS aerial right whale sightings: 1 whale on 5/10 *SW417 vessel sightings: 0 right whales*

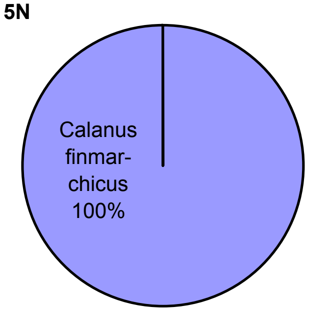
MEASURES:

Technique	Station	Total Zpl/m^3	Settled Vol/m^3	Total Calories/m^3	Total Dry Wt./m^3
Surface Tow	6M	25.49	0.03	1.09	0.0002
Surface Tow	**5N**	**26016.98**	**8.77**	**6784.48**	**1.9069**
Surface Tow	8N	121.65	0.21	26.44	0.0072
Surface Tow	8M	37.73	0.03	5.10	0.0014
Surface Tow	6S	13.09	0.02	0.39	0.0001
Surface Tow	5S	68.34	0.05	12.72	0.0035
Surface Tow	9S	14.86	0.01	1.20	0.0003
Surface Tow	7S	8.22	0.00	0.31	0.0001
Cruise Average:		**3288.30**	**1.14**	**853.97**	**0.2400**
Previous Cruise Avg:		**1835.35**	**1.04**	**444.32**	**0.1244**

Zooplankton Species Average CCB Percent Composition: SW417 7 regular stations



Zooplankton Species CCB Percent Composition: SW417 Station 5N

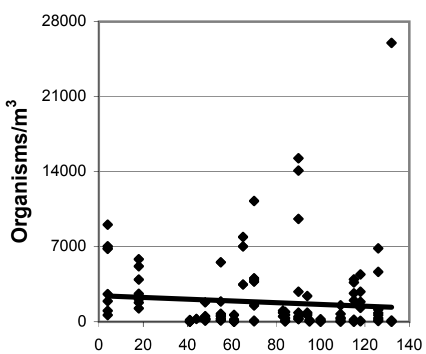


2004 SEASONAL TRENDS: x-axis values are expressed as Julian days in all graphs

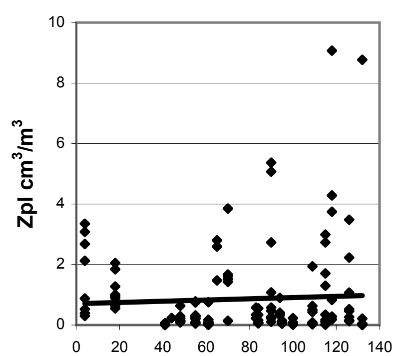
Entire Cape Cod Bay:

Note scale differences between surface and oblique graphs

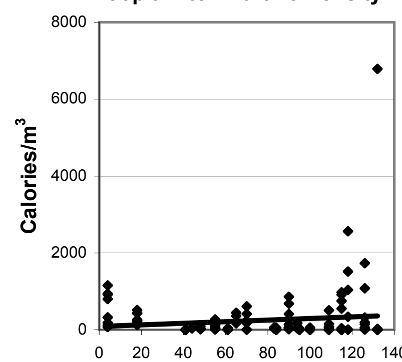
Zooplankton Densities



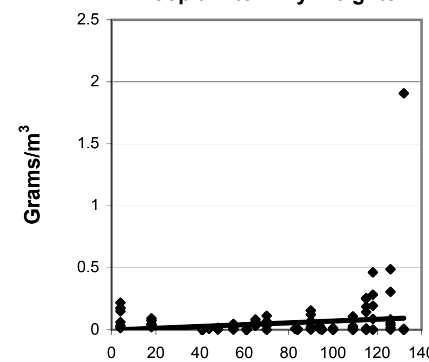
Zooplankton Settled Volumes



Zooplankton Caloric Density

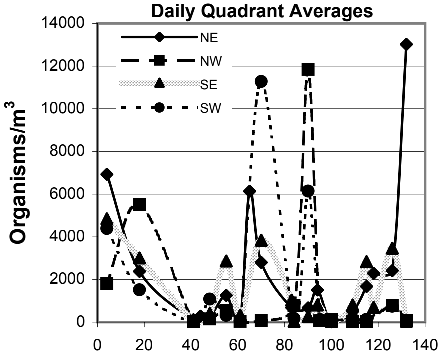


Zooplankton Dry Weights

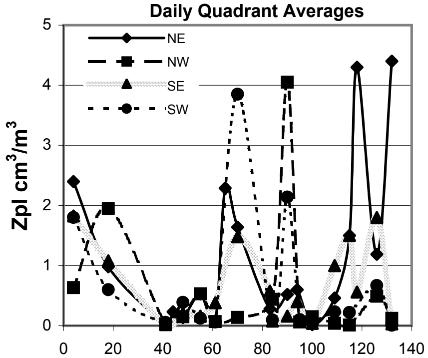


Geographic Quadrants:

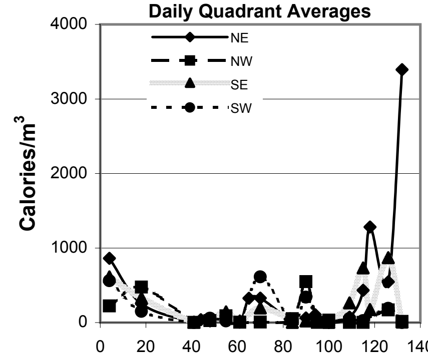
Zooplankton Densities- Daily Quadrant Averages



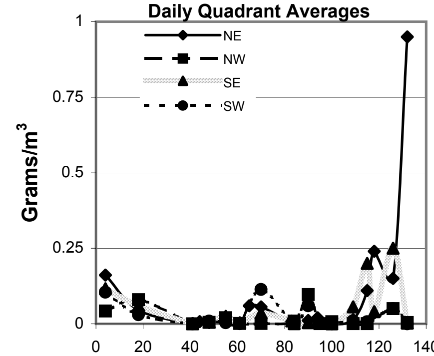
Zooplankton Settled Volumes- Daily Quadrant Averages



Zooplankton Caloric Density- Daily Quadrant Averages



Zooplankton Dry Weights- Daily Quadrant Averages



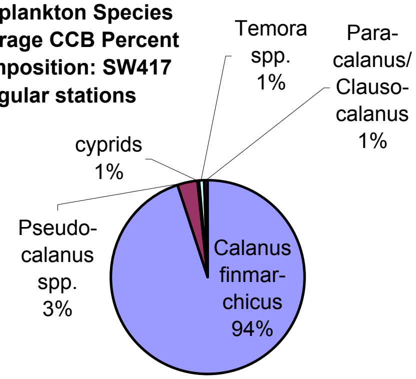
Oblique Zooplankton Assessment: SW417 (5/11/2004) Julian Day 132

DMF-funded CCS aerial right whale sightings: 1 whale on 5/10 *SW417 vessel sightings: 0 right whales*

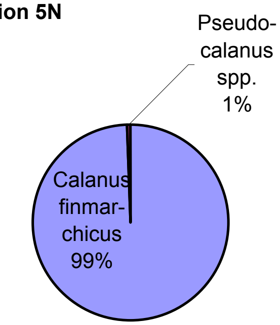
MEASURES:

Technique	Station	Total Zpl/m^3	Settled Vol/m^3	Total Calories/m^3	Total Dry Wt./m^3
Oblique Tow	6M	11620.73	5.35	3049.36	0.83
Oblique Tow	5N	6984.43	2.61	1666.90	0.48
Oblique Tow	8N	4611.14	2.27	1093.08	0.31
Oblique Tow	8M	5277.32	2.45	1243.68	0.35
Oblique Tow	6S	6927.27	2.57	1664.81	0.47
Oblique Tow	5S	11649.28	4.31	2801.05	0.80
Oblique Tow	9S	4449.85	2.76	1106.66	0.30
Oblique Tow	7S	5325.27	1.93	1245.94	0.36
Cruise Average:		**7105.66**	**3.03**	**1733.93**	**0.49**
Previous Cruise Avg:		**8418.34**	**3.36**	**2091.92**	**0.58**

Zooplankton Species Average CCB Percent Composition: SW417 7 regular stations



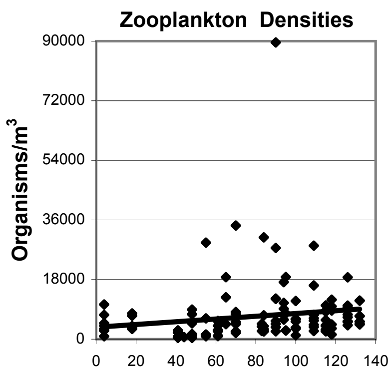
Zooplankton Species CCB Percent Composition: SW417 Station 5N

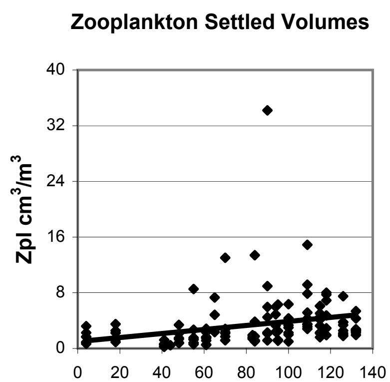


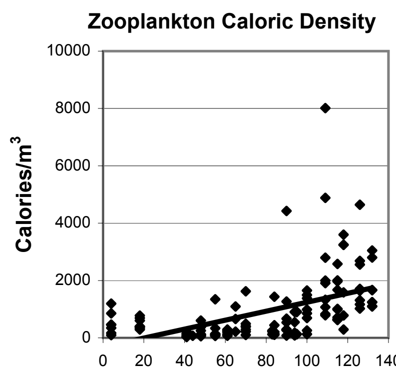
2004 SEASONAL TRENDS: x-axis values are expressed as Julian days in all graphs

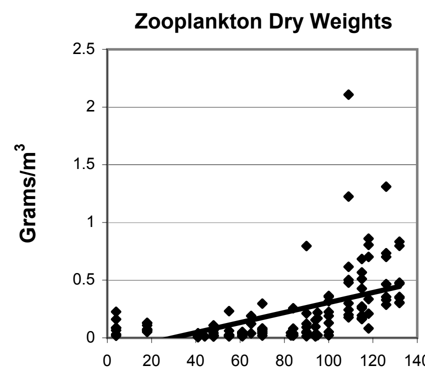
Entire Cape Cod Bay:

Note scale differences between surface and oblique graphs

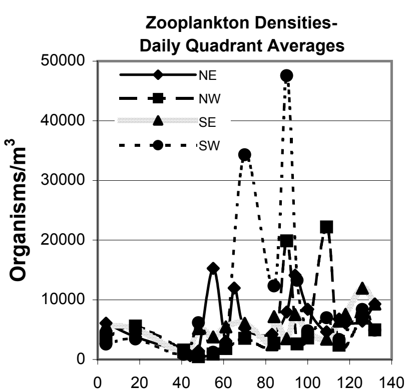


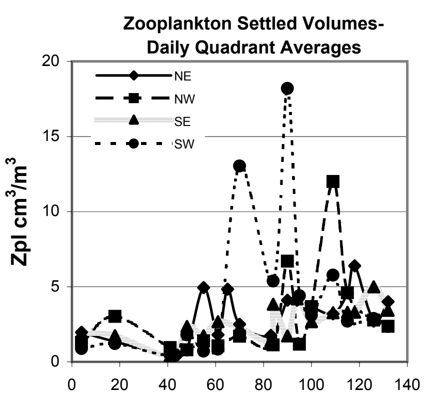


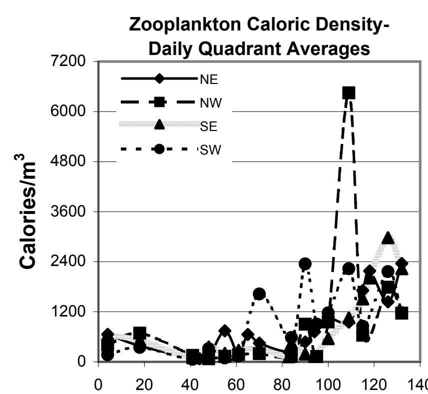


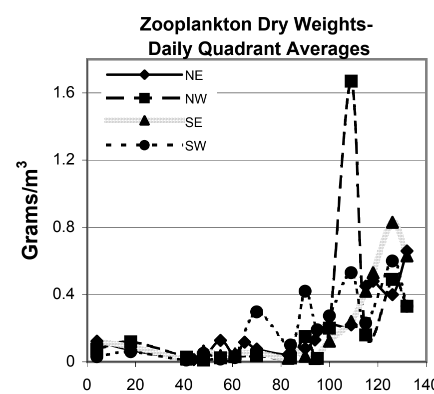


Geographic Quadrants:









SECTION 3: A COMPARISON OF RIGHT WHALE AND ZOOPLANKTON DISTRIBUTION

Introduction

The management responsibilities of the right whale surveillance program taken together are intended to alert the Division of Marine Fisheries (DMF) to the presence of right whales within the Critical Habitat. Alerting DMF to the presence of whales is central to the Division's effort to manage the Cape Cod Bay Right Whale Critical Habitat because it is generally understood that the habitat conditions, particularly zooplankton density and distribution, influence the occurrence and distribution of the whales, and that the co-occurrence of whales and unmodified fixed fishing gear increases the threat to whales of entanglement, serious injury, and mortality. In order to further the goal of better predicting the occurrence patterns of the whales so that the DMF can take management action to mitigate the threat of entanglement mortality, information from the aircraft-based survey efforts would best be used in concert with zooplankton density information to produce a coherent image of the distribution of the whales and of the food resources within the Critical Habitat. This section of the 2004 report presents a preliminary method for better summarizing the two aspects of the surveillance program that together make up the basis for DMF management actions. The following approach to the comparison of the two data sets will be refined and used in the 2005 assessment forms in much the same way as they are here.

Methods

The collections of zooplankton used in the comparative studies were obtained using those methods referred to in Section 2. For these summaries the mean raw zooplankton abundance was calculated at each of the eight fixed stations sampled using oblique net sampling techniques that integrate the zooplankton to a depth of 19 meters. Zooplankton density and right whale distribution data were plotted using a Geographic Information System (ArcGIS 9, ESRI). An Inverse Distance Weighted (IDW; ArcGIS Spatial Analyst) interpolation method was applied to the zooplankton data from the eight fixed stations in order to obtain a bay-wide projection of density distribution. IDW generates a raster dataset composed of cells that derive their value based on the average of sample data points in the vicinity of each cell. The distance to sample points of known value influences the averaged value of each cell. The plotted variable (zooplankton density) decreases in influence with greater distance from the sample location. The distribution of whales projected over the zooplankton abundance plots is the same that is presented in Section 1 of this report.

The unusual nature of this preliminary comparative approach to the datasets of the surveillance program presents problems in interpretation that deserve to be identified:

1. Oblique zooplankton samples were used in the development of the zooplankton abundance contour plots. This collection method, while offering an integrated dataset, is limited to depths of less than 19 meters and cannot be used to describe

the zooplankton resource at greater depth or those engybenthic plankton layers that have been identified as occasionally controlling the distribution of the whales. These deeper layers though unsampled nevertheless could be controlling the distribution and movement of the whales yet not be accounted for in the contoured zooplankton comparisons.

2. The smoothing algorithm used in the comparisons to create the contour plots suggests a distribution of zooplankton over large areas of the bay that were not sampled. Because the zooplankton samples that were used in the GIS comparisons were collected at only 8 stations, the collections are probably not always representative of the resource abundance in the waters over the entire bay. The comparisons suffer, therefore, from small-sample size. In the smoothing algorithm small sample size can be particularly misleading because the contoured plots imply more data than underlies the smoothing procedure.

The collection of zooplankton often did not temporally coincide with the flights that were used to document the distribution of whales. Because the Cape Cod Bay system is dominated by a counterclockwise current onto which is superimposed a semi-diurnal tidal flux, the movement of plankton and the dispersal and aggregation of organisms into layers is dynamic and complex. In some cases the zooplankton samples used in this analysis were collected more than a week removed from the dates of sightings reported from over flights. Because prey patches form, disperse, and move about the system, such separation of sample collection time from flight time presents a problem of bias that cannot be accounted for in this preliminary method.

We propose that the caveats listed above should be addressed in future research plans (See Section 4) so that methods used to combine variables can be refined in order to further improve the accuracy of the assessment and prediction of the reporting.

Results and Discussion

A comparison of the gross occurrence of whales identified during aircraft survey efforts with surface and oblique mean zooplankton densities from the 8 fixed stations are shown in Figures 1 through 4.

For the comparison of the spatial and temporal distribution of zooplankton and whales in the Cape Cod Bay Critical Habitat the observations were grouped into three presentations: bi-weekly plots (Figure 5 through 9 and 11-15), 1.5-month plots (Figures 16 through 18), and whole season (Figure 19). Each of these time groupings show different characteristics of the spatial and temporal structure of the whale aggregation compared with the dispersion pattern of the controlling zooplankton resource.

Gross Occurrence Patterns and Zooplankton Abundance

The pattern of observed right whale presence in the study area during 2004 is compared with mean zooplankton abundance from surface and oblique net collections in Figures 1 and 2 respectively. These observations are compared with similar treatments of the combined data from 2003 in Figures 3 and 4. While the pattern of high mean zooplankton resource reflecting high whale density in the Cape Cod Bay Critical Habitat is generally maintained, the data from the two seasons suggest some interesting differences that may point to important, if subtle, considerations for management of the habitat. Particularly in 2004, but also to a degree in the whale-plankton comparisons of 2003, there is an indication that zooplankton abundance in the early winter (J.D. 0-20) was high, above threshold values, while whale presence lagged. At the other end of the season, during J.D. 125-140, there are similar indications, particularly in 2004, that whale occurrence dropped while zooplankton abundance was high enough to support aggregations of whales. The apparent decoupling of zooplankton and whales during the shoulder seasons was interpreted as reflecting the complex interaction of larger habitat – use patterns employed by the whales. The late arrival of whales strongly suggests that whales did not 'follow" advected patch of zooplankton into the bay as has been previously suggested. Rather it is more likely that whales either visit places that are known to be seasonally rich in food resources, sampling perhaps in loosely knit aggregations, and leaving those areas of declining food resources in favor of locales, such as Cape Cod Bay, that have in the past proven rich in food resources. Thus, it appears that the entry into and departure from Cape Cod Bay may be a combination of local resource cues coupled with responses to historic resource quality.

It is of paramount importance for DMF managers to identify the entry and departure of whales in the Cape Cod Bay Critical Habitat because of the need to effectively manage fixed fishing practices. The use of simple measures of zooplankton abundance that may be useful in the middle part of the season may not offer the amount of information needed during the shoulder periods of the season (December, early January, late April and May). In order to explain whale occurrence during the shoulder seasons the development of a method that is capable of accounting for such entry and departure scenarios, a model driven by regional resource conditions, should be a priority for development as a management tool (see Section 4).

Bi-Weekly Plots

Taken together, the plots of air survey sightings and contoured zooplankton concentrations illustrate the widely varying nature of the controlling resource. In the early season when whales were absent, the smoothed zooplankton distribution was variable (Figures 5-7) and some periods were characterized by very low zooplankton abundance throughout the habitat (Figure 7). The mid season was characterized by the coincident influx of whales (February 12-25; Figure 8) and a general increase in enrichment, particularly in the eastern quadrants of the bay. The assessment forms for these periods generally reflected these characteristics, with the eastern two-thirds of the bay usually enriched with respect to zooplankton while the western area of the critical habitat and west of the demarcation was low in zooplankton abundance. During the middle part of the season when whale abundance was high, the resource was also high and comparatively stable throughout the eastern bay. Thus the coarse, contoured zooplankton abundance and whale aggregation figures map well over one another.

One exception to the association of whales with the food resource among the bi-weekly comparisons is represented by the period 26 February – 11 March (Figure 9). During this period whales were distributed north of the rich zooplankton patch dominating the contour plot at Station 7S. Absent directed data collection it is not possible to conclusively identify the cause of this displacement, however evidence from vertical pump sampling northeast of station 6M on 1 March (Figure 10) identify a very high abundance of zooplankton within the water column below 19 meters (the maximum depth of the oblique sampling methods) and a bottom or engybenthic layer of zooplankton with a calculated density of 72 to 87 x 10^3 organisms/m^3. This evidence suggests that the enrichment of a deep zooplankton resource that was not documented using our traditional oblique sampling methods, coupled with the low abundance of zooplankton in the upper 19 meters of the water column, had a strong influence on the distribution of whales in areas where, as in Figure 9, the comparative plots appear to show whale distributions not reflective of zooplankton abundance. The comparative plot in Figure 9 illustrates the constraints of the current oblique techniques used to assess the habitat, being both limited in numbers of samples (and hence producing contoured plots that can be misleading), detail, and vertical extent. Section 4 addresses the data needs of future management efforts with the goal of further improving the quality of the assessments and deepening the capacity of the assessment process to predict the distribution of whales.

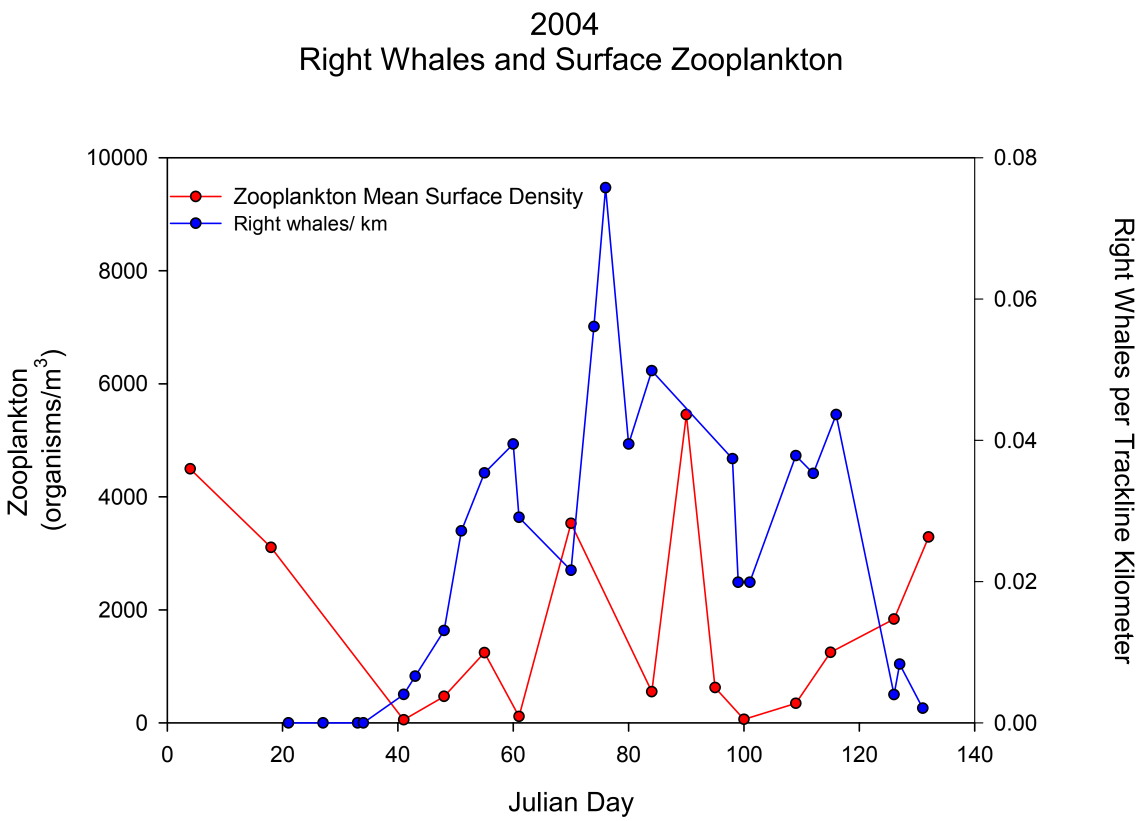
The late season, shown in the bi-weekly comparisons starting in early April 2004 (Figure 12), suggests other characteristics of the whales' response to the resource. As apparent in Figures 1 through 4, the late season period may give rise to high-density patches of zooplankton; however the plots of whale sightings are substantially less concentrated and not centered on the areas of high zooplankton density. During the late season it is likely that patches form and disperse depending upon the dynamics of the weather and circulation associated with the increasing thermocline. Thus, the scattered pattern of whales likely is indicative of a heterogeneous distribution of acceptable patches of decreasing size and quality coupled, aptly reflecting the behavioral context of whales responding to ever decreasing patch sizes and to the draw of other habitats where, later in the spring, rich resources are usually found. Absent a method to obtain a more detailed description of the resource, it will not be possible to identify the triggers that control the distribution of the whales during the last 2-3 weeks of their residency in Cape Cod Bay. A focus on the characteristics of the habitat before and after the whales' peak residency should be a central goal of habitat assessment and reporting in the future because more accurate prediction of the mechanisms of entry into and departure from the habitat will expose processes essential to better management of the Cape Cod Bay region.

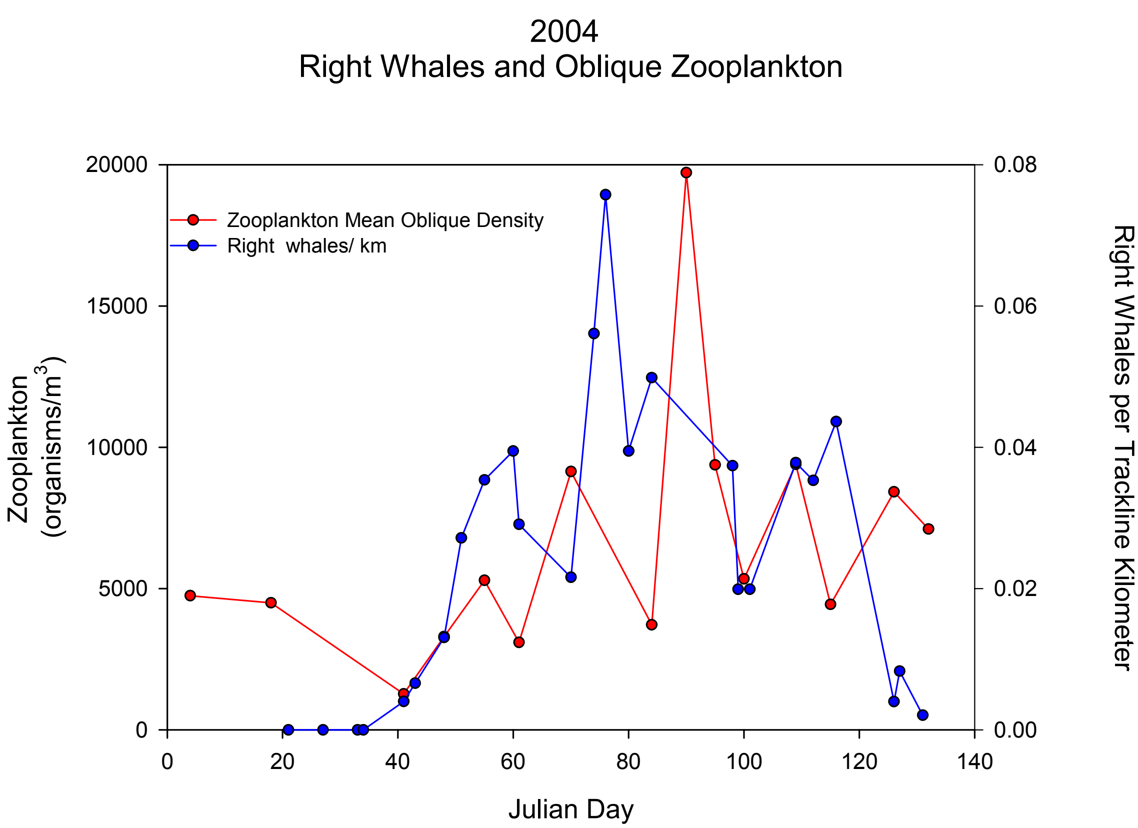
Seasonal Plots

To examine the more general patterns of zooplankton abundance and the related right whale occurrence, the right whale residency season was divided into three periods roughly corresponding to the peak abundance of the three most influential taxa, *Centropages spp*. (1 January through 13 February), *Pseudocalanus* complex (14 February through 28 March), and *Calanus finmarchicus* (29 March through 11 May). Comparisons of right whale sightings and zooplankton abundance contours divided into these 1/3 season, 44 day, segments (Figures 16 – 18) are presented to illuminate the larger patterns of the relationship between the variables over longer time scales. Conditions during the 2004 season are compared in Figure 19, associating the entire data set of oblique sampled zooplankton from the 8 stations, 124 samples in total, with the whale sightings of 2004.

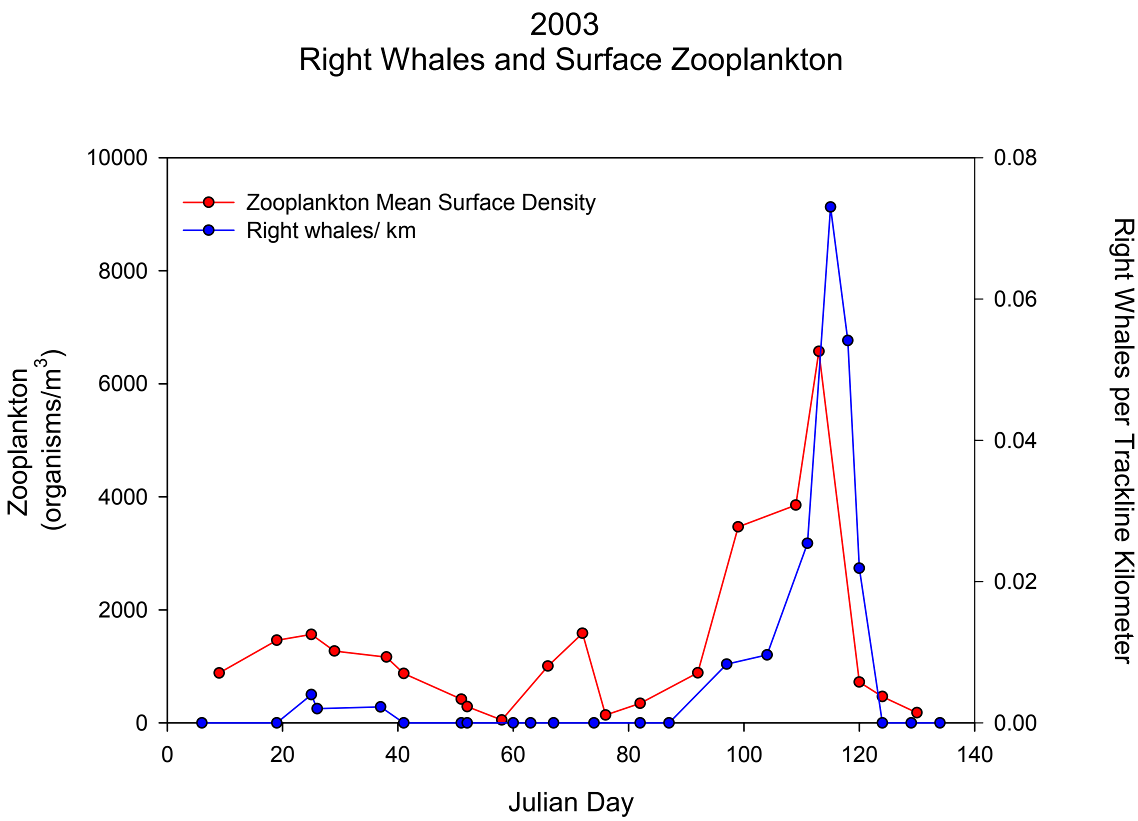
The one-third season comparisons describe the zooplankton distribution from approximately three times more data but do so at the expense of further disassociating in time the hypothesized cause of the whale distribution from the distribution pattern. These three comparisons do demonstrate substantial support for the hypothesized association while some of the caveats that control the interpretation of the association are even more important considerations than in the interpretations of the bi-weekly comparisons.

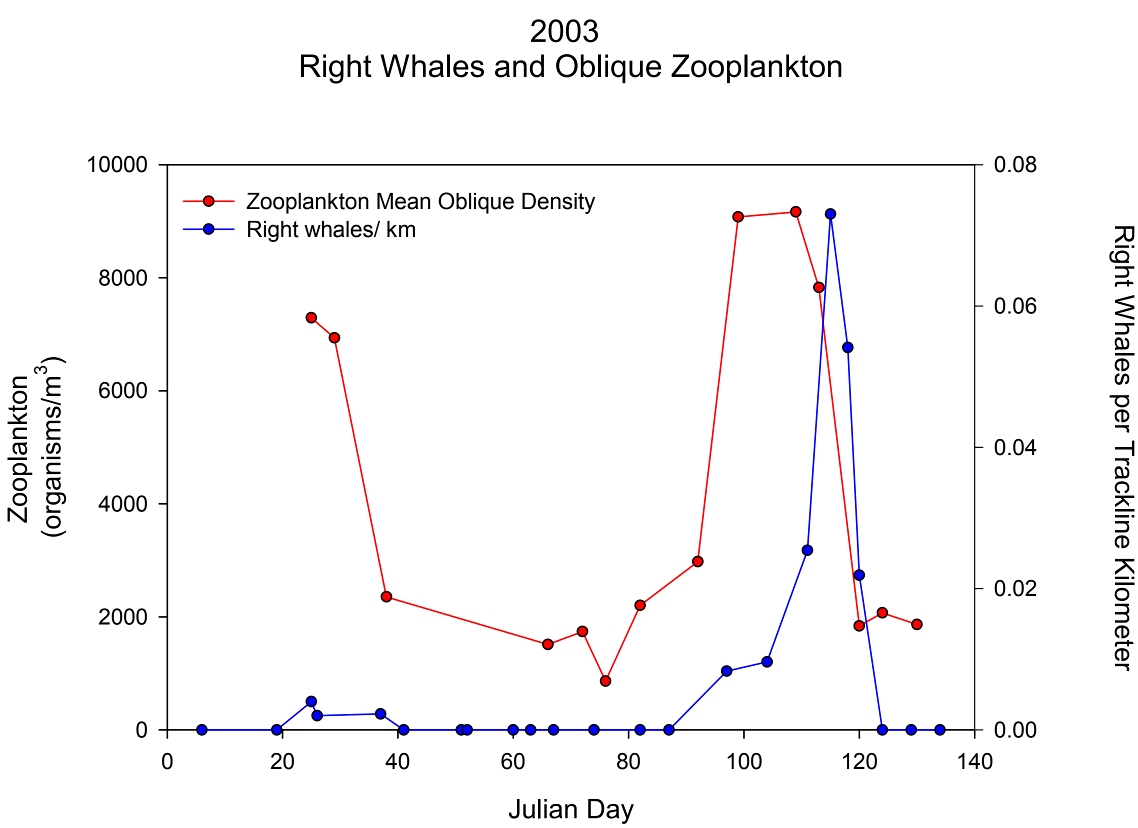
That said, the one-third season and whole season comparison plots demonstrate some important characteristics of the Cape Cod Bay Critical Habitat that doubtless control the distribution of whales and should influence the further development and responsiveness of management plans. In particular, the long-held view, supported by aircraft survey data, that right whales aggregate in the eastern half of the designated habitat fits well with the contoured zooplankton distribution, particularly during the middle part of the season (Figure 17). Additionally, the late season comparison plot (Figure 18) supports the observation that whale distribution when the whales are preparing to depart is less explained by the zooplankton contour plots than is the distribution during the middle portion of the residency season. As discussed above, this disconnect appears to be part of the general characteristics of the late season right whale residency pattern and probably reflects a change in the extent and continuity of the patches of zooplankton during the mid spring.





Figures 1 (top) and 2 (bottom). 2004 comparisons of right whales and plankton densities.





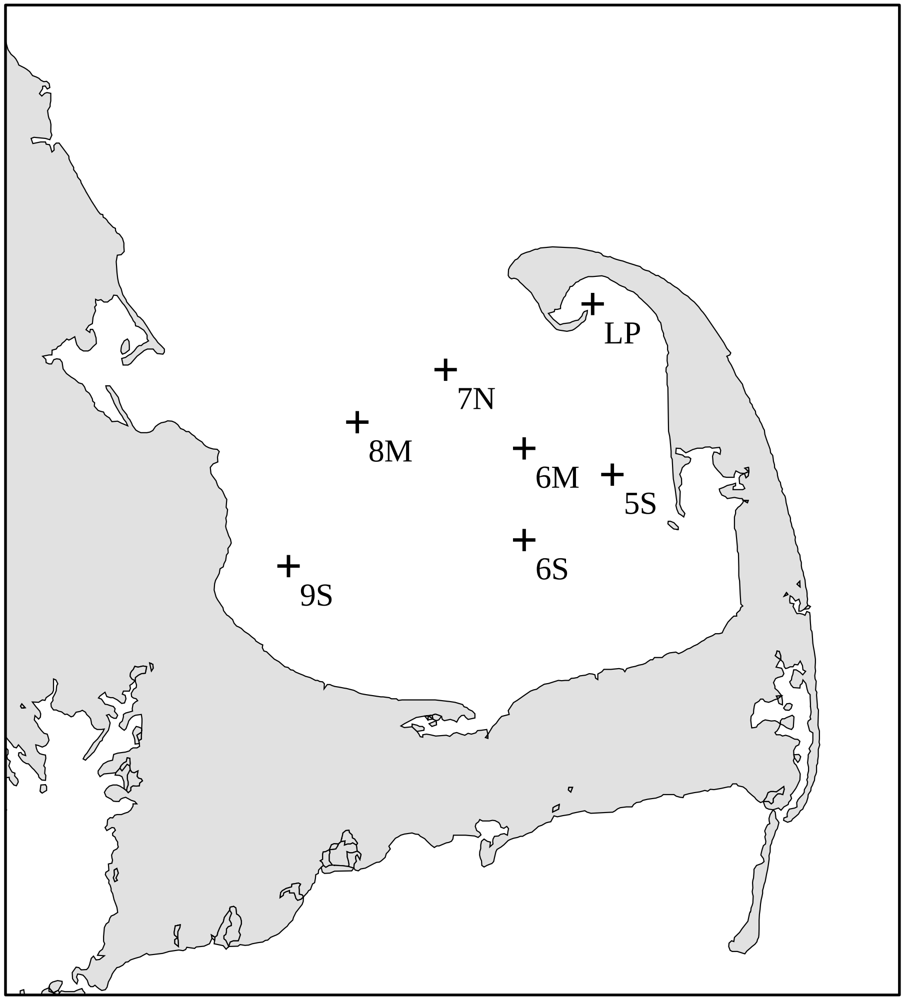
Figures 3 (top) and 4 (bottom). 2003 comparisons of right whales and plankton densities.

Station Legend for Figures 5 - 9 and 11 - 19

A. Seven fixed stations at which oblique zooplankton net tows were conducted during the two week period 1 through 14 January 2004.

B. Eight fixed stations at which oblique zooplankton net tows were conducted from 15 January through 15 May 2004.

A.



B.

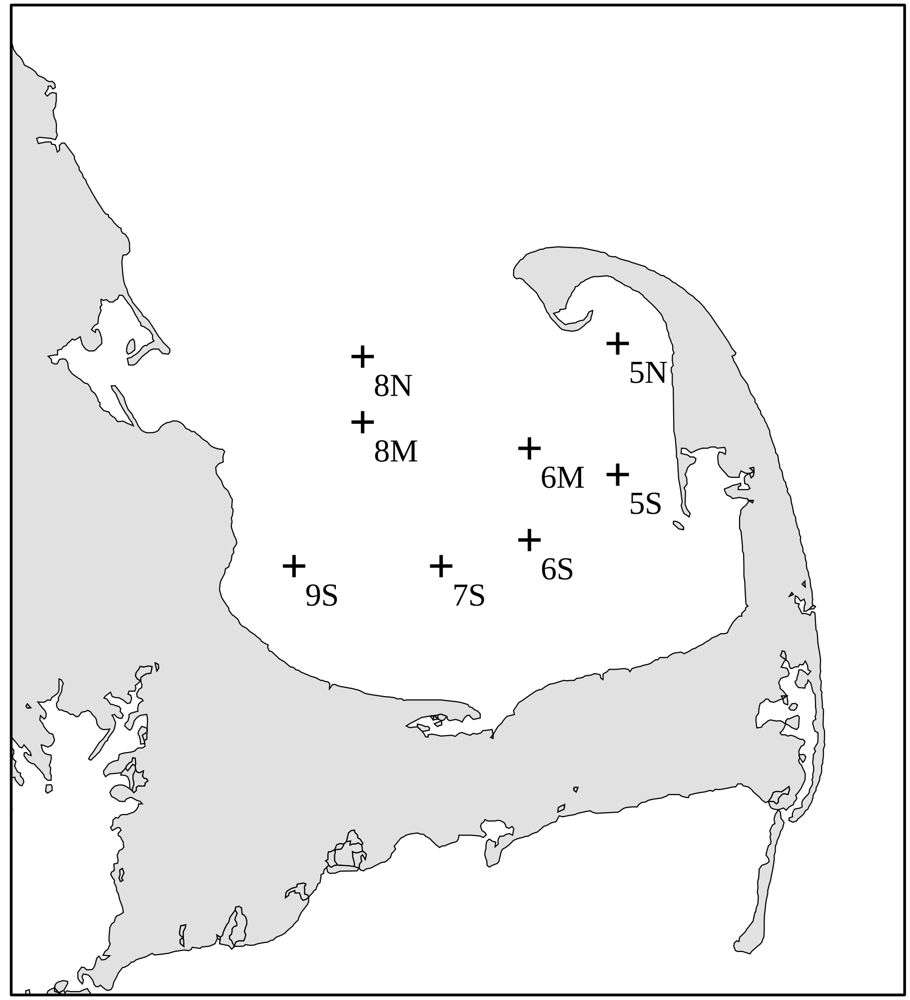
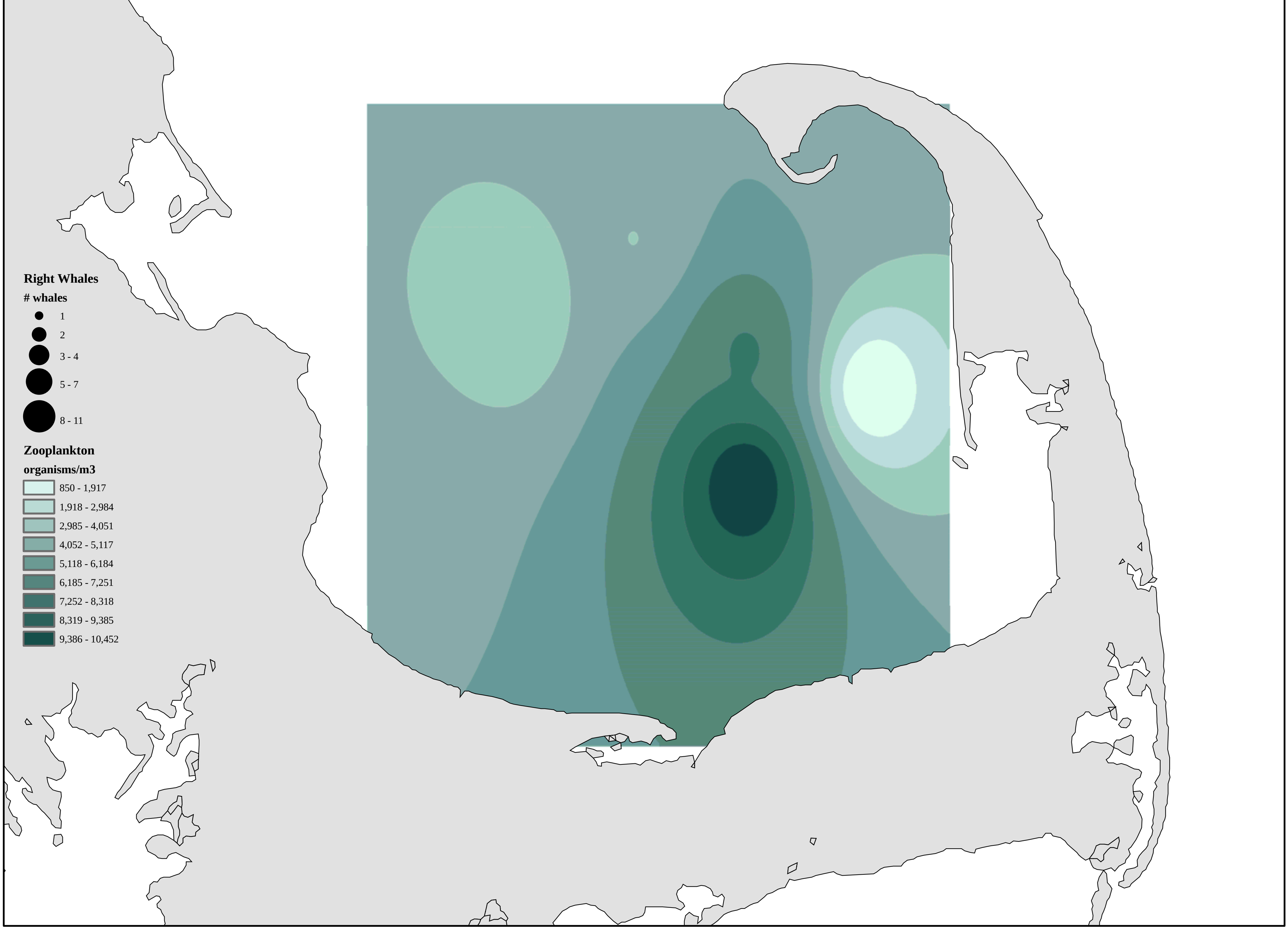


Figure 5. Contour plots of the distribution of zooplankton estimated from averaged oblique net tow data collected at 7 fixed stations in Cape Cod Bay and compared with right whale sightings from aircraft track surveys during the two week period 1 through 14 January 2004.



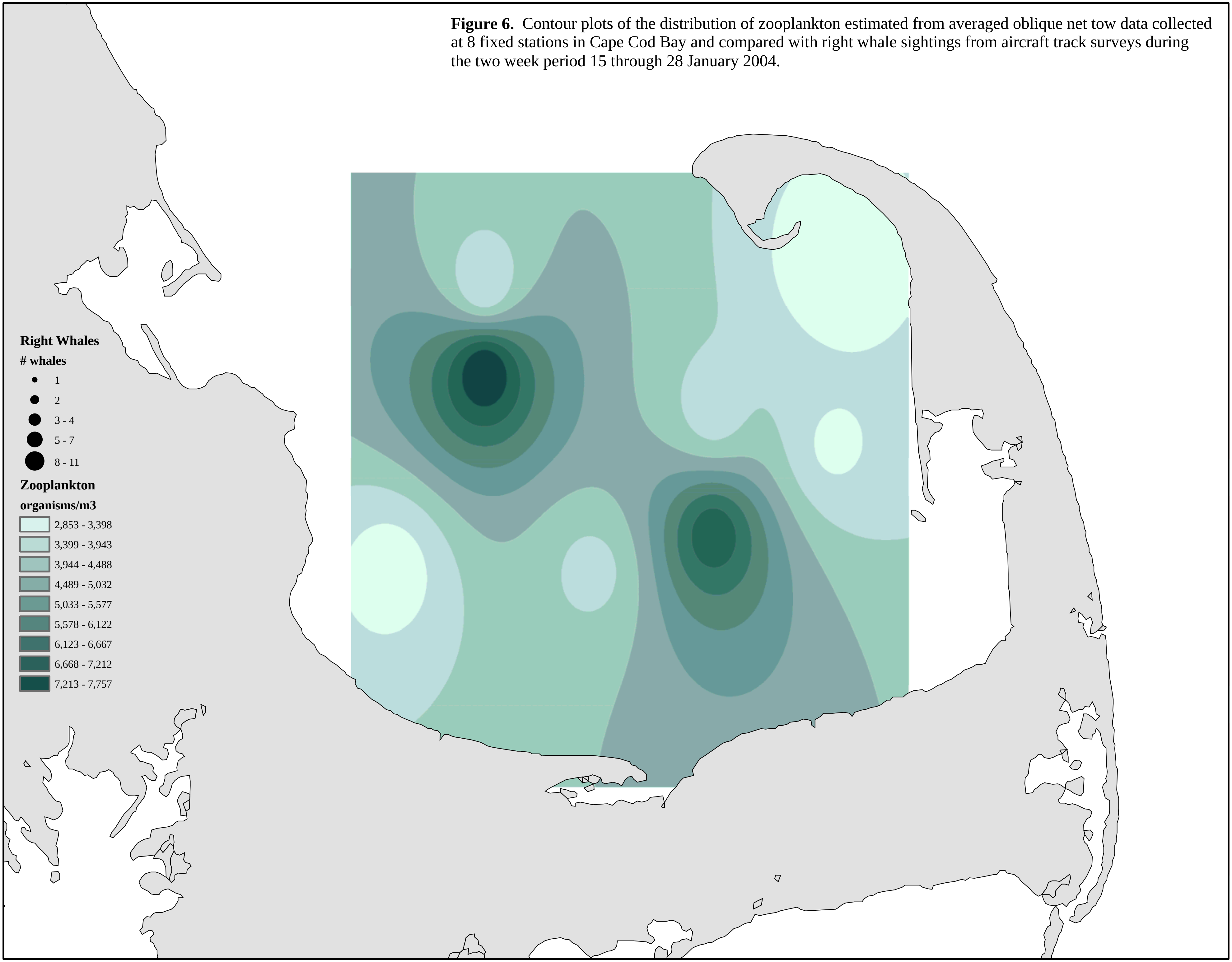
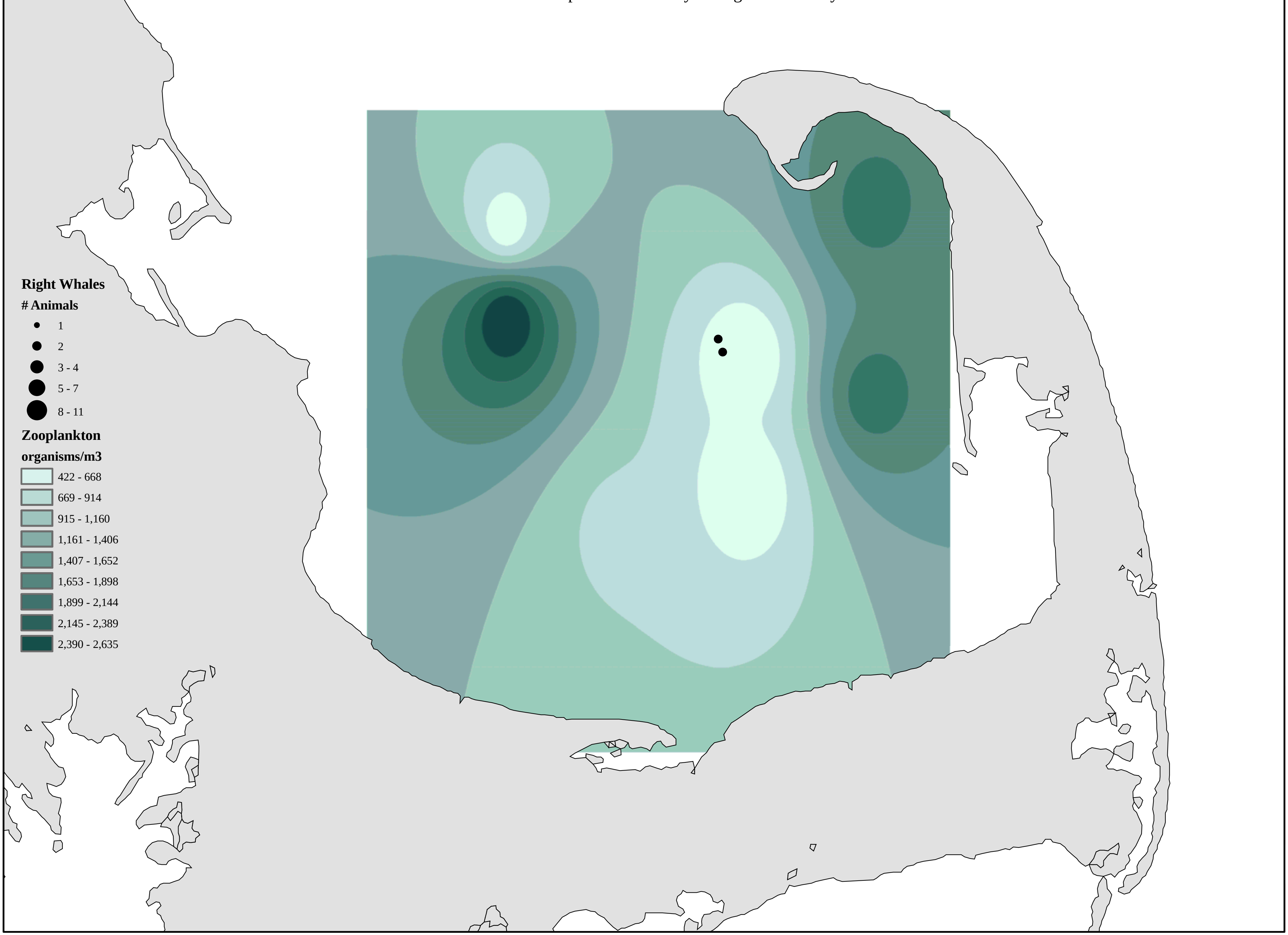


Figure 6. Contour plots of the distribution of zooplankton estimated from averaged oblique net tow data collected at 8 fixed stations in Cape Cod Bay and compared with right whale sightings from aircraft track surveys during the two week period 15 through 28 January 2004.

Figure 7. Contour plots of the distribution of zooplankton estimated from averaged oblique net tow data collected at 8 fixed stations in Cape Cod Bay and compared with right whale sightings from aircraft track surveys during the two week period 29 January through 11 February 2004.



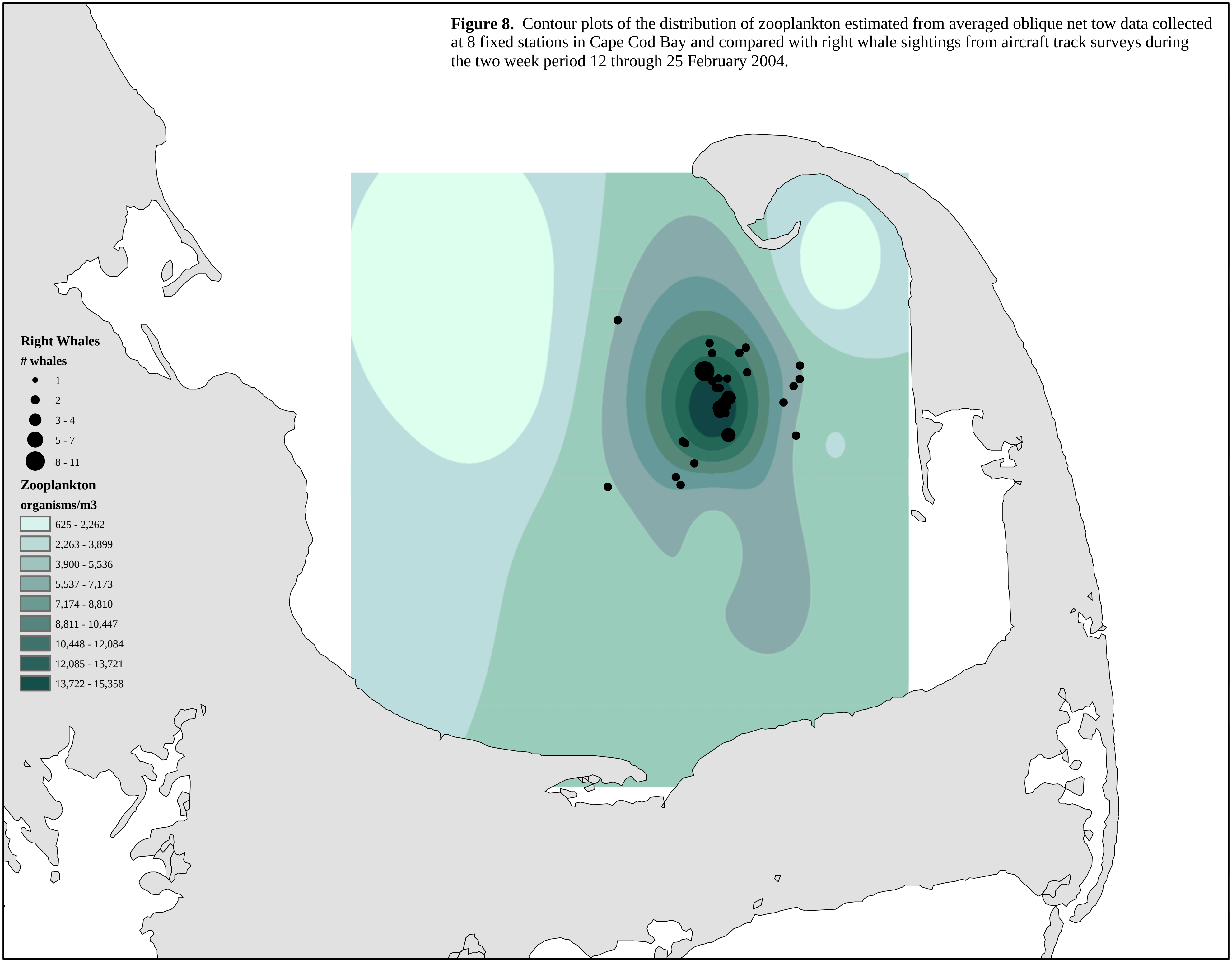


Figure 8. Contour plots of the distribution of zooplankton estimated from averaged oblique net tow data collected at 8 fixed stations in Cape Cod Bay and compared with right whale sightings from aircraft track surveys during the two week period 12 through 25 February 2004.

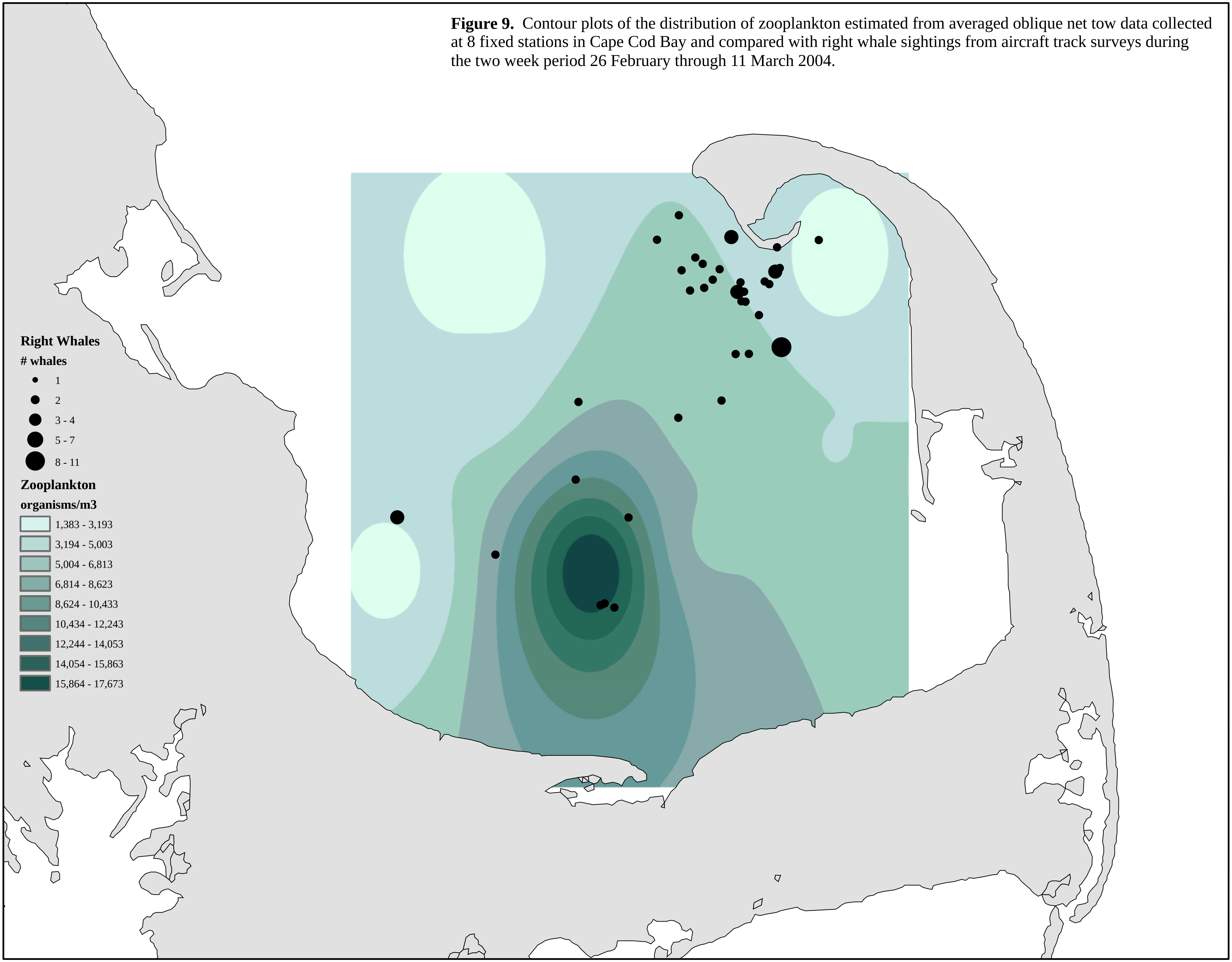


Figure 9. Contour plots of the distribution of zooplankton estimated from averaged oblique net tow data collected at 8 fixed stations in Cape Cod Bay and compared with right whale sightings from aircraft track surveys during the two week period 26 February through 11 March 2004.

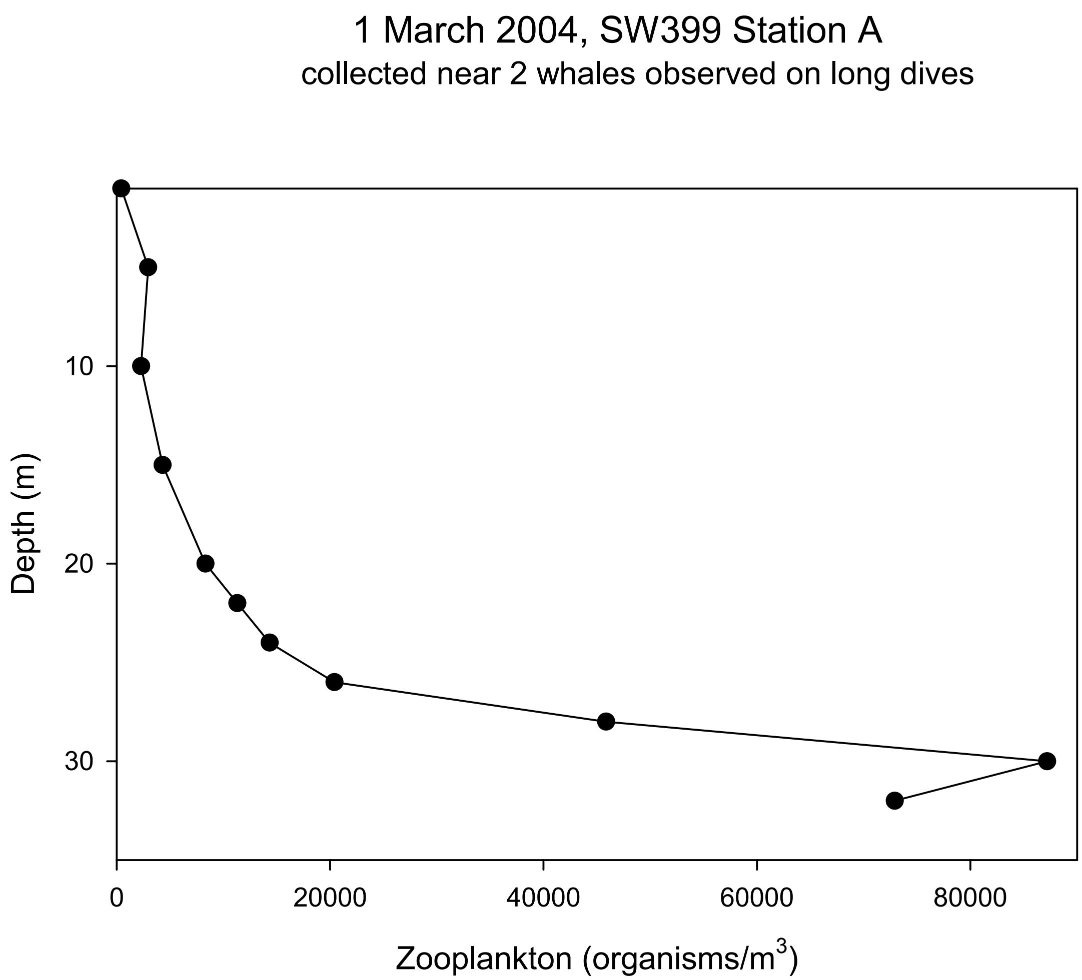


Figure 10. Vertical profile at Station A on 1 March 2004 (SW399).

Figure 11. Contour plots of the distribution of zooplankton estimated from averaged oblique net tow data collected at 8 fixed stations in Cape Cod Bay and compared with right whale sightings from aircraft track surveys during the two week period 12 through 25 March 2004.

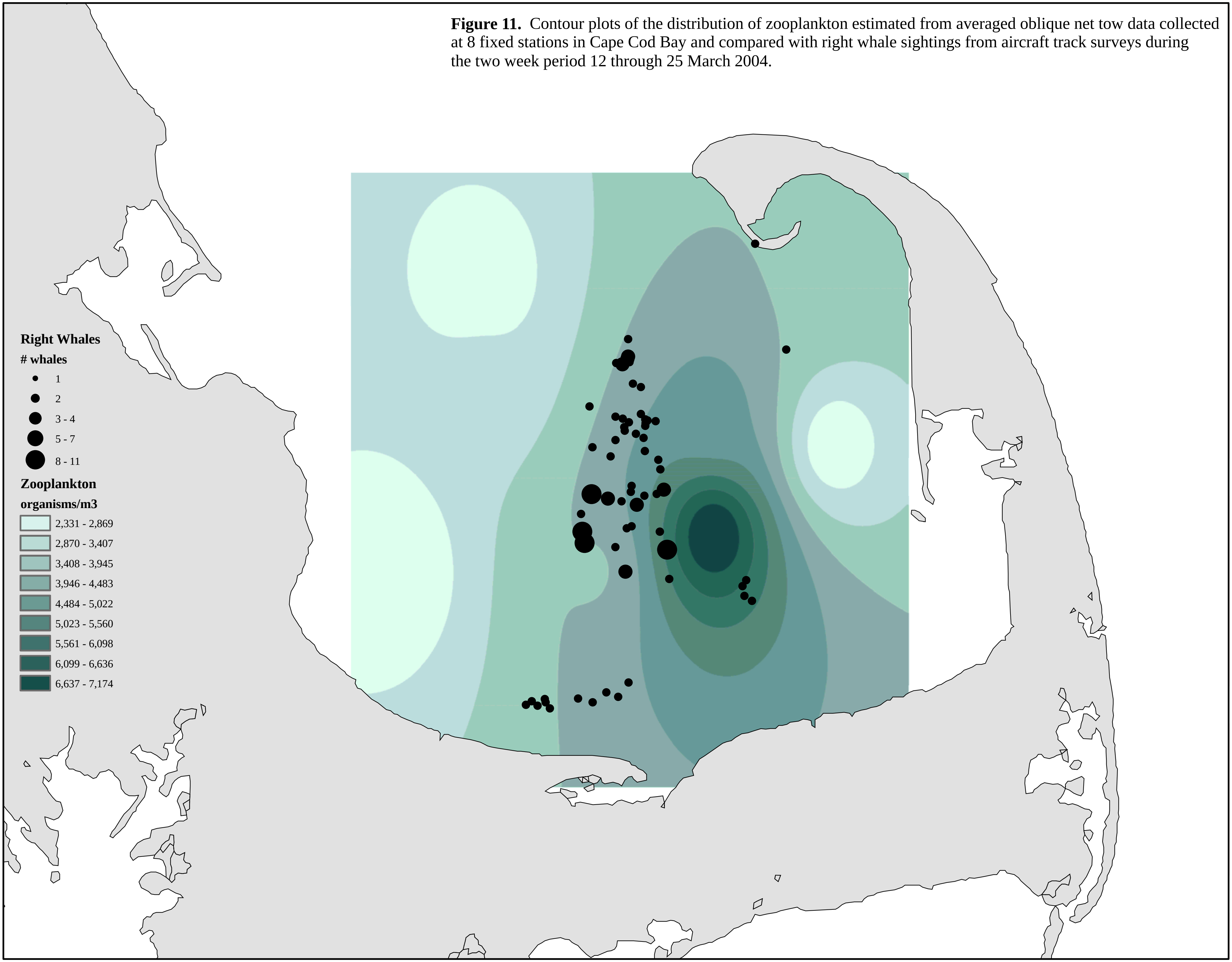


Figure 12. Contour plots of the distribution of zooplankton estimated from averaged oblique net tow data collected at 8 fixed stations in Cape Cod Bay and compared with right whale sightings from aircraft track surveys during the two week period 26 March through 8 April 2004.

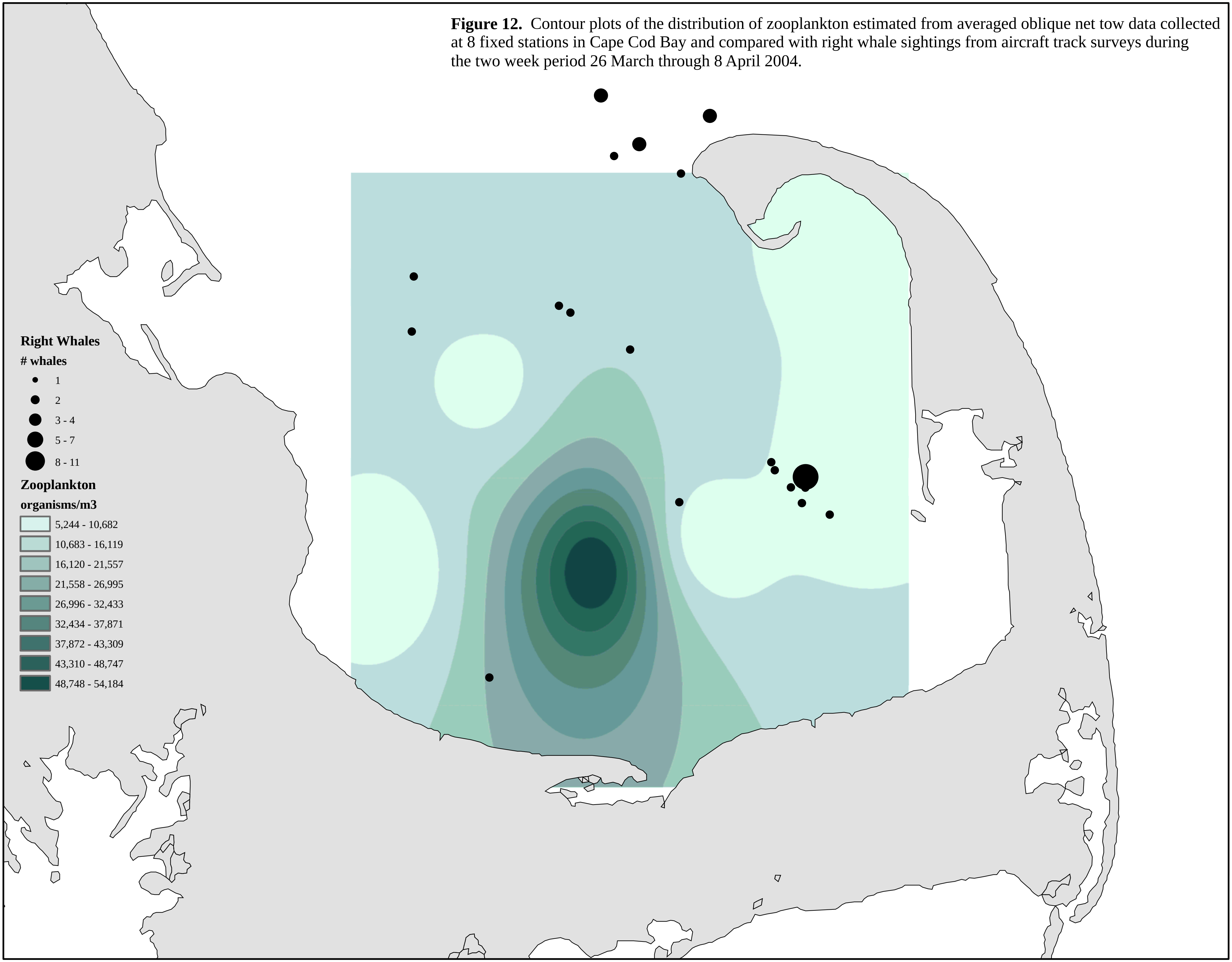


Figure 13. Contour plots of the distribution of zooplankton estimated from averaged oblique net tow data collected at 8 fixed stations in Cape Cod Bay and compared with right whale sightings from aircraft track surveys during the two week period 9 through 22 April 2004.

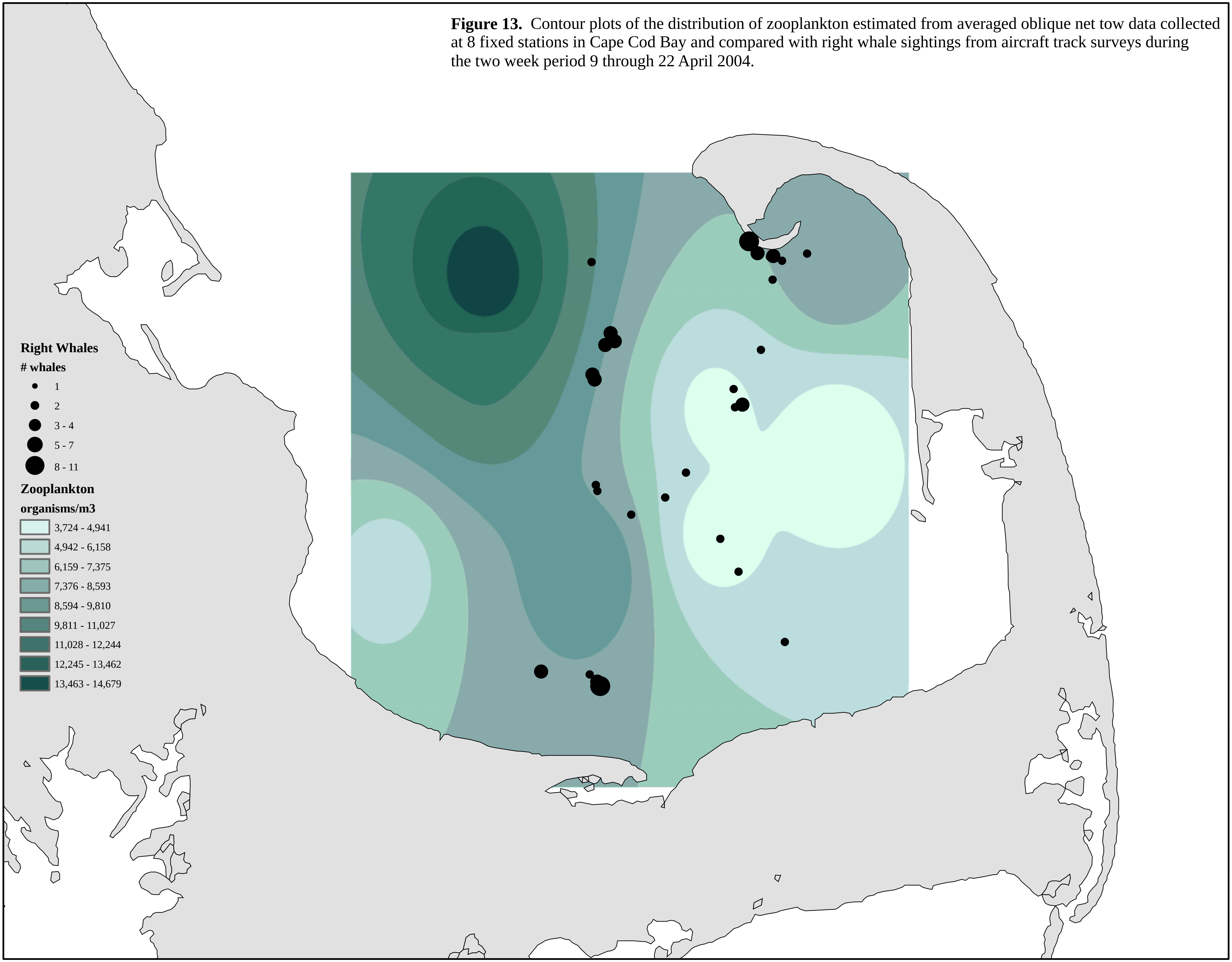


Figure 14. Contour plots of the distribution of zooplankton estimated from averaged oblique net tow data collected at 8 fixed stations in Cape Cod Bay and compared with right whale sightings from aircraft track surveys during the two week period 23 April through 6 May 2004.

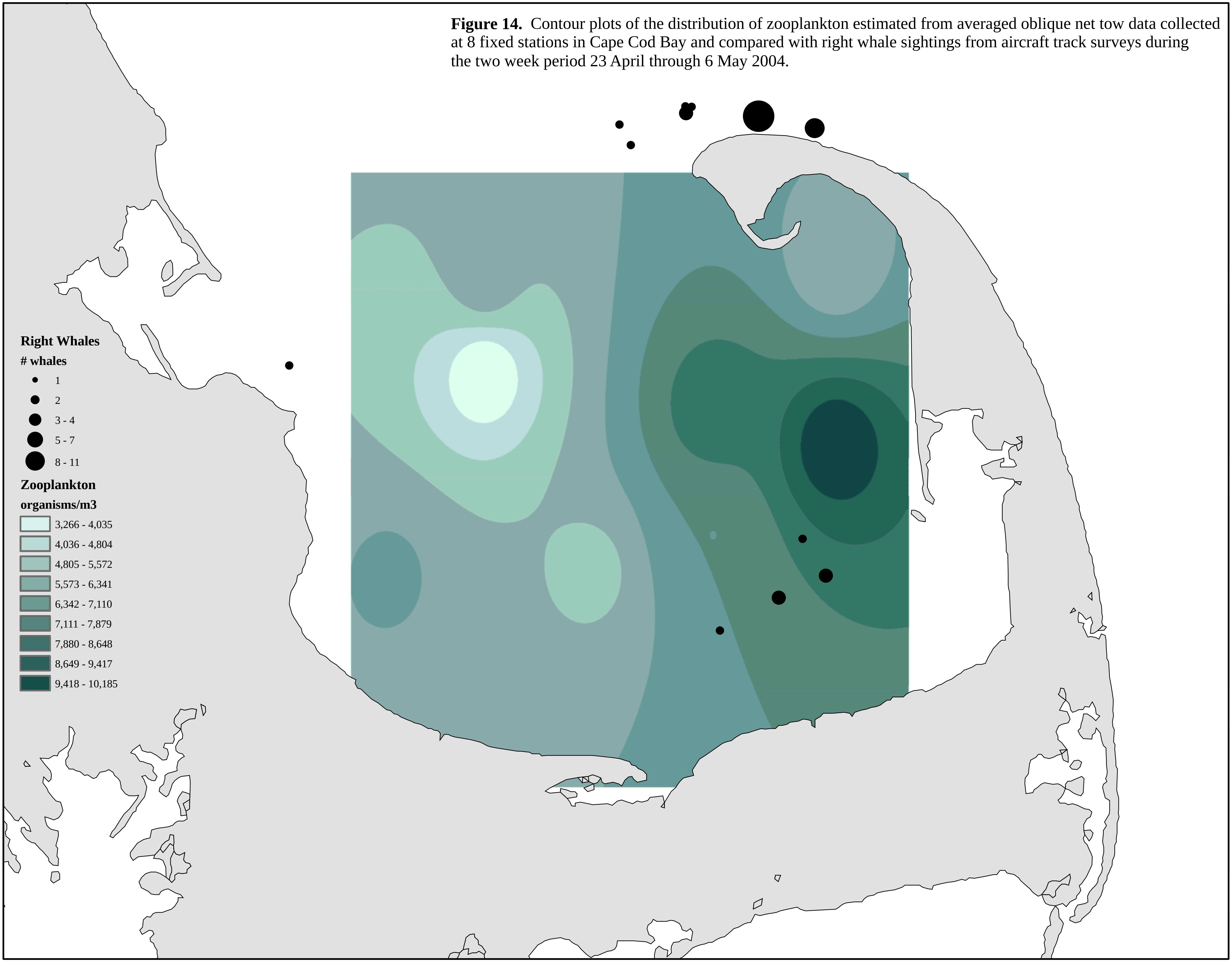
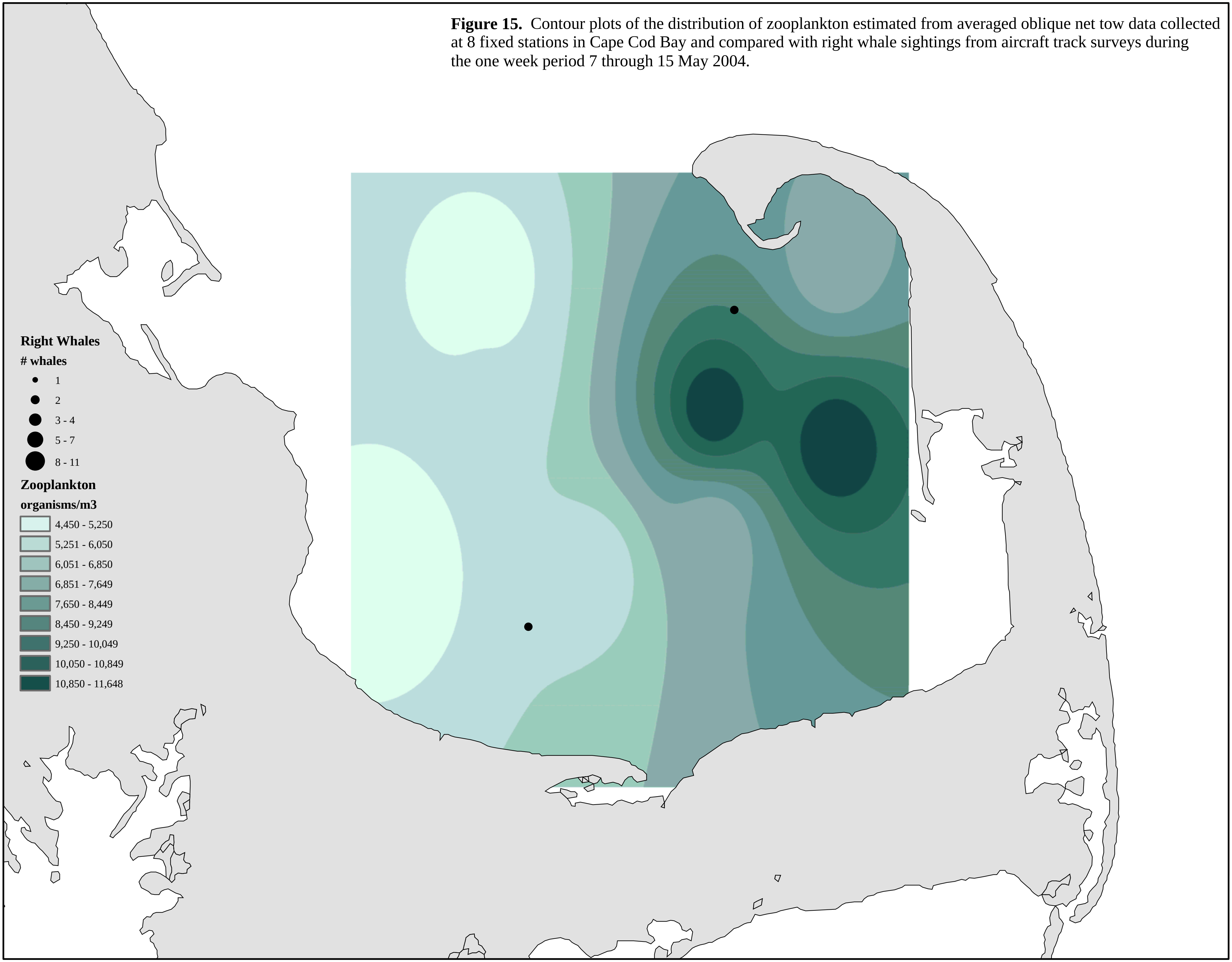


Figure 15. Contour plots of the distribution of zooplankton estimated from averaged oblique net tow data collected at 8 fixed stations in Cape Cod Bay and compared with right whale sightings from aircraft track surveys during the one week period 7 through 15 May 2004.



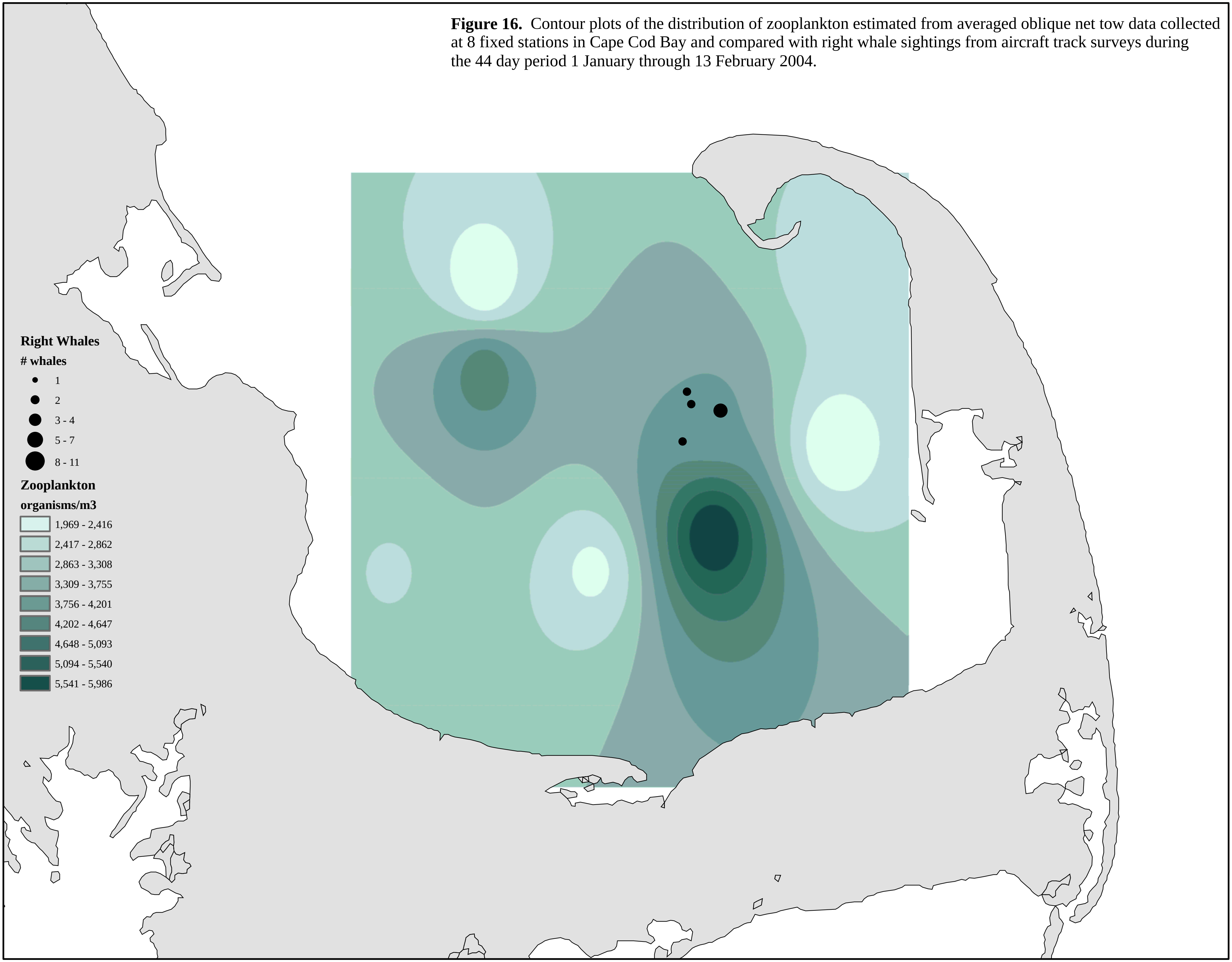
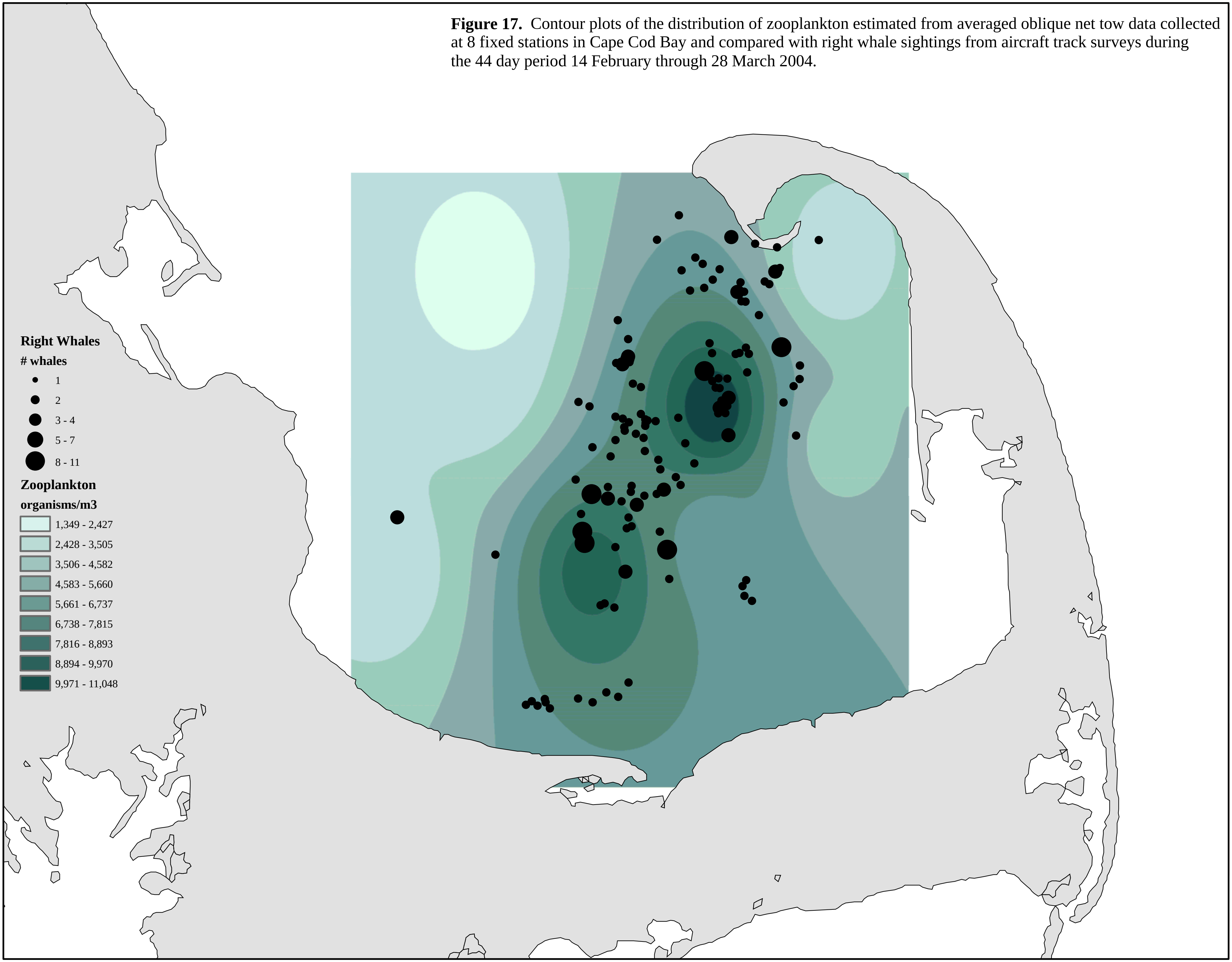


Figure 16. Contour plots of the distribution of zooplankton estimated from averaged oblique net tow data collected at 8 fixed stations in Cape Cod Bay and compared with right whale sightings from aircraft track surveys during the 44 day period 1 January through 13 February 2004.

Figure 17. Contour plots of the distribution of zooplankton estimated from averaged oblique net tow data collected at 8 fixed stations in Cape Cod Bay and compared with right whale sightings from aircraft track surveys during the 44 day period 14 February through 28 March 2004.



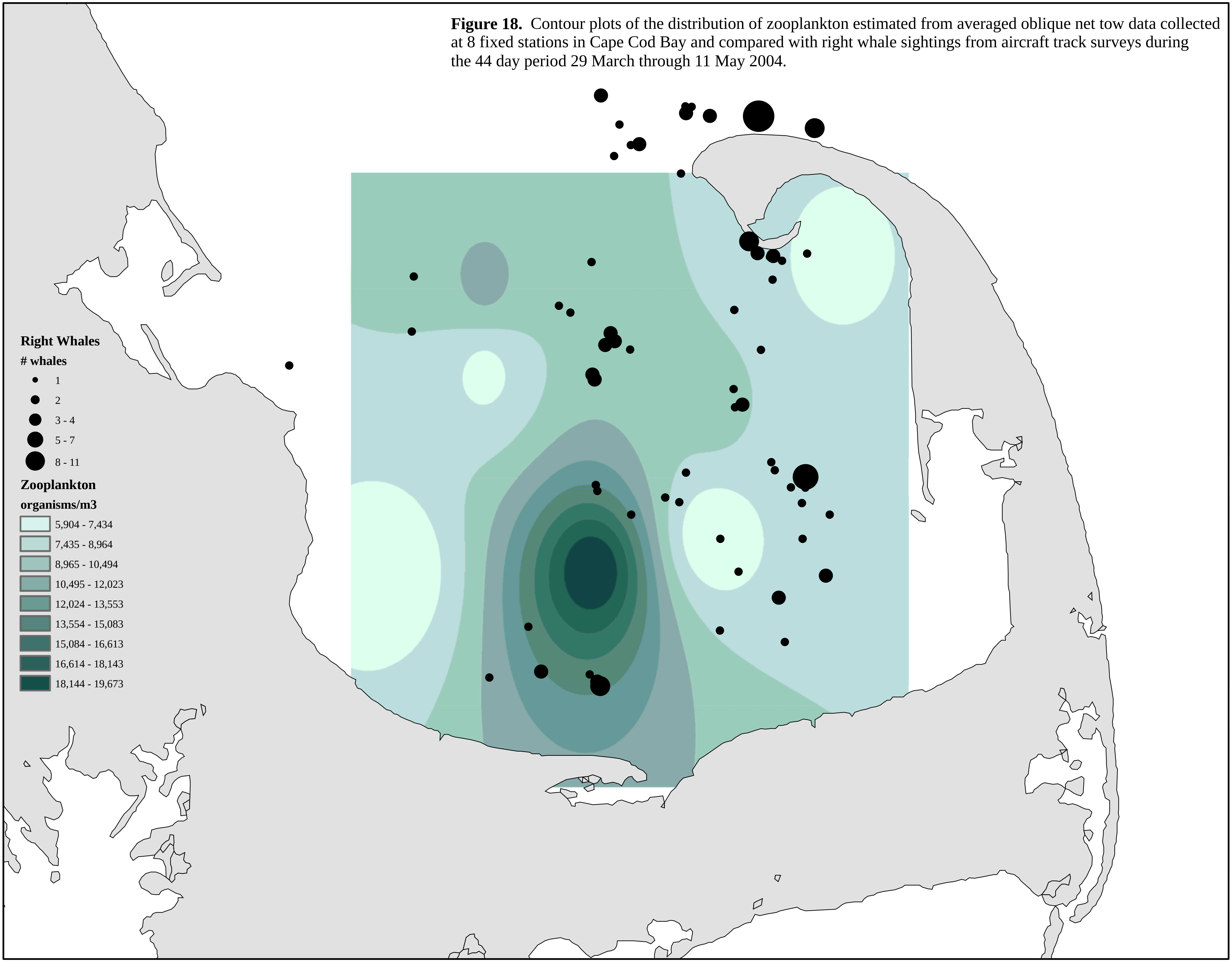
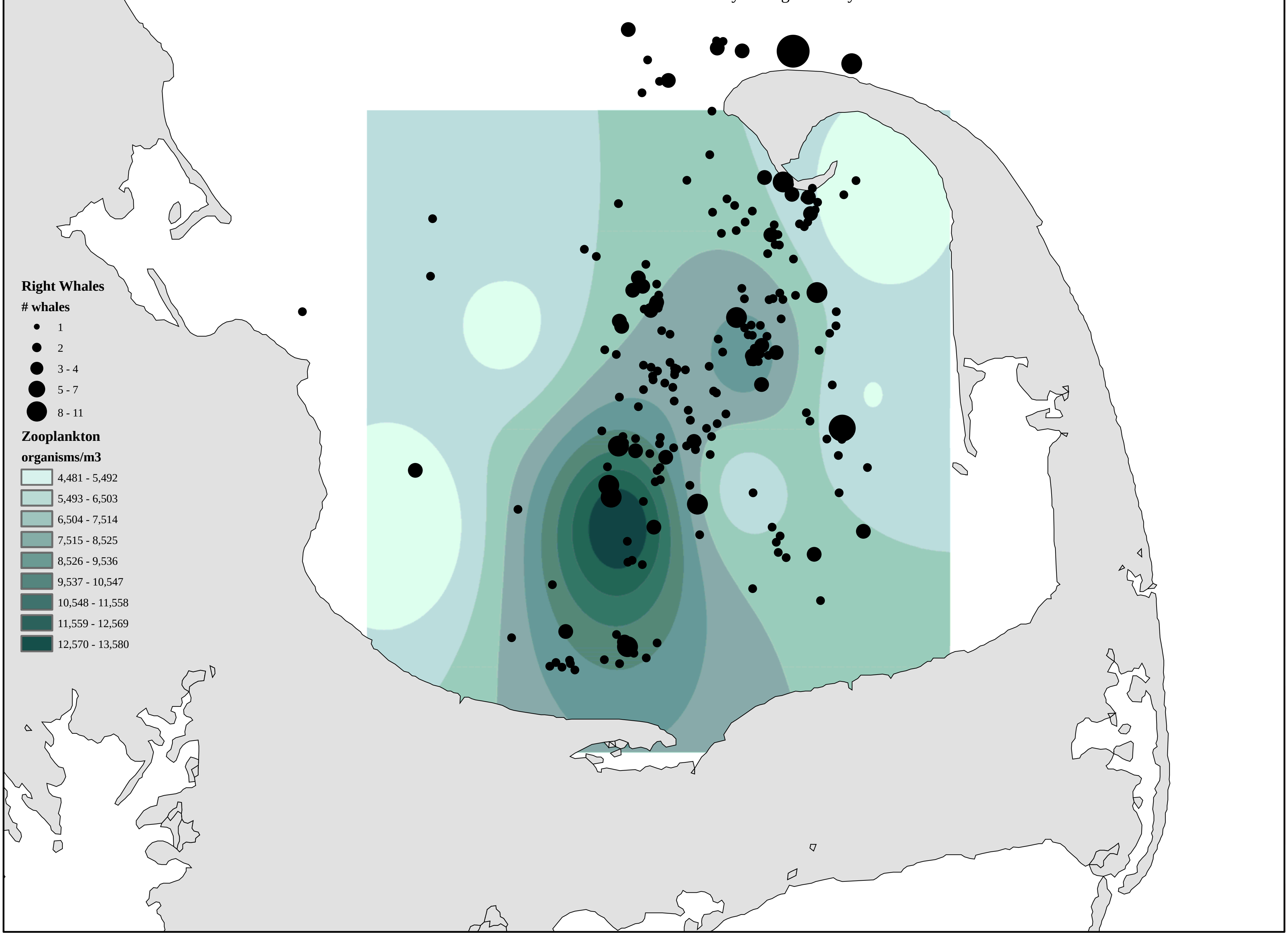


Figure 18. Contour plots of the distribution of zooplankton estimated from averaged oblique net tow data collected at 8 fixed stations in Cape Cod Bay and compared with right whale sightings from aircraft track surveys during the 44 day period 29 March through 11 May 2004.

Figure 19. Contour plots of the distribution of zooplankton estimated from averaged oblique net tow data collected at 8 fixed stations in Cape Cod Bay and compared with right whale sightings from aircraft track surveys during the 2004 winter season from 1 January through 15 May 2004.



SECTION 4: PROPOSED EXPANSION AND MODIFICATION OF CAPE COD BAY SURVEILLANCE STUDIES

Introduction

Efforts to develop a management paradigm for the Cape Cod Bay Right Whale Critical Habitat have evolved from early efforts to locate whales and describe the general condition of the food resource to a rapid reporting system replete with efforts to predict the presence and location of whales based on the distribution of the controlling food resource. The foregoing 2004 report is an example of the most advanced management reporting program undertaken in any of the known right whale habitats, incorporating a dense track aerial survey, description of the habitat using rapid reporting techniques, and the presentation with wide dissemination of an assessment document that inform both the managers at the Division of Marine Fisheries (DMF) and the conservation and research community of the findings and assessment of the Center for Coastal Studies (CCS) surveillance team. In this section of the 2004 report we outline efforts to further advance methods of the collection, interpretation, and dissemination of the management – based studies of Cape Cod Bay for 2005. Below are simple descriptions of the proposed plans for 2005 including some innovative uses of data, the application of advanced assessment tools, and the deepening of the assessment reporting instrument.

Synoptic Studies Using Steerable Multi-Sensor Towed Device

The assessment reporting system presented in Section 2, Appendix 2 is based upon the collection and detailing of the zooplankton resource at 8 fixed stations sampled on each research cruise (2 each in the four reported quadrants of the bay). While this method for analysis offers an opportunity to describe in detail the controlling zooplankton resource, the lack of a synoptic collection technique has hampered our ability to assess the system in the detail and with the range that is needed to produce a detailed prediction instrument. In response to the need for a much more accurate and rich source of physical and biological data, the DMF purchased a steerable towed vehicle (Acrobat device from Sea Sciences) while CCS provided the communication/tow cable and CTD. As part of the sensor and recovery package, an Optical Plankton Counter (OPC 2T from Focal Technologies) and a low frequency pinger (Underwater Acoustic beacon, RJE International) were purchased by DMF. The package of sensors and associated equipment has been tested in the laboratory and will be deployed during the 2005 season.

The following strategies are used for the analysis and dissemination of what is expected to be a substantial data flow is proposed:

I. The sensor package will be deployed during early January to test required communication and data acquisition processes and hardware.
   a. Organization and coupling of the two computers needed to run and acquire data will be tested
   b. Coupling between the multiplexed data from the GPS and associated vessel sensors will be established

c. Rates of data acquisition will be established
d. Techniques for directing the Acrobat will be developed

II. Working with DMF (Lyman) and CCS research assistant (Osterberg, a new temporary hire with extensive OPC and CTD experience), CCS will develop analytical methods for dealing with the data flow and putting the results into the assessment reports to DMF.

Revision of Assessment Forms

The assessment forms will be revised during the 2005 season to incorporate a more detailed expression of the right whale distribution patterns demonstrating the observed areas of aggregation overlaying zooplankton distribution plots from contemporaneous sampling. Additionally, we anticipate incorporating the near-real time observations from the Cornell listening stations in collaboration with Dr. Clark at the Cornell Laboratory of Ornithology as agreed upon with the CLO principal investigator. We will be working to combine these data elements to make the management documents that have formed the foundation of the assessment of the habitat to date more robust and useful to DMF. All elements of the management assessment forms that are sent to our colleagues and to DMF will be attributed to P.I.s and managed by Mayo and Bessinger.

Development of a Mathematical and Graphics Model of Right Whale Habitat Use

The observations of the past 4 years of work in Cape Cod Bay have demonstrated the value of linking habitat quality, particularly food resource distribution and abundance, with whale distribution. The further intermixing of resource assessment with acoustic and aircraft monitoring will offer a deeper, multi-disciplinary product to the management agency and approaches the goal of accurately monitoring and predicting the presence of right whales. Indeed, Cape Cod Bay is also a natural laboratory for testing the surveillance paradigm that has evolved. The combination of the most concentrated habitat, acoustic, and aircraft survey in the study of rare cetaceans with the responsiveness of an active management agency demonstrates management techniques that elsewhere would be impossible.

The surveillance program of the past years has revealed the value of the use of food resources to predict the distribution and behavior of whales. That said, as the foregoing report and assessment forms demonstrate, many influential variables are not easily accounted for in the text assessments and predictions that accompany the habitat assessment forms. Two such missing elements that clearly will have influence on the arrival and departure of whales from the Critical Habitat are competition between enriched and adjacent habitats and the influence of long-term memory on departure times. The foregoing report advances the idea that while the departure from Cape Cod Bay in 2003 was due to declining zooplankton resources, in 2004 an unusually rich late season *Calanus finmarchicus* resource coupled with the departure of the whales while the resource was high suggested that other variables may influence the whales in ways that must be understood if late-season occurrence patterns are to be predicted. With this need in mind we propose to begin the development of a numeric/graphic model populated with elements that are generally accounted for in the interpretation and prediction presented in past assessment forms but with added variables that are known to influence other large grazing mammals.

Rationale for the Proposed General Model of Right Whale Foraging

The proposed model will seek to address the questions: where are the whales? what controls their distributional activities? and what is the condition of the habitats on which they depend? The model will provide the underpinnings of information on the energetics of the species with particular application to studies of the health and the reproductive success of the whales

The Whale and Foraging

The largest of the true plankton feeding whales, over millennia the right whale has developed a highly specialized method for finding and consuming a rich planktonic food resource that is notoriously variable and difficult to harvest. The right whale is a true grazer, feeding for hours on end with mouth widely gaped, sieving macroscopic food organisms from the water. It is this grazing behavior that the model will seek to replicate.

There is good reason to believe that the movement and distribution of the right whale through much of the year is wholly influenced by the distribution of the patches of food that it feeds upon. Thus, as happens with grazers, the whale and its food are inexorably bound to one another. Simply defined, the relationship is framed by the development of patches of plankton, driven by physical and biological processes within the sea, and the responses of the whales to those patches. The movement of whales is therefore dependant upon the food, as in most animals, but the unusual and ephemeral nature of the food resource adds a special set of conditions at many scales that lead to aggregations of whales in places where patches of food are concentrated.

The General Model

The proposed model is both data-rich and graphical and is intended to demonstrate the movements and consequence of movement (in the form of distribution and occurrence patterns) of a whale through a locale where food patches are of certain qualities which the user would define based on empirical data (thus linking the model predictions and output directly to the Cape Cod Bay Critical Habitat). The whole model will recognize that physical and biological processes shape the resource (Fig.1) but for the first iteration of the model the user will set the parameters of the resources rather than develop them from the modeled physical processes of the bay. Initial focus will be on “constructing the whale algorithm” such that it will react according to empirically derived rules to the resource conditions presented to it. The conceptual model in Figure 2 focuses on the general characteristics of the whale itself, and in this first iteration pays little attention to the demands for energy and to the input from bio/oceanographic models that “create” the food resource.

The Plankton Food

The graphic portion of the model will be a simple expression of an underlying mathematical/probability algorithm that will generate the essential elements of the output. The zooplankton patches will, in the first iteration be structured according to these general characteristics:

- The operator will "create" a distribution of the patches of food made up of cells (pixels in the graphic form) that will represent 1 meter^2 of sea surface, a cell structure with each cell having a specific density of food, the value that the whale will pass through and sample and on which the activity of the whale, its decision-making, will be principally based. In the graphic form the screen will be filled with cells each with a value. The plankton field thus constructed will be "shaped" so that the distribution of the cells will create from groupings of cells a heterogeneous distribution of plankton, with areas perhaps 5-100 meters long and in loosely geometric shapes with varying densities of plankton. These aggregations of higher density cells in geometric shapes are the patches through which the whale algorithm will forage.
- In later iterations of the model, an oceanographic sub-model will "shape" a homogeneous plankton resource by exerting physical and biological pressures on it to form a heterogeneous cellular matrix of micro patches, and from them patches that will be fed upon by whale algorithms.
- The patch quality, the density of the food, along the path where whales were feeding, will be made to decline in density after the whale passes – this is a graze-down factor and will be presented in some "data out" format.

The "food" harvested from the patches will end up consumed by the whale and thus maintain the fundamental synergy between the whale and the food that underpins the foraging decisions that result in observed occurrence and distribution patterns.

The Whale

The whale algorithm will be imbued with a number of qualities or rules related to spatial decision-making that are derived or modified from empirical data and observation. Some rules are geometric, foraging path characteristics (e.g., how much angularity there is in the whale's movement or how far along a path encompassing poor quality food cells at the edge of a patch does a whale swim before turning). Other presently poorly defined rules will be estimated from terrestrial mammal studies in early iterations of the model (e.g., memory's role in decision- making, or the sensory mechanisms that govern the whale's foraging).

Generally, the work with DMF has produced pertinent data to put into the whale portion of the model and the building of the first order algorithm is within reach. Two aspects of the model development will require particular attention:

- Several of the activities of whales are best described by application of probability analysis (e.g., the angularity of movement that defines the aggregations). For example, whales we know zig zag much more when feeding than when searching and while the angularity of the movement per 10 meters of path may be a mean of +25 degrees to -25 degrees from the present course when encountering food cells of a certain density, the actual angle of the path changes according to a probability relationship set around the mean. Thus, in this example, the whale must act based on some probability of angularity. Development of a method for dealing with these probability considerations will be essential in developing the predictive output that will be precise enough to assist managers in their decisions.

- There are many scale considerations but the one we propose to model is the smallest scale, the building block of the larger distributional structures that arise from the additive effect of food density fields on the distribution patterns of the whales.

<u>Output</u>

We propose that the output of the model contain:

- Input variables, the density of plankton in the cell in which the whale is located and the whale's angularity of movement, along with other behavior of the whale including food-capture rates and total consumption.
- The results of the run should be savable and replayable.
- A summation of a run of the model should include the qualities and rules that whale algorithm used for the run and data summing the results of the run: food intake, kilometers covered, means of such things as time feeding, mean quality of the zooplankton in the environment.
- Output of final or on the fly distribution patterns of whales that can be used by managers should be exportable to GIS applications.

<u>Later Evolution of the Model</u>

- The model should be able to accommodate 10's of whales all acting based on different characteristics of variables (e.g. demographic characteristics).
- The model should be scalable so that the numeric matrix and the whales can be placed to swim in the Gulf of Maine, 350 whales and an ecosystem 450 km long and 200 km wide.
- The managers of marine areas need to know that whales might be present in areas of intense shipping and fishing, therefore development at all stages should be focused on scaling and prediction.
- An advective component should be added to any simple bio/physical patch-creating model so that the patches made will naturally enrich or disperse over short time scales according to data from field studies.

<u>Model Variables</u>

These variables are set before run by entry in response to queries in an opening window.

The conventions:

- *subscript* identifies the variable group
- *superscript* identifies details of the variable
- *CAPS* generally identifies a variable that is fixed or uniform for the run
- *lower case* identifies a dynamic dependant variable that varies by input or evolves

- *p* indicates a probability function

Scale note: the smallest scale is one pixel = 1 m^2, other scales are expanded by addition to create larger environments and scales from the smallest.

<u>Input Variable Sets</u>
Zooplankton: a pixel at the smallest or base scale is equal to 1 m^2 of sea water containing zooplankton and imbued with characteristics set by the variables:

$_z b^D$ = background environment density
$_z P^L$ = patch low density boundary (start quality influenced by graze down/ and a combo of $_z D^R$ and $_z E^R$
$_z P^X$ = patch high density boundary
$_z D^R$ = zooplankton dispersion rate
$_z E^R$ = zooplankton patch enrichment rate (= background depletion rate)
$_z K^f$ = Kcal transform factor

Environment: the cells above are distributed in an environment of 1 km^2 or multiplication of 1 km^2

$_e S$ = environment size
$_e R$ = environment resolution
$_e T$ = environment timer (seconds/count)
$_e D$ = date (mm/dd)
$_e L$ = location of the environment (e.g., areas where whales are known to aggregate: BoF/CCB/Roseway/NE Peak/Jeffereys/GSC/SEUS/unknown offshore)

Whale: The whale algorithm is parameterized in at the base scale – at enlarged scales each whale will receive parameters, some of which will be assigned from the right whale catalogue of individual whales. Since nearly all whales of the western North Atlantic are known and their gross distribution and movements have been described along with age and demographic class, it will be possible in later iterations of the model to individualize each modeled whale. To be used as a management tool, the larger N Atlantic model will be built from the modules made of the smallest scale.

$_w f^{yn}$ = feeding (mouth open or closed)
$_w a^f$ = path angularity mouth opened (feeding/not feeding) *p*
$_w m^f$ = memory force (multi scale)
$_w I^t$ = bio-imperative tension
$_w S^d$ = sensory distance (6 scales: extra long [100 km] to micro [1m]
$_w s^t$ = sensory tension (each scale receives a degree of force/tension0
$_w T^s$ = satiation
$_w E^d$ = energy demand from energetics model
$_w D^g$ = demographic group
$_w A^a$ = intra area time tension *p*
$_w v^f$ = velocity *p*

${}_{w}F^{f}$ = filtration factor %
${}_{w}B^{f}$ = acoustic far field sensory
${}_{w}E^{n}$ = error factor

Model Output Polling

I. LEGEND DISPLAY: explaining colors and scale

II. SET VARIABLE VALUES: the above set variables, zooplankton, environment, and whale, used in the run

III. OUTPUT VARIABLES at time of polling the model
T = time/date
d = path distance Since Model Start (SMS)
p = particles captured SMS
k = Kcal captured SMS
c = current behaviour feeding/socializing/searching
% = percent satiation

IV. GRAPHS: vs. time or distance SMS of above output variables
L=latitude/longitude of whale
E=zooplankton cell encounter rate by kcal density
P=particles captured
C=caloric capture
B=graphic display of behaviours
A=angularity of path

V. DISTRIBUTION OUTPUT: at model stop or on the fly a static display in GIS of the distribution of the whales

Model Processes
For clarity we propose we call the actual scales in time and space of a whale feeding "RW" for "real world", the conditions being modeled; MW = modeled world, the machine time and space world; NMW = numeric/process world (the numeric foundation of the model); GMW = the graphics output of the NMW.

Scales
The scales of the MW develop around the base scale, the smallest scale, the graphic building block of 1.28x1.02 km for the GMW environment (the NMW is not bounded) with a time scale for each refresh or "polling" of both NMW and GMW of 1 second in the RW (at this small scale obviously the time of the MW and the RW are the same). We propose that the time and spatial sales NOT be linked.

The proposed spatial scales are:
1: 1.28 X 1.02 km. (patch scale)

2: 12.8 X 10.2 km. (Cape Cod Bay scale)
3: 128 X 102 km. (Southern Gulf of Maine scale)
4: 1280 X 1020 km. (N. American Shelf scale)
5: 12800 X 10200 km. (N.W. Hemisphere/Atlantic Basin scale)

With time scales of 1 sec. polling of the variables in the MW equals RW time of:

1: 1 sec.
2: 10 mins.
3: 1 hr.
4: 1 day

The model will poll the variables and check the data coming from the NMW whale, looking at the conditions the whale is encountering at small time scales regardless of the output scales referred to above. Thus at time scale 1 and space scale 1 the NMW would look at the data coming in from the modeled whale, seeing what conditions it has encountered in the short time/space period and, after updating memory, would establish a new position, refreshing the location, in NMW and GMW, based on rules and variables and updated strategies. At, for instance, scales 3 and 3 the whale model would poll the data coming from the discoveries of the NMW at every second or so and do so by updating as in scale 1 but would put out numeric and graphics data for every hour of the RW, that by choice of the scale 3/3 would be represented every second of MW. Hence in this example the model would appear to run very fast and give output of a very detailed result quickly, allowing us to run the whale or whales through a season rapidly.

Tensioning Variables
Those variables that fall into two categories: Internal Absolute Tensioning Variables and Relative Tensioning Variables. The tensioning variables apply a subtle continuous pressure to the simple whale model, and change through time adding or reducing a tension to the whale's activities. The tensioning variables are vectors in the sense that they have a direction and a value.

- Absolute Tensioning Variables are those that place a pressure on the whale to react and, though they may be overridden by external discoveries (such as good food), they will eventually have their absolute effect. The most obvious of such tensioners is what may be called "intra-area time tension" that refers to the large-scale cycles that whales go through, the most obvious of which is the birthing migration. In this example if the subject whale is pregnant, a sharply rising tension to commence migration will be placed on the whale in late November if the individual is in Cape Cod Bay or the southern Gulf of Maine. Under the effect of this tensioning variable a modeled pregnant female would pay little attention to a very low tension to move south from high latitude feeding areas to calving grounds until the migratory period is upon her. As departure time in early December approaches, the model sees, as the days pass, a sharply rising value for the tension, reaching absolute requirement to migrate, regardless of food quality or other imperatives, around mid Jan. If by that MW date of January 15 a pregnant female has not departed, then an overriding migratory tension will cause the whale to depart the feeding habitats and a migratory algorithm will be triggered to cause that whale to head south along pretty well established routes. In the model this process will happen simply by increasing the value of a variable, the migratory tensioning variable, as the MW date changes. For each polling and refresh of the model, every second of MW, the migratory tensioner will be polled and to apply its tension to the whale.

- Relative Tensioning Variables are drawn from slow rises and falls in tension to move or to search or to go into other behavioral phases. These tensioners are less assertive than the Absolute Tensioning Variables illustrated by birthing imperatives. Relative Tensioning Variables include such short-term tensions as wide area senses (such as smelling/hearing/or medium-term memory) that may suggest to the whale richer food elsewhere. The tension of such a sense would then be weighed against local discoveries of plankton quality revealed to the NMW whale as it searches and forages among the environment's cells. Other examples of Relative Tensioning Variables are satiation and energy demand variables that, while important, do not have an absolute influence unless extreme conditions are reached. Under any circumstances the NMW should poll the tensions of both types at every cycle and run them against local data on quality of habitat.

Running the Model

At the very center of the processes, and hence the starting point for the model development, is the simple and direct relationship between food and whale movement in Cape Cod Bay. At the base of the model operation is a distribution of plankton, which the model must "construct" from user input, as previously discussed. The whale searches with mouth closed. When the mouth is closed a particular pattern of movement that our data clearly establishes, a bit faster than when feeding and in significantly straighter lines, ensues. In the search mode, using the search algorithm, some various mix of sensory input (sensing plankton density in its near vicinity or perhaps hearing whales from some distance as they feed) will guide the whale. Added to the basic algorithm is a component of memory/history, which, while difficult to quantify, must play a powerful role in shaping occurrence and distribution patterns.

When the whale, directed by general search geometry and influenced by tensioners of both types and by incoming information on the quality of the cells, passes through an area of higher zooplankton density, above the threshold that is believed to control the whale's feed/no feed responses, the whale goes into a feeding mode, a mouth-open algorithm applies and movements change from those put out by the search algorithm to those patterns that optimize capture of food. As the whale feeds in a slow and highly angular pattern, the NMW processor checks the tensioners, the recent history (memory) of the conditions that the whale has passed through, and the geometry begins to generally mimic the shape of the patch that the whale samples as it feeds. The principal influence on the whale's movements is the feedback in the form of capture of food but in later iterations it will be necessary to consider the tensioners and to mix in information from recently processed/sampled cells, perhaps 10-15 meters behind the whale, in order to define the next movements.

During or after a model run using these algorithms the distribution of the whales will be evident in the pattern of whale locations that have evolved, and a management product in the form of a prediction of whale occurrence and distribution will be produced. In the final form such a model will allow the input of zooplankton data collected in the field to predict whale distribution related to observed zooplankton abundance.

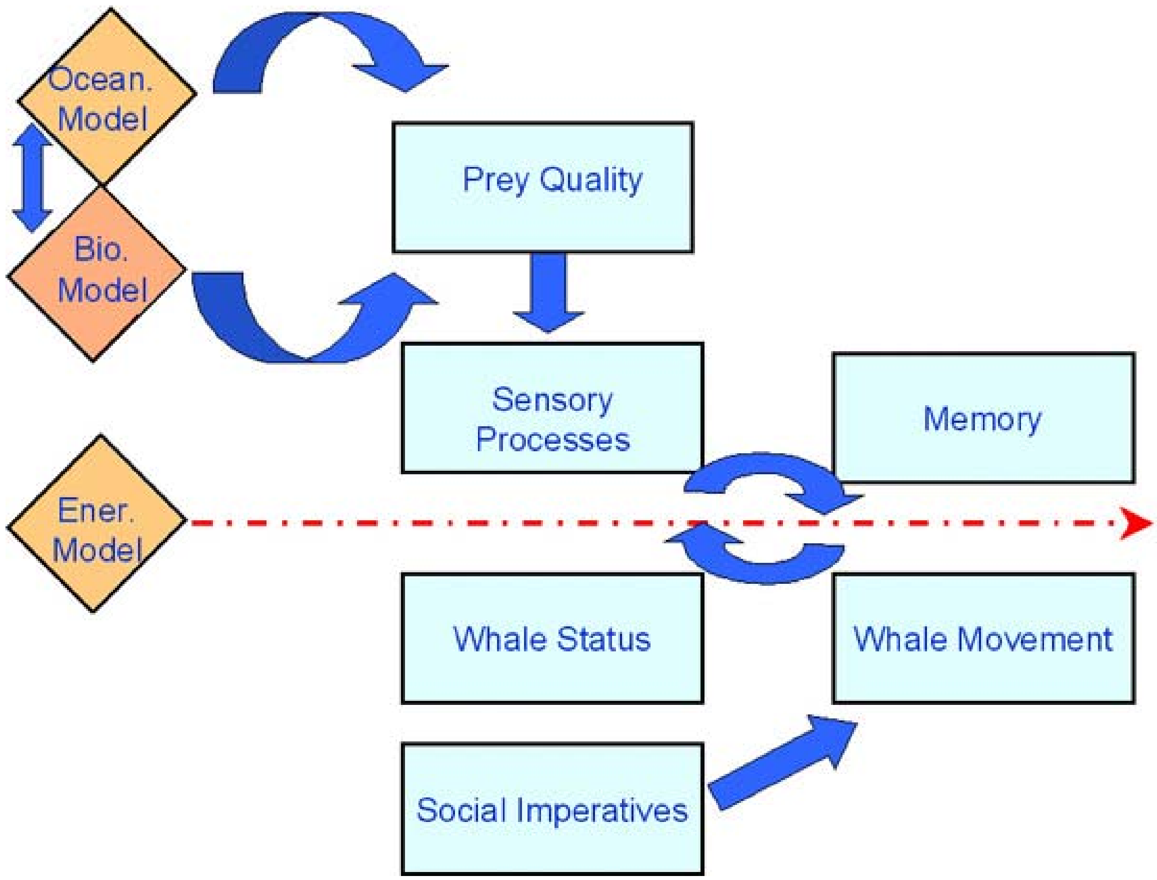


Figure 1. A general conceptual model showing the interconnections of oceanographic and biological processes that influence the model of right whale movement and occurrence.

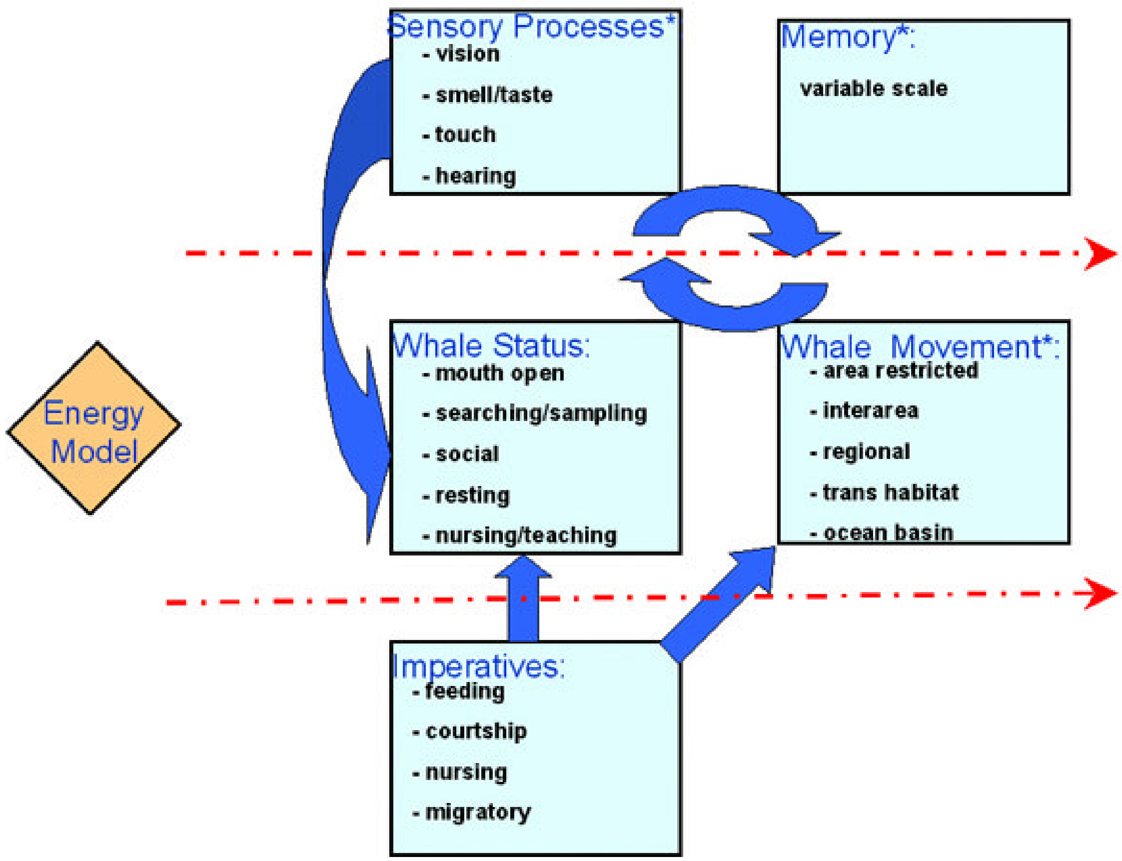


Figure 2. A conceptual model of the influences on right whale movements including the pathways and connections of the principal categories of variables that will be defined in the algorithm.

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