Surveillance, Monitoring and Management of North Atlantic Right Whales in Cape Cod Bay and Adjacent Waters - 2005

Final Report

Nathalie Jaquet[1], Charles A. Mayo[1], Owen C. Nichols[1], Moriah K. Bessinger[1], David Osterberg[1], Marilyn K. Marx[2], and Cynthia L. Browning[1]

[1]Provincetown Center for Coastal Studies
[2]New England Aquarium, Central Wharf, Boston, MA 02110

Provincetown Center for Coastal Studies
59 Commercial Street, P.O. Box 1036
Provincetown, MA 02657

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EXECUTIVE SUMMARY

In 2005, the right whale surveillance program supported by 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 Provincetown Center for Coastal Studies (PCCS). The program included bi-weekly aerial surveys and weekly habitat sampling. Two flights were also conducted on 9 and 18 December 2004. 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.

During the 2005 winter and spring season, PCCS observers performed 39 aerial surveys totaling 175 hours of flight time covering Cape Cod Bay and the near-shore of the outer shore of the cape.

Right whales were observed in Cape Cod Bay for 86 days, from 30 January through 26 April. This period of occupation of the bay is only slightly shorter than in 2004 (90 days), although in 2004 zooplankton was substantially more abundant than in 2005 (at least by a factor of two). In 2005, a total of 264 right whale sightings were recorded from all platforms, of which 249 were photographed. Of the photographed sightings, 192 were in Cape Cod Bay representing 45 different individuals, and 57 were in an area east of the Cape, representing another 45 individuals. Although all identification photographs have already been matched to the existing right whale catalogue by two independent experienced researchers, most of the matches are still awaiting final confirmation by the New England Aquarium, and the results outlined in the present report may change slightly once confirmation is obtained.

In 2005, fewer right whales than average visited CCB (45 individuals versus an average from 1998 to 2004 of 60) and their average individual residency time was also shorter ($\bar{x}$=13 days versus a project average of 21 days). This substantially shorter individual residency time was likely related to the low zooplankton density throughout the season. Unlike 2004 when only 1% of the sightings occurred in adjacent waters, a large number of sightings (28%) occurred in adjacent waters in 2005 and a similar number of individual right whales were identified in CCB and in adjacent waters. Ten mother and calf pairs were sighted in CCB and adjacent waters. The residency time of mother and calf pairs was substantially longer than of single females and the residency time of single females was also substantially longer than that of single males. This result was consistent with that of all previous years (1998-2004) suggesting that CCB is an important nursery area and that the habitat is more intensively used by females than by males. Few juveniles were seen in 2005 (n=5) and the adult:juvenile ratio was significantly different than the ratio found in the catalogued right whale population. Twelve right whales, principally mothers with calves, identified in the southeastern US calving grounds were re-identified in CCB and adjacent waters by the PCCS aerial survey team a median of 39 days later, providing some indication of transit time. As in previous years, the number of right whales increased slowly between late January and late March, peaked from late March through late April, and dropped off to zero at the end of April. Gaps in the sighting histories of individually identified whales may indicate that some animals periodically

leave the bay for short periods, perhaps traveling to adjacent areas beyond detection by standard aerial surveys.

Most of the whales were sighted in the southern-central part of the Bay, a region that corresponds to the area of highest zooplankton concentration (from oblique tows) during the 45-day period from 1 April to 15 May. Therefore, at the time of peak abundance of both copepod density and right whales, there seemed to be a good overlap between whale and copepod distribution. Large aggregations of whales in the northeast part of the bay (close to Provincetown) that were frequently observed in previous years were not observed in 2005.

Two previously entangled whales were sighted during the 2005 season; an updated assessment is presented on the condition of these two whales each entangled since 2002 (#s 1424 and 2320). Both were also sighted in the bay in 2004.

In 2005, the right whale habitat sampling team was available for Cape Cod Bay field sampling aboard the R/V *Shearwater* from 1 January through 15 May. Twenty-two habitat sampling cruises were completed between 5 January and 14 May, totaling over 170 hours at sea. 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 2005. Weather permitting eight stations located throughout the Bay were selected and sampled on every cruise to maintain a baseline data set. Data, graphics and written assessments from every cruise were, in most cases, sent out within a 36-48 hours to an e-mail distribution list including interested academic, governmental, scientific, and management agencies and individuals for the purposes of aiding the 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. In 2005 the evolving habitat assessment technique repeatedly demonstrated its utility of explaining the movements of right whales, often in a predictive capacity.

A total of 434 zooplankton samples (from surface tows, oblique tows and vertical pump casts) were collected. Data from surface and oblique net tows and vertical pump samples showed 2005 as a year of substantially lower zooplankton densities than many prior years. The usual seasonal progression of dominant taxa (*Centropages* spp. to *Pseudocalanus* spp. to *Calanus finmarchicus*) began earlier in 2005 than in previous years, resulting in a shorter peak period for *Centropages* spp. February was characterized by very low copepod density and it has been hypothesized that during this time right whales were feeding on juvenile midwater euphausiids of the genus *Meganyctiphanes*, a “krill” organism, that are poorly sampled using standard zooplankton nets.

The comparative plots offer some insights into the influence of the zooplankton resource on whale distribution. The long-held view that the zooplankton resource in the eastern two thirds of the Critical Habitat is a controlling factor of whale presence in the eastern bay is supported by the comparisons presented. The comparisons also show that the zooplankton sampling methods do not fully capture the controlling influence of the food resource, failing to fully represent the importance of deep layers of plankton that may contribute to the aggregation of whales.

The 2005 right whale habitat monitoring season was also designed as a testing period for the incorporation of an optical plankton counter (OPC) into PCCS's existing zooplankton sampling and assessment program in Cape Cod Bay. The OPC collects high-frequency data on the abundance and size of zooplankton that pass through its sampling channel as the instrument is towed behind a vessel or deployed as a vertical profiler. When used in conjunction with other sensors, such as a Conductivity-Temperature-Depth Probe (CTD), this sampling method yield high-resolution oceanographic and zooplankton data that can aid in predicting when conditions are conducive to right whale presence and foraging.

Many unforeseeable difficulties arose during this trial season, including antiquated and simplistic OPC software, an inherently flawed configuration of instruments, and a trio of platforms with many sensors that were not designed to communicate with one another. However, despite these problems, the OPC/CTD package was deployed vertically on-station during every habitat cruise from 18 March onwards and the results showed the amazing potential of these instruments to detect temporal trends and to make spatial comparisons.

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GENERAL INTRODUCTION

The Cape Cod Bay ecosystem is one of five known seasonal high-use habitat areas used by right whales (*Eubalaena glacialis*) in the western North Atlantic. The Critical Habitat for the North Atlantic right whale in Cape Cod Bay was federally designated in 1994 (Federal Register 59 FR 28793) in recognition of the seasonal importance of the Bay as an important feeding, socializing, and nursery area for the species (Watkins and Schevill 1979, Schevill *et al.* 1986, Hamilton and Mayo 1990, Mayo and Marx 1990, Kraus and Kenney 1991), and a habitat seasonally visited by 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 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). Survey data collected in the last two decades suggest annual variation in the numbers of whales visiting the Bay. 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 eight years (1998 – 2005) have confirmed that Cape Cod Bay and adjacent waters are usually important feeding, nursing and socializing areas from late December through early May for as many as 95 individuals during some years, almost a third of the known catalogued population (Brown and Marx 1998, 1999, 2000, Brown *et al*. 2001, 2002, 2003, Mayo *et al.* 2004).

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). Furthermore, 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, Kraus *et al.*, 2005) suggest we should view the present situation with increasing concern.

[*] 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 the North Atlantic 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. Furthermore, in the last 11 months, another 6 right whales deaths have been documented, increasing the number of documented deaths since 1970 to 68. Three out of these 6 whales died from collision with ships, and one from entanglement with fishing gear. 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 of health and may be responsible for more deaths than previously thought (Knowlton and Kraus 2001), so that entanglement may be equally responsible for right whale deaths as ship collisions (Kraus 2002). In addition, many animals disappear from the population (The New England Aquarium uses the metric “presumed dead” when a whale is not photographically identified for more than 6 years; this number stands at 100 through 2004, Hamilton *et al*. 2004), and it is obvious that not all deaths are seen on the beach (Knowlton and Kraus 2001). Based on the aforementioned information Caswell *et al.* (1999) estimated that if human - caused mortality is not reduced, the North Atlantic right whale 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 relatively recent human activities have affected the right whales using the area. Right whales are slow moving (particularly when accompanied by a calf) and very difficult for vessel-based observers to see 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 Critical Habitat with the Cape Cod Canal 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 has been performed to identify areas of potential risk to right whales from shipping traffic in the Bay (Nichols and Kite-Powell 2005).

The model has shown that an average of seven large (>65') vessels transited Cape Cod Bay each day to and from the Cape Cod Canal, the highest volume of which is bound to or from Boston (four/day) and ports in the northern Gulf of Maine (two/day). Furthermore, the results of the simple two-dimensional model suggest that there are approximately 1.5 expected ship/whale encounters (assuming whales are always at the surface and no avoidance behavior is attempted by whales or vessels) in Cape Cod Bay each year; Boston traffic contributing about 46% of this risk, and Gulf of Maine traffic ~35%. Large commercial fishing vessel transits contribute an additional 0.4 expected encounters in Cape Cod Bay each year if assumed to follow the same route as Gulf of Maine traffic, generating a combined total of 1.9 encounters per year (Nichols and Kite-Powell 2005).

Right whales are at risk of entanglement in fixed fishing gear in the area. In response to this risk, the Division of Marine Fisheries, Commonwealth of Massachusetts (DMF) has taken management action to mitigate the threat to right whales. Under DMF management gill nets have been prohibited and the use of modified gear is required in the Cape Cod Bay Critical Habitat area. These gear 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 set in the Cape Cod Bay Critical Habitat area during the survey period is located in the northern margins in depths greater than 30 fathoms. Fixed fishing gear is also set to the west of the western margin (070° 30' W) of the Critical Habitat in state waters where only a few right whales have been reported west of the critical habitat area in the past (Brown *et al.* 2003, Mayo *et al.*, 2004). Until recently fisheries in the western bay were not subject to the above gear restrictions because the area is outside the federally designated critical habitat area. Gear in the western portion of the bay was included in the above restrictive regulations 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 further 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 (PCCS 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 monitoring cruises conducted annually from January to mid-May during 1998 to 2005 as part of the program described in this report (Brown and Marx 1998, 1999, 2000, Brown *et al*. 2001, 2002, 2003, Mayo *et al.*, 2004). 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 state- and federally-mandated 500-yard exclusion zone around right whales for non-permitted vessels.

Program Objectives – 2005

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 that was begun in the winter and spring of 1998 and has continued for the past eight years (Brown and Marx 1998, 1999, 2000, Brown *et al.* 2001, 2002, 2003, Mayo *et al.* 2004 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 2005 as described below. The objectives of the 2005 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 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 Provincetown 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, RESIDENCY AND DEMOGRAPHICS OF NORTH ATLANTIC RIGHT WHALES IN CAPE COD BAY AND ADJACENT WATERS - 2005

1.1. Introduction

The following section addresses Objectives I through III and V of the PCCS/DMF right whale surveillance and monitoring program. Objective IV is discussed in section 2, 3 and 4.

In April 2005, an additional two-day pilot study was funded by DMF to gain preliminary data on right whale surface/dive behavior, small-scale movements and vocalization rates in relation to demographic group and food resources. Although in the last 20 years, survey data and opportunistic sightings have greatly improved our understanding of the right whale population, individual whales were seldom followed and thus little data is available on variability in behavior and small-scale movements in relation to food resources. An understanding of this aspect of the ecology of right whales would greatly increase our understanding of right whale vulnerability to ship strikes and thus is crucial in the conservation scheme of the species. Furthermore, the power of passive acoustics monitoring programs has been demonstrated for several species of cetaceans and could potentially be very useful for monitoring the presence/absence of right whales in hard to reach areas. However, to date, there are little data on the variation in vocalization rates in relation to demographic group, number of animals present, behavior and/or amount of food resources. It is clear that, before passive acoustics can be used as a monitoring tool, it is critical to gain a better understanding of the behaviors during which individuals may be silent as well as an understanding of the proportion of time that various demographic components of the population of right whales are emitting sounds. The main objective of the pilot study was to investigate the feasibility of such an investigation and to design preliminary protocols that would enable us to answer these questions during a full study.

1.2. Methods

1.2.1 Aerial Surveys

Aerial surveys were conducted regularly from 1 January 2005 through mid-May 2005 in the Cape Cod Bay Critical Habitat and adjacent waters. Two surveys were also completed in December 2004. 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 at 1.5 nautical mile (nm) intervals from the mainland to the Cape Cod Bay shoreline (Fig. 1a). An additional outer Cape Cod track line, 35 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 technical and safety reasons. In these latitudes, winter aerial surveys are hampered by low sun angles in the early and late hours of a survey day and this 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 of the observers' view, 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-D, Figures 1b-d).

The surveys were flown under visual flight rules conditions up to and including Beaufort sea state four. Surveys were aborted in Beaufort sea state five and/or when visibility decreased below two miles in fog, rain or snow. All aerial surveys originated at Chatham Airport, Chatham, MA. and 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, a floating ditch kit containing a medical kit, a waterproof VHF radio, a portable 406 MHz EPIRB, and an aircraft mounted ELT (emergency locator transmitter). All occupants 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.

Data were recorded by one observer (the left hand side one) 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. This protocol allowed the observer to enter data without taking his/her eyes from the survey area.

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 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. When an observer sighted a right whale or an other large whale 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.

1.2.2. Shipboard Data Collection

The Provincetown Center for Coastal Studies (PCCS) maintains a 40' (12m) long, twin diesel engine research vessel the "R/V *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 2005 (Mayo 1997, 1998, Mayo *et al*. 1999, 2000, 2001a, 2001b, 2004, Mayo and Bessinger 2002, Bessinger *et al.* 2003, Mayo *et al.* 2004). The results of this part of the program are reported in sections 2, 3 and 4 of this report.

Although the primary objective of the 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 however observers did not follow a strict survey protocol. An observer from the aerial survey team was present on board R/V *Shearwater* whenever possible to aid in opportunistic data collection. Photographs of right whales obtained during habitat cruises were integrated with the photographs collected during aerial surveillance. These vessel-based sightings were also included in the analyses of residency, demographics, and life history. Sighting data from the daily vessel logs were entered into the Right Whale Initiative DBase program as opportunistic sightings.

1.2.3. Photo-Identification Techniques

<u>i) 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 in the daily log of the image numbers shot by each photographer. Digital images were downloaded and backed up immediately following each flight and cruise.

ii) Photo-Analysis and Matching

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 34,432 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 PCCS by experienced researchers, with matches confirmed using original photographs catalogued and archived at NEAq.

Once images were submitted to NEAq, analysis was conducted using DIGITS software (developed by Philip Hamilton and colleagues at the New England Aquarium). DIGITS 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.

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, Surface Active Group, 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) Photographic Data Archiving

Original digital images are kept on file at PCCS on CD-R and an external hard drive. As digital photography has only been used for the last two years, 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, DIGITS will be available for use by those outside of NEAq, and similar software will likely be used to manage digital images at PCCS. All PCCS digital images from the 2005 season have been archived at NEAq and are available for access by collaborators per North Atlantic Right Whale Consortium protocols.

1.2.4. Focal Follows

To investigate right whale surface and diving behavior, small-scale movements, and vocalization rates in relation to demographic group and food resources, we closely followed a single individual or a pair of individuals for several hours. During the focal follow, the times of surfacing and diving, its behavior, and whether it showed its fluke or not was entered using a custom-written software into a HP 200 LX palmtop computer linked to a Garmin 12 XL GPS. Furthermore, the position of the research vessel was recorded automatically every 120 seconds. The position of the whale was determined (whenever possible) by recording the bearing to the vessel using a Minimorin hand held compass and the distance using a Bushnell Yard Pro laser range finder. During one of the two cruises dedicated to focal follow, recordings of vocalizations were made by Chris Clark (Cornell University, NY) using a one element hydrophone deployed at depths of approximately 10m. Because this was a pilot study, we attempted to use different techniques of recording data to gain an understanding of what methods were most practical.

1.2.5. 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 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 PCCS. 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 Cape Cod Bay in 2005. 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 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 PCCS 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 had calved were classified as adult. Sexes were assigned based on one of three methods: 1) by 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).

1.2.6. Notification of Agencies

Prior to and following an aerial survey, both US Coast Guard Group Woods Hole 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 (SAS) 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 PCCS 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.

1.3. Results

1.3.1. Aerial Surveys

In 2005, the PCCS/DMF aerial survey team was in position to survey for 135 days from 1 January through 15 May and also completed two surveys in December 2004. Thirty-seven full and partial surveys were flown in Cape Cod Bay and four in adjacent waters (Table 2). Out of the 37 surveys in Cape Cod Bay, eight surveys were aborted due to inclement weather and nine did not include track 15 due to low tide (Figure 1, Table 2). These represented 10,855 miles flown and 175 hours of flight. The weather in winter and spring of 2005 was substantially better for aerial surveys than in 2004, and in 2005, we flew an average of 1.9

surveys per week in CCB compared to 2.0 surveys per week planned and 1.3 surveys per week flown in 2004 (Table I).

Table I Summary of aerial survey effort in 2004 and 2005

	Number of surveys in CCB (include track 16)	Number of surveys in adjacent waters	Number of nautical miles flown	Number of hours flown
2004	25	3	7,164	139
2005	37	4	10,855	175

Two flights were conducted in December 2004 (9 Dec and 18 Dec), and the first flight of 2005 was conducted on the 2nd of January. The only stretch of bad weather that prevented us from flying for over a week was between the 16th and 29th of January. The first right whales were sighted in the Bay on the 30th of January and the last ones on the 26th of April.

The average duration of the standard Cape Cod Bay survey was approximately 4.6 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 duration was about 1 hr shorter than the mean for 2004 and 0.6 hr longer than the mean survey length for 1998 through 2003. The longer survey length in comparison to surveys prior to 2004 is attributable to the longer time required to adequately photograph individual right whales with only one photographer in a rear seat, as opposed to earlier surveys flown with one pilot and a photographer in the copilot position and a secondary photographer in the rear (Mayo *et al.* 2004). 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 sufficient quality for matching. The decrease in average CCB survey duration between 2004 and 2005 was likely due to: 1) The total number of right whale sightings was substantially larger in 2004 than in 2005 (271 versus 210 sightings respectively) and up to 27 individuals were photographed in a single day in 2004 versus a maximum of 22 individuals identified in a single day in 2005 (Table 2, Mayo *et al.* 2004); 2) In 2005, the observers were used to taking identification photographs from the rear seat and were more experienced than in 2004.

The standard Cape Cod Bay survey includes track 16 and thus encompasses about 35 nautical miles of survey outside the Bay (Fig. 1). However, in the analyses below, all right whale sightings from track 16 are included in "adjacent waters", and sightings from track 1 to 15 are included in "CCB". Most of the aerial survey effort was concentrated within CCB and 9,008 miles of transects were flown in CCB while only 1,847 miles were flown in adjacent waters.

1.3.2. Shipboard Data Collection

The R/V *Shearwater* completed a total of 22 habitat sampling cruises between 5 January and 14 May 2004 (Table 3). The primary purpose of these cruises was to collect oceanographic data in the Cape Cod Bay Critical Habitat area on a weekly basis 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, 3 and 4 of this report for the results and discussion of this portion of the program. 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 1 February, thus two days later than the aerial crew. Right whales were not seen again by the R/V *Shearwater* during February, and their next sighting happened on the 7th of March. Right whales were then sighted on all but one subsequent cruise (on the 7th of April) until their last sighting on the 26th of April (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 PCCS/DMF right whale team spent over 170 hours at sea in 2005. In addition to the work described above, one cruise was conducted in collaboration with Cornell University (Pershing contract) and two cruises were conducted on the 5 and 17 of April to collect preliminary data on behavior and vocalizations of individual right whales (focal follows).

In addition to habitat sampling and recording opportunistic sighting data, the vessel team also photographed 23 right whale sightings during the habitat cruises and 17 during the three other cruises (Table 3 and Table II).

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 in the methods, the results of which are detailed in the following analyses.

1.3.3. Sightings and Photo-Identification

In 2005, a total of 264 right whale sightings were recorded from all platforms, of which 249 were photographed and analyzed in this report (Tables 2 and 3). From these 249 photographed sightings, 82 different individuals were identified including 10 first year calves. Another eight right whale sightings have not yet been matched to known individuals. Although all identification photographs have already been matched to the existing right whale catalogue by two independent experienced researchers, most of the matches are still awaiting final confirmation by the New England Aquarium, and the results outlined in the present report may be slightly changed once confirmation is obtained.

The sighting histories of right whales photographed and matched to an individual in the catalogue during the duration of this project (1998-2005) are presented in Appendix I. This appendix includes all right whales seen in Cape Cod Bay (classified in this appendix as “M” for whales seen in Cape Cod Bay and Massachusetts Bay) as well as whales seen by PCCS in other habitats (e.g. “G” for Great South Channel).

For the purpose of this report, and following the definitions outlined in previous PCCS reports, CCB means Cape Cod Bay tracks 1 to 15 (see Fig 1), and adjacent waters means track 16 (see Fig. 1) plus all surveys flown outside CCB. The number of photographed sightings and different individuals identified by platform and location are outlined in Table II. Sightings of a mother and calf pair are counted as a single sighting as these are not independent.

Table II **Number of photographed sightings and individual right whales identified by platform and location in 2005.**

Platform and Location	Photographed sightings	Number of different individuals	Sightings not yet matched	Number of miles flown or number of days on the water
Aerial – CCB (track 1 to 15)	152	45	3	9008 miles
Aerial – Adjacent waters (track 16 and other 4 surveys)	57	45	5	1847 miles
Habitat Cruises - CCB	23	17	0	22 days
Other Cruises – CCB (including focal follows)	17	13	0	3 days
Total	**249**	**82**	**32**	

The total number of different individuals identified is lower than the sum of individuals per platforms and locations as eight individuals were sighted both in CCB and adjacent waters, and as all the individuals but one that were sighted from cruises were also identified from the aerial surveys. The right whale that was only identified from the R/V *Shearwater* was #3123.

Despite a much lower overall effort and a much smaller area surveyed in adjacent waters than in Cape Cod Bay, a similar number of individuals were identified in both areas (45 in CCB versus 45 in adjacent waters).

At the time of this writing, 82 individual right whales have been identified from all platforms combined. This is substantially larger than the total number of individual right whales identified in 2004 (54 individuals, Mayo *et al.*, 2004, Right Whale NEAq data base). However, in 2004, only one right whale was identified in adjacent waters while 53 were identified within the Bay. Therefore a slightly higher number of whales were identified within the Bay in 2004 than in 2005 (53 versus 45 respectively, Fig. I). On the other hand, many more whales were identified in adjacent waters than in 2004 (45 individuals versus 1) despite a very similar survey effort, suggesting that in 2005, the waters adjacent to CCB were used more frequently by right whales than in the previous year. During the eight years of the project, an average of 60.4 individuals (SD=27.12 ind.; range: 20 - 89) were present each year in CCB representing 18% of the individuals believed to be alive in December 2003 (342 ind, Hamilton *et al.* 2004).

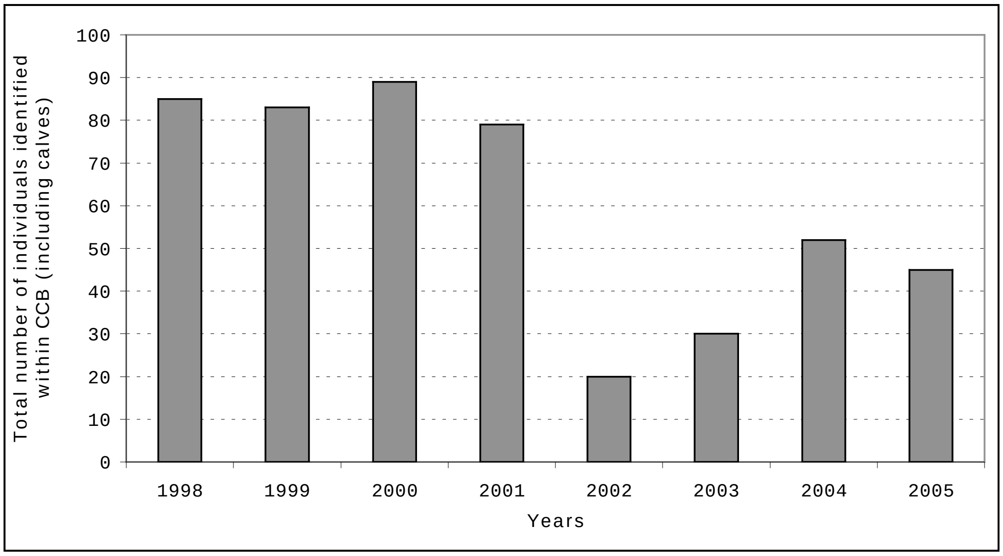


Figure I **Total number of individual right whales identified within CCB each year.**

Since 1984, 228 individual right whales (excluding calves) have been identified in CCB and adjacent waters (Appendix 1). In 2005, eight whales that had never been identified in CCB or adjacent waters were observed in adjacent waters. However, the 45 individual whales sighted within CCB in 2005 had all been seen in CCB in previous years. During this project (1998-2005), 180 individuals have been identified within CCB, 74 individuals (34%) only during one year while two individuals (1%) were identified in CCB every year of the project (Figure II).

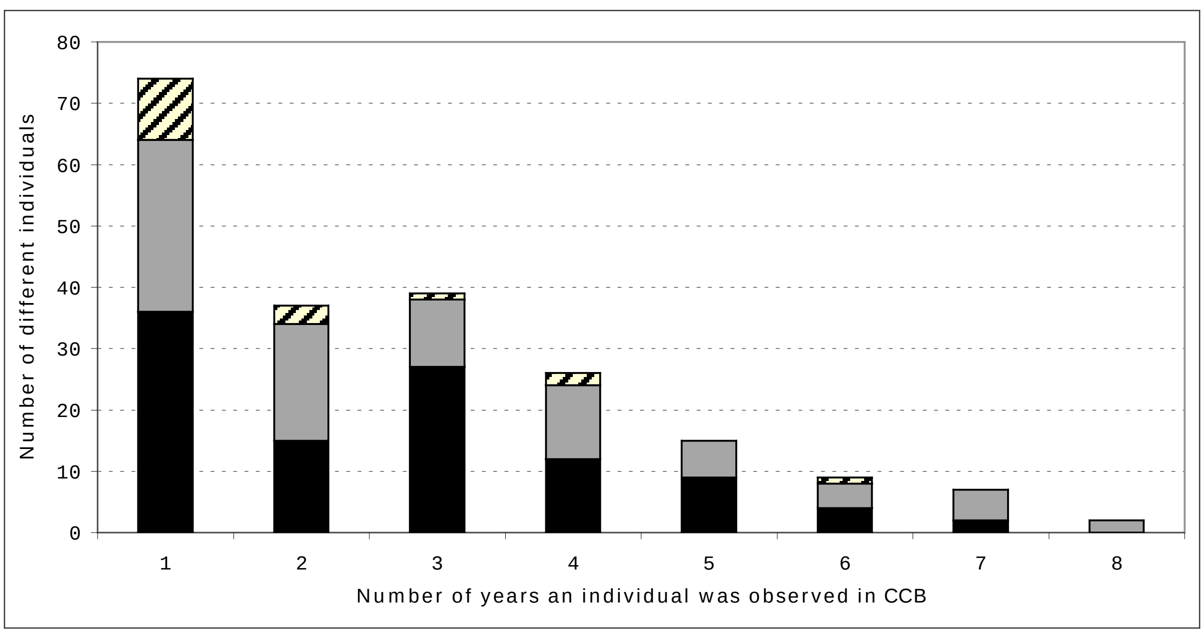


Figure II **Numbers of year individual right whales (males in black, female in grey and unknown sex in stripes) were sighted within CCB during the duration of the project (1998-2005).**

The discovery curve showing the rate at which "new" individuals are identified within CCB for the duration of the project is shown in Figure III. As the curve is showing sign of a plateau for the last couple of years, and as 180 individuals have been identified so far in relation to a total population of about 342 individuals (Hamilton et al. 2004), this result suggests that a part of the population may never or very rarely enter CCB.

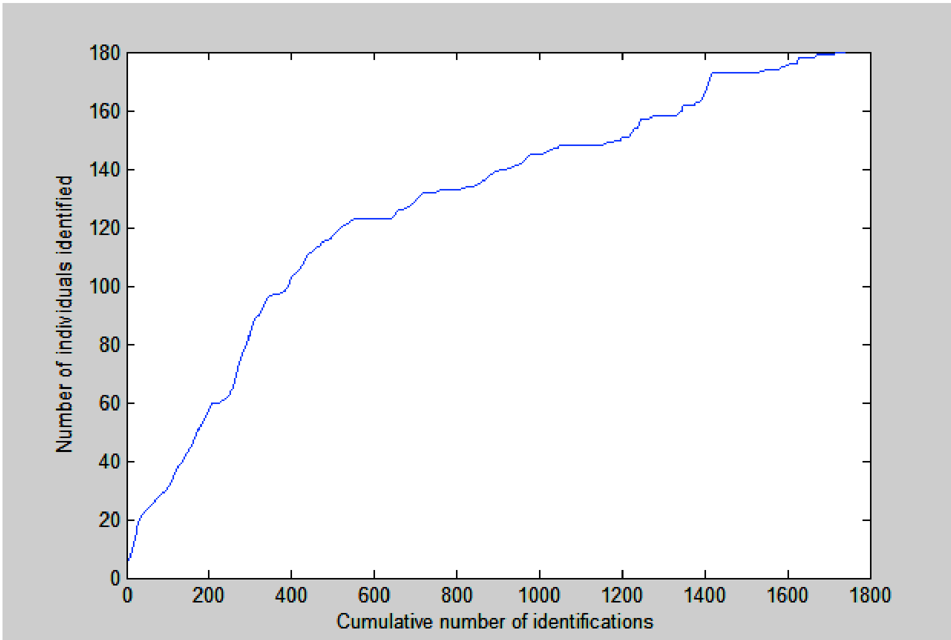


Figure III Discovery curve for individual right whales identified within CCB (excluding all adjacent waters) for the duration of the project (1998-2005).

1.3.4. Mother/Calf Pairs

Ten mother/calf pairs were photographed in Cape Cod Bay and adjacent waters in 2005 (Table III).

Table III Identities, calving histories and residency of the 2005 mothers sighted in CCB and adjacent waters.

Identification numbers	Number of known calves that the mother had before 2005	Area seen	Number of days seen	Time span in days between first and last sighting
1013	5	Adjacent waters	1	1
1204	5	Adjacent waters	2	2
1241	3	CCB	8	31
1245	2	CCB + Adjacent waters	7	31
1303	4	CCB	6	17
1310	5	CCB + Adjacent waters	4	13
1632	1	Adjacent waters	1	1
1703	1	CCB	7	39
2223	0	CCB	8	27
2413	0	Adjacent waters	1	1

In 2005, 28 mother and calf pairs were observed in the southeastern United States (SEUS), a substantially larger number than in the three previous years (16, 19 and 22 respectively), but fewer than observed in 2001 (31). Ten (35.7%) out of these 28 mother and calf pairs identified in the SEUS were also observed in CCB and adjacent waters (Fig. IV) in spring 2005, and six of them (21.4%) were identified within CCB (Fig. V).

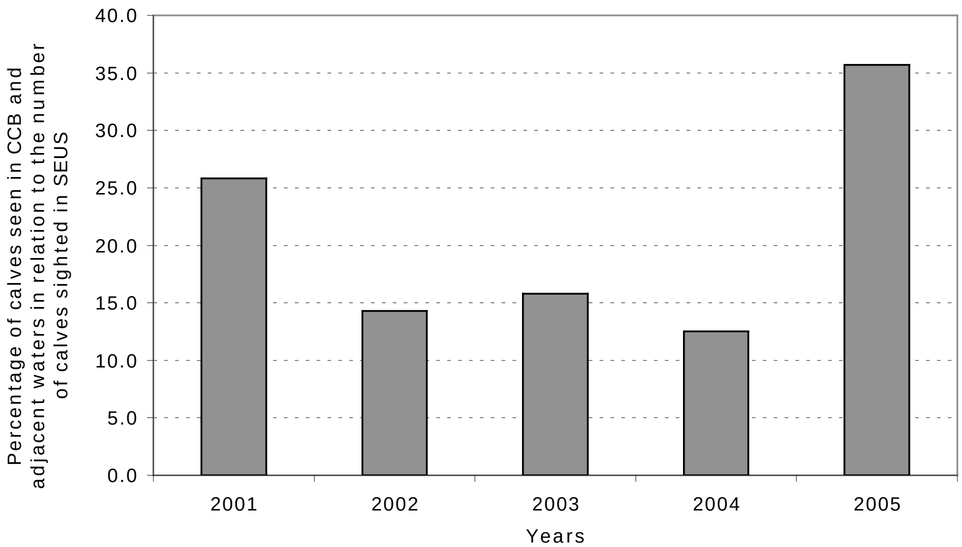


Figure IV **Proportion of calves seen in CCB and adjacent waters in recent years in relation to the total number of calves born in the SEUS.**

Although a higher percentage of mother and calf pairs were observed in CCB and adjacent waters in 2005 than in previous years (Fig. IV), the difference was not statistically significant (χ^2=4.198, df=4, p>>0.05). The years from 1998 to 2000 are not shown as no calves were sighted in CCB or adjacent waters during these years despite a similar aerial survey effort. However, because few calves were sighted in the SE during these years, 6 in 1998, 4 in 1999 and only 1 in 2000 (New England Aquarium unpublished data), it is not surprising that none were observed in CCB.

When only CCB is taken into account, the proportion of calves sighted in CCB in relation to the number of calves seen in the SEUS is shown in Figure V.

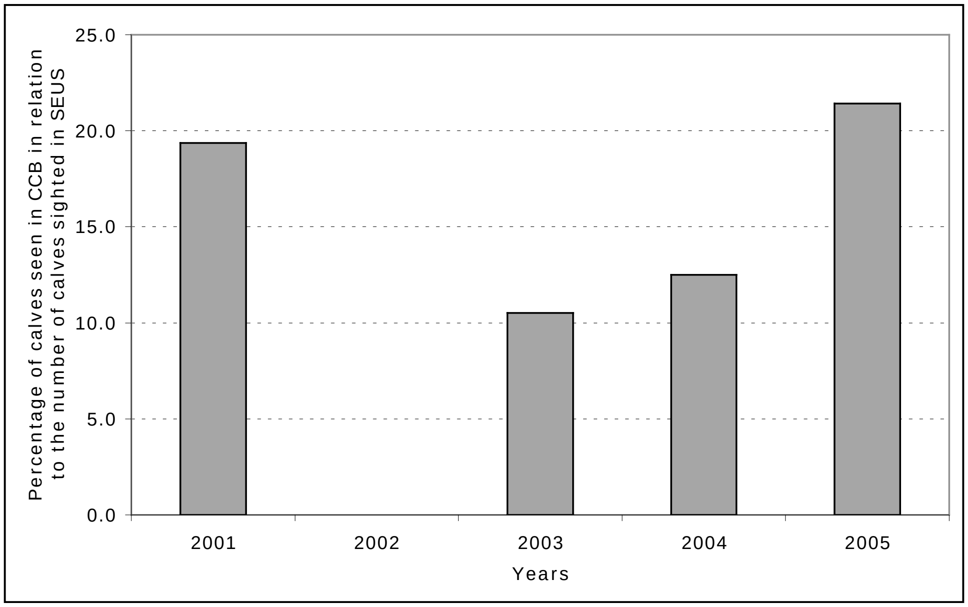


Figure V **Proportion of calves seen in CCB in recent years in relation to the total number of calves born in the SEUS.**

Since 2001, on average, 12.1% of the calves seen in the SEUS were also sighted within CCB, and this percentage reached 21.4% in 2005. Although a higher percentage of mother and calf pairs were observed in CCB in 2005 than in previous years, the difference was not statistically significant (χ^2=5.079, df=4, p>>0.05).

1.3.5. Demographics

Overall, a slightly larger number of females (42.2%) than males (32.5%) were seen in Cape Cod Bay and adjacent waters in 2005, and 25.3% of the individuals identified were of unknown sex (Figure VI). However, this sex ratio was not significantly different from the expected ratio of 1:1 (χ^2=1.69, df=1, p>0.05). When only the individuals of known sex are taken into account, and our study area is divided into CCB and adjacent waters, significantly more females (63.8%) than males (36.2%) were observed within CCB (χ^2=7.61, df=1, p<0.05), while slightly more males than females were identified in adjacent waters (53.8% versus 46.2%, χ2=0.578, df=1, p>>0.05).

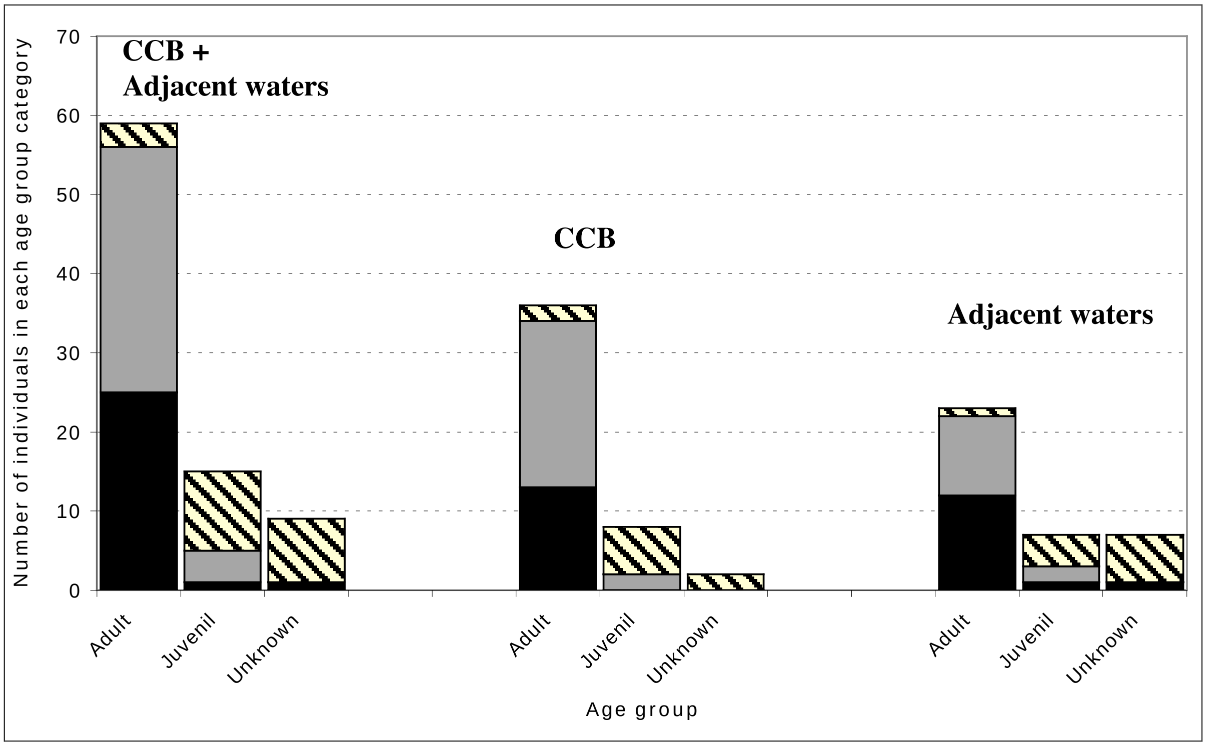


Figure VI **Number of males (black), females (grey) and whales of unknown sex (stripes) in relation to age groups and areas. A whale is considered a juvenile from its birth until age nine, and thus the 10 calves identified in 2005 are considered in the "Juvenile" category and were still of unknown sex at the time of writing.**

In 2005 CCB was frequented mainly by adults and by mother and calf pairs as only five individuals between 2 and 9 years of age were identified in CCB and adjacent waters (Fig. VI and Table IV). The age structure of animals of known age class (criteria defined in 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). Therefore, in 2005, out of the animals of known age class (n=64), we had 59 adults and 5 juveniles (excluding calves), and thus a proportion of 92.8% of adults versus 7.8% of juveniles. This age structure is significantly different from the right whale catalogue (Hamilton *et al.* 2004; $\chi^2=5.12$, $p<0.05$) 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. However, this proportion is very similar to that found in 2004 (Mayo *et al.*, 2004) where 94% of the individuals of known age class (excluding calves) were adults and 6% were juveniles. Comparisons between all years from 1998 to 2005 are outlined in Table IV.

Table IV Proportion of age groups and sex over the duration of the project (1998 to 2005) in CCB and adjacent waters.

Year	Minimum # individuals	Adult : Juvenile (excluding calves)	# of Calves	# Unknown age	Males : Females	# Unknown sex
1998	75	58 : 15	0	2	28 : 38	9
1999	86	55 : 23	0	8	37 : 35	14
2000	86	64 : 15	0	7	42 : 36	8
2001	87	57 : 05	8	17	40 : 30	10
2002	19	10 : 06	3	0	02 : 12	5
2003	27	21 : 02	3	1	14 : 10	3
2004	54	47 : 03	2	2	22 : 27	5
2005	82	59 : 05	10	8	27 : 35	20

A timeline depicting the demographic composition of right whales identified in Cape Cod Bay in 2005 and separated into two-week periods by age and sex is presented in Table 4. Within the Bay, all the individuals identified during the first month of sighting (from January 30 to February 25) were females. The first male was sighted within the Bay on February 26 and was seen only once. The second male was sighted on March 7, despite two surveys between these two dates (Table 5). Five males were observed in adjacent waters within a Surface Active Group (SAG)[1] on January 30 (together with another two females), but otherwise no males were observed in adjacent waters until March 22. This result is similar to what was observed in 2004 where all but two of the individuals seen in the first month of sightings were females.

Out of the 180 individuals that have been sighted in CCB between 1998 and 2005, 71 were females, 95 were males and 14 were of unknown sex. Although slightly fewer individual females than males visited CCB during these eight years, females were observed on a significantly larger number of days than males ($\bar{x}$=15.7 days, SD=13.07 and $\bar{x}$=9.4 days, SD=8.04 respectively, t=3.803, df=164, p=0.0002). These results suggest that females are utilizing CCB more than males. Figure VII shows the number of days each of the 180 individual right whales were sighted within CCB. Except for one male, all whales that were observed on more than 30 days were females (n=14).

[1] 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).

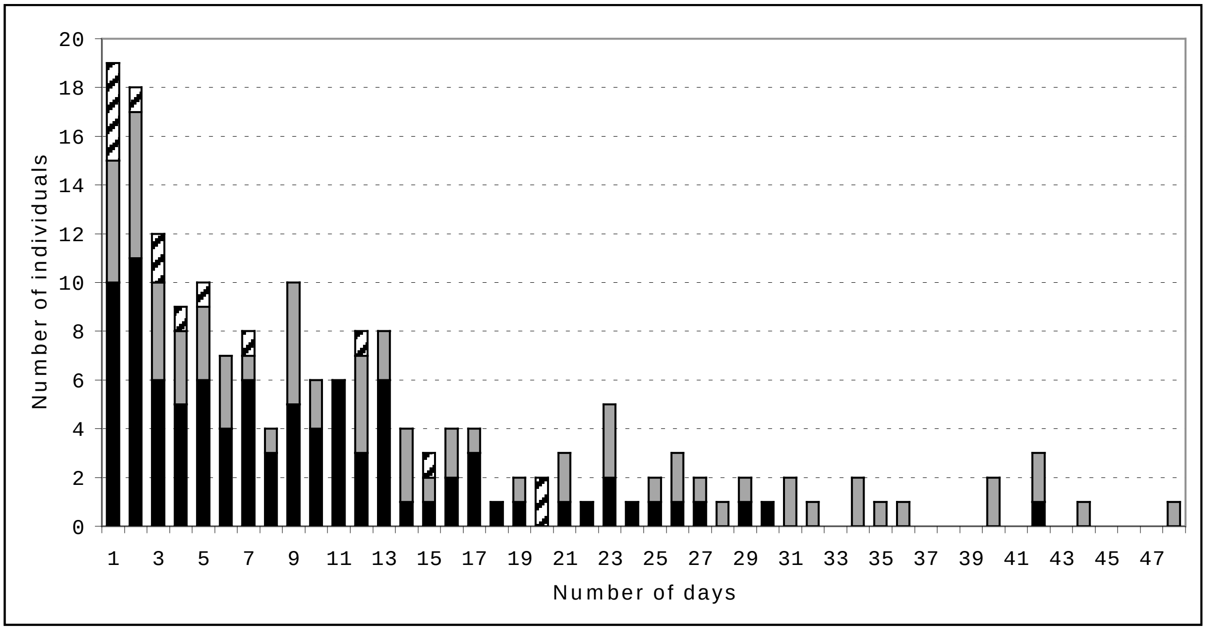


Figure VII Number of days each of the 180 individuals was sighted within CCB between 1998 and 2005. Males are in black, females in grey and unknown sex in stripes.

1.3.6. Distribution and Abundance of Right Whales within CCB

Right whales recorded during aerial surveys of Cape Cod Bay and adjacent waters are plotted by two-week periods in Figure 2. 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. The first right whales were observed within the Bay on 30 January 2005, and were observed in CCB in every 2 week period until they left the Bay around 26 April 2005. Therefore, there were no large temporal gaps in right whale sighting within the Bay as was observed in 2003. The few right whale sightings for the period 12-25 Feb (Fig. 2d) was partly due to some bad weather as only two flights were conducted during this 2 week period in comparison to six flights in each of the previous and following two week periods (Table 4). However, the flight conducted on 14 February was one of only two flights on which no right whales were sighted within the Bay during the observed right whale residency period 30 Jan to 26 April 2005.

The number of right whale sightings within CCB increased from 30 January until late March, then remained stable until about 22 April when it decreased abruptly in late April (Fig. 2a to 2j, Table 4).

Figure VIII shows right whale abundance per unit effort within CCB in 2005 and illustrates the slow increase in abundance during February and mid March, the peak in abundance between late March and late April and the “en masse” departure of all individuals in late April.

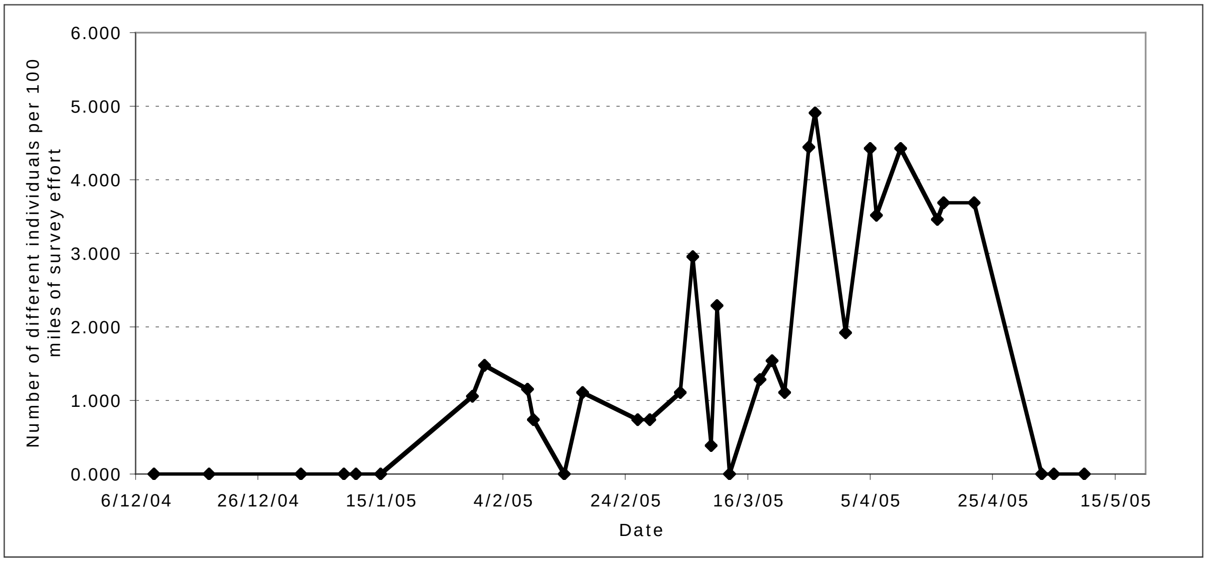


Figure VIII Number of individual right whales identified within CCB in 2005 per 100 nautical miles of aerial survey effort.

On the other hand, no consistent pattern emerges when number of individual right whales per 100 miles of survey effort is plotted for adjacent waters in 2005 (Fig. IX). Except for a SAG on January 30 on track 16 (Fig. 1) and two individuals sighted east of CCB on February 8, no right whales were sighted in adjacent waters until March 22. From March 22 to May 6, whales were commonly sighted in adjacent waters but in highly variable numbers (Fig. IX, Table 5).

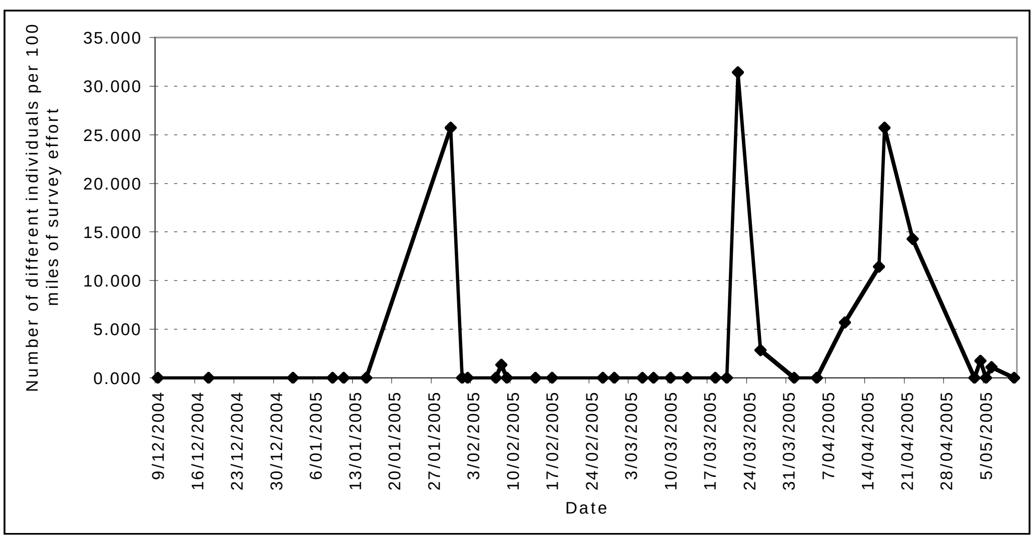


Figure IX Number of individual right whales identified in adjacent waters in 2005 per 100 nautical miles of aerial survey effort.

Table V shows the date right whales were first and last sighted within CCB. During the eight years of this study, right whales were present for the longest period during the 1999 season

(Table V). The value of 95 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. Furthermore, the timing of the first survey varied greatly between years (from 9 December for the 2005 season to 21 January for the 2004 season) and therefore it is possible that, during some years, the time period during which right whales were present was longer than the one described in Table V. On average, right whales are observed to be present in CCB for about 96 days (SD=32.3 days) each year; and thus the time period that right whales was present in CCB in 2005 (86 days, Table V), is similar to the yearly average.

Table V Time period when right whales are present in Cape Cod Bay over the 8 years of the project. Numbers in brackets represent the number of individuals identified on the sighting date. Numbers in square brackets represent the total number of individual right whales identified in CCB during the year.

Year	Date of 1st survey		Date of 1st survey right whale were sighted within CCB		Date of last survey right whales were sighted within CCB		Minimum # of days when right whales were present in CCB	
1998	04 Jan 1998	(9)	04 Jan 1998	(9)	21 April 1998	(1)	108	[75]
1999	13 Dec 1998	(5)	13 Dec 1998	(5)	02 May 1999	(1)	140	[86]
2000	20 Jan 2000	(1)	20 Jan 2000	(1)	11 April 2000	(3)	82	[86]
2001	19 Dec 2000	(5)	19 Dec 2000	(5)	29 April 2001	(2)	132	[87]
2002	06 Jan 2002	(0)	7 Feb 2002	(1)	15 March 2002	(3)	36	[24]
2003	10 Dec 2002	(0)	25 Jan 2003	(5)	30 April 2003	(8)	95	[26]
2004	21 Jan 2004	(0)	10 Feb 2004	(2)	10 May 2004	(1)	90	[54]
2005	09 Dec 2004	(0)	30 Jan 2005	(3)	26 April 2005	(6)	86	[45]

Except for 2002 when few right whales were sighted within the Bay, the whales seem to enter CCB for the first time between late December and early February and leave the Bay between late April and early May. Therefore there seems to be large variation in the time right whales enter CCB, but little variation in the time they leave it. Furthermore, during all years, whale abundance seemed to increase slowly during the first two months of their residency period, then reached a peak for a couple of weeks followed by an abrupt departure.

Out of the 210 sightings in 2005 (Table 2), 59 (28%) occurred outside the Critical Habitat. This is significantly more than what was observed in 2004 when only 1% of the sightings occurred in waters outside the critical habitat. Within the Bay, one right whale was observed close to the western edge of the critical habitat (Fig. 2f), and two were observed outside the boundaries (Fig. 2f). Therefore 72% of the right whale sightings occurred within CCB and within the Critical Habitat. Most of the whales were sighted in the southern central part of the Bay (Fig. 3a). This overall distribution of sightings is quite different from the 2004 distribution (Mayo *et al*., 2004, Fig. 3b). In 2004 the sightings were spread out over a larger area, and the area the most used was between Race Point (in the NE corner) and the center of the Bay (Fig. 3b). In 2005, many whales, including several mother and calf pairs, were observed in proximity to the Cape Cod Canal, making them particularly vulnerable to ship strikes (Fig. 2g and 2h), and more right whales than usual were observed in the western portion of the Critical Habitat.

1.3.7. Individual Residency

As aerial surveys were not conducted every day, we have no way of knowing whether a whale was present in the Bay between two surveys or whether it had left the Bay and re-entered it at a later date. Therefore we define individual residency time as the time span between the first and the last sighting of an individual whale.

Right whales are often seen multiple times in Cape Cod Bay over a four-and-a-half month field season. Table 5 shows the sighting history for each of the 82 individuals identified in 2005 in CCB and adjacent waters. Right whales were present in CCB and adjacent waters for 97 days in 2005 (30 Jan to 6 May) and the longest time span between first and last sighting for a single individual was 87 days ($\bar{x}$=8.9 days; SD=14.92, n=72). Calves were not included in the analyses as their residency time is not independent of their mother's. There were differences in the number of days seen and time span from first and last sighting between individuals seen in CCB and individuals seen only in adjacent waters. Of the 39 right whales identified in Cape Cod Bay in 2005 (excluding calves), 14 (36%) were seen only once (Table VI). The greatest number of days on which individual right whales were identified in CCB was 8 (three females; Table 5). On the other hand, 94% of the individuals sighted exclusively in adjacent waters were identified on a single occasion and only two individuals (6%) were identified on two different days (Table VI).

Table VI Number of days individuals were identified in CCB and in adjacent waters (calves excluded).

Number of days an individual was photographed in 2005	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Number of individuals photographed **in CCB** (n=39)	14	5	6	3	2	3	3	3
Number of individuals photographed **exclusively in adjacent waters** (n=33)	31	2	0	0	0	0	0	0

Therefore, the individuals sighted only in CCB were seen on a significantly larger number of days than those identified only in adjacent waters ($\bar{x}$=3.6 days, SD=2.69 days versus $\bar{x}$=1.1, SD=1.42; t-test: $p \ll 0.001$). This result suggests that the individuals identified in CCB were staying or returning in the area over a period of a few days to a few weeks while the individuals identified in adjacent waters must have been transiting to another area. This is confirmed by the time span in days between first and last sighting. In CCB there was an average of 13.2 days between first and last sighting (SD=17.14 days, median=7 days, range= 1 to 87 days, Figure X), while in adjacent waters there was an average of 1.8 days between first and last sighting (SD=4.52, median=1 day, range= 1 to 27, Figure XI). Note that Figure X and XI have different y axes. Similarly to single individuals, mother and calf pairs sighted within CCB were identified on multiple occasions (4 to 8 days), while mother and calf pairs identified exclusively in adjacent waters were sighted only on one or two days (Table III).

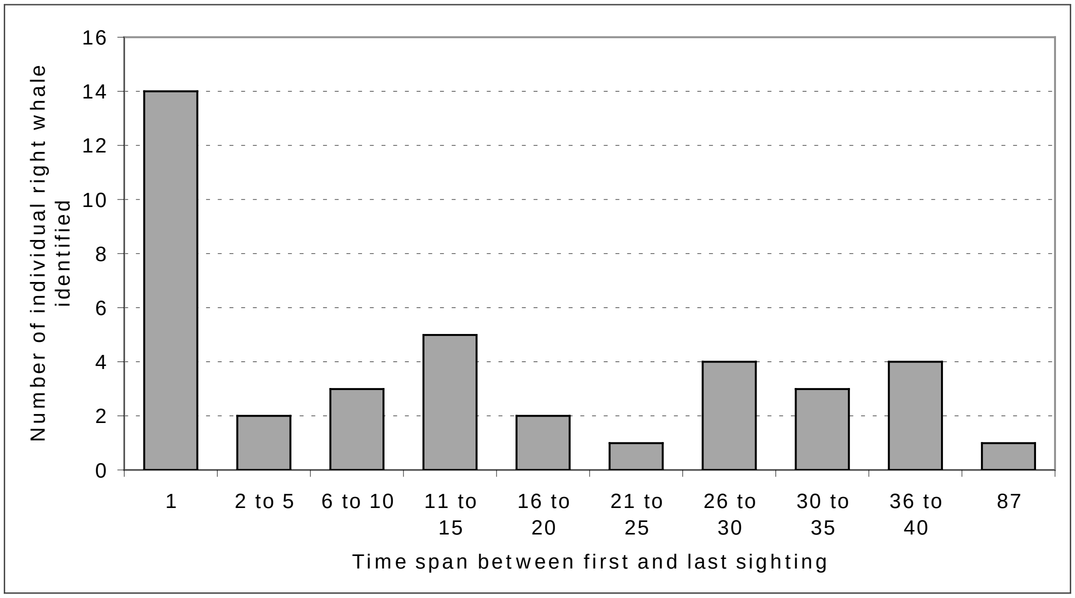


Figure X Time span between first and last sightings for right whales identified in CCB.

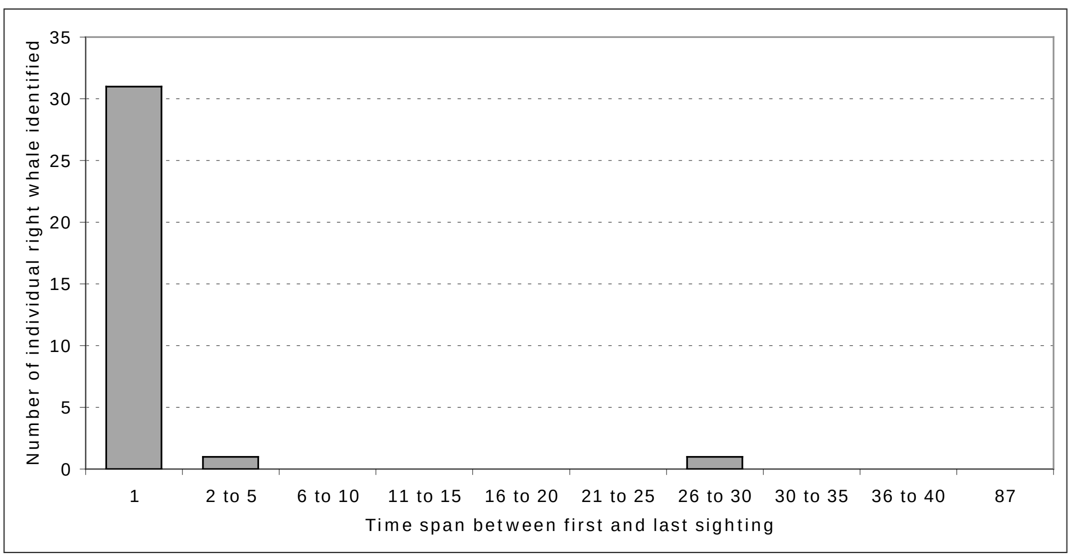


Figure XI Time span between first and last sightings for right whales identified exclusively in adjacent waters.

Due to little photo-identification effort in areas other than CCB and the SEUS during winter/early spring, and due to the fact that most of the 2005 sightings from teams other than the PCCS team are still awaiting identification, it is not possible to assess whether the time span between first and last sighting in CCB represents the real residency within CCB or whether there are extensive movements in and out of the Bay between sightings. However, it seems clear that some individuals exited the Bay and re-entered it at a later date. For example, right whale #2460 was observed in CCB on 30 January, 1, 2 and 8 February, observed again on March 5 and 7, and again on April 22 and 26. It is therefore much more likely that this individual made three different visits to the Bay rather than had a residency time of 87 days (Table 5). Table 5 also shows that, except for a few individuals, right whales were usually sighted on only a few consecutive surveys during February and mid-March, and were sighted on many more consecutive survey dates between late March and late April. If we assume that an individual whale has left CCB when not sighted during three or more consecutive surveys, then, in 2005, 15.4% of the individuals left and re-entered CCB one to three times during their residency period. When only the residency time within CCB was considered (and not the gaps in between), whales had a mean residency time of 8.0 days (SD=9.72).

In CCB and adjacent waters, there were significant differences in residency time between demographic groups. Seventy-seven percent of the males were seen on only one day, and only one male was observed on four different days (average number of days identified=1.4, median=1, n=27). Furthermore, the time span between first and last sighting for males was short (average=2.5 days, median=1 day). In contrast, individual females were identified on a substantially larger number of days ($\bar{x}$=3.2 days, n=35) and the time span between first and last sighting was also considerably larger ($\bar{x}$=15.6 days, median=11 days). Mother and calf pairs had the longest residency: they were identified on up to eight different days ($\bar{x}$=4.5, n=10), and had the longest time span between first and last sighting ($\bar{x}$=16.3 days, median=15days). Within CCB only, there were also similar differences in residency time between demographic groups both for 2005 and for the entire project (Table VII and VIII).

Table VII Time span (between first and last sighting) and residency time (excluding gaps when not sighted during ≥3 consecutive surveys) for individuals sighted within CCB in 2005.

	Sample size	**Mean Time Span in days (SD)**	**Median Time Span in days**	**Mean residency, no gaps ≥ 3 surveys (SD)**	**Median residency, no gaps ≥ 3 surveys**
All	39	13.2 (17.14)	7	8.0 (9.72)	2
Males	13	3.8 (4.73)	1	3.8 (4.73)	1
Females	17	18.9 (22.14)	11	7.1 (8.77)	2
Mother/calf pairs	6	22.6 (9.52)	24.5	22.6 (9.52)	24.5

Table VIII Time span (between first and last sighting) and residency time (excluding gaps when not sighted during ≥3 consecutive surveys) for individuals sighted within CCB during the entire project (1998-2005).

	Sample size	**Mean Time Span in days (SD)**	**Median Time Span in days**	**Mean residency, no gaps ≥ 3 surveys (SD)**	**Median residency, no gaps ≥ 3 surveys**
All	468	21.4 (25.50)	12.5	11.0 (12.04)	7
Males	231	19.4 (26.69)	8	9.5 (10.63)	5
Females	194	24.9 (24.48)	19	12.8 (13.50)	8
Mother/calf pairs	18	16.3 (11.96)	16.5	16.3 (11.96)	16.5

There were significant differences in residency time between mother/calf pairs, single females and males (Kruskal Wallis: p=0.0063), suggesting that mother/calf pairs stay in CCB about twice as long as single females and three times as long as males. Mother and calf pairs were the only demographic group that did not occasionally show movements in and out of the Bay between first and last sighting and thus the mean time span was always equal to the mean residency time.

Figure XII shows the lag identification rates as well as the fitted model calculated using the SOCPROG suit of programs (Whitehead, 2005). Lag identification rates express the probability of re-identifying an individual a time lag τ after having first identified it. The results suggest that right whales are resident in CCB for an average of 22 days (from first to last sighting), and followed an "emigration + reimmigration" model with an emigration rate of 0.22 individual/day.

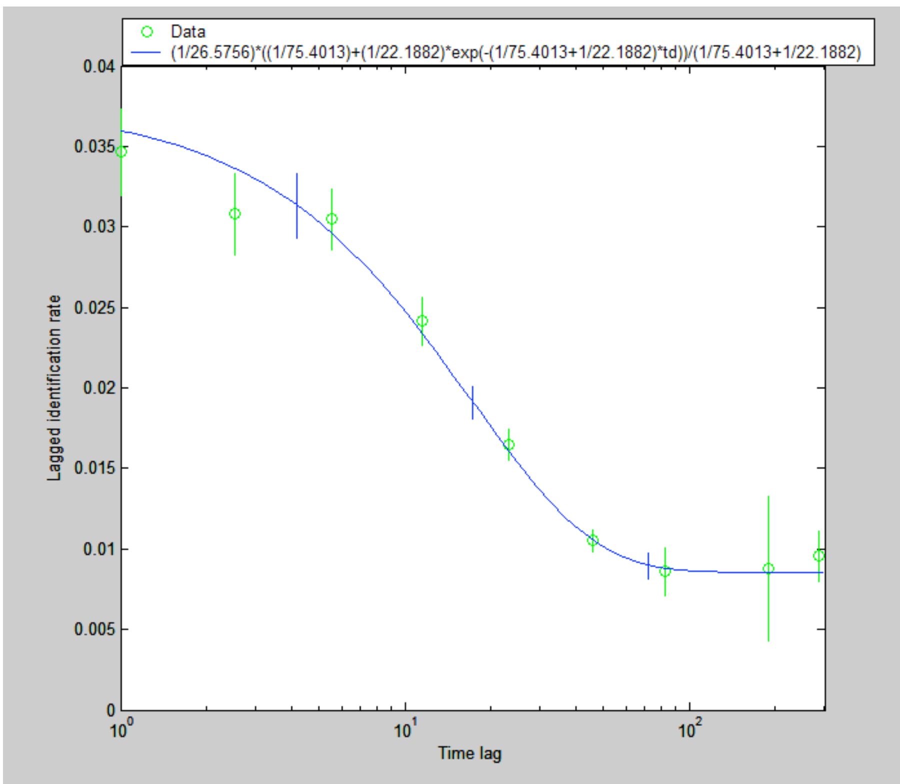


Figure XII Lagged identification rates for CCB from 1998-2005. Vertical bars represent jackknife errors and blue line the fitted model.

1.3.8. Sightings Between Habitat and Transit Time

Twelve right whales were seen both in the SEUS and Cape Cod Bay or adjacent waters in 2005 (Table IX). The mean number of days between sightings in the two areas was 49 (SD=25.2, Median=39 days). The number of days between sightings ranged from 34 to 123.

Table IX Individuals sighted both in the SEUS and in CCB and maximum transit time.

Catalogue number	Last sighting in the SEUS (Florida/Georgia)	First sighting in CCB and/or adjacent waters	Days elapsed between sightings (maximum transit time)
1013 + Calf	3/1/05	6/5/05	123
1241 + Calf	19/2/05	27/3/05	36
1245 + Calf	17/2/05	5/4/05	47
1303 + Calf	28/2/05	10/4/05	41
1310 + Calf	4/3/05	10/4/05	37
1427	16/2/05	26/3/05	38
1632 + Calf	6/3/05	22/4/05	47
1703 + Calf	19/2/05	26/3/05	35
2223 + Calf	17/2/05	27/3/05	38
2413 + Calf	5/3/05	17/4/05	43
2614	9/1/05	20/3/05	70
3180	16/2/05	22/3/05	34

These results suggest that, in 2005, it took individual right whales an average of 49 days to migrate from Florida/Georgia to CCB and/or adjacent waters. When only the transit time from SEUS to CCB is taken into account (thus disregarding any resightings in adjacent waters), the average is slightly smaller ($\bar{x}$=41.8 days, SD=11.73).

These transit times are similar to those seen in previous years. Between 1998 and 2005, a total of 66 right whales (not including calves) were identified in both the southeast US and within Cape Cod Bay in the same year (Table X). The minimum transit time was 23 days and the maximum was 95 days. The average transit time was 47.7 days (SD=17.14, Median=43, n=66). There were no significant differences in transit time between mother/calf pairs and the other demographic groups (t=1.808, df=64, p=0.752).

Table X Transit time between SEUS and CCB over the 8 years of the project (calves are not included in the total because they are not independent from their mothers).

Year	Tot number of individuals	# of female	# of males	# of juveniles	# of mother/calf pair	Mean transit time (SD)	Tot # whales seen in CCB	%tage seen from SEUS in CCB
1998	9	4	5	8	0	49.4 (13.58)	85	10.59
1999	5	3	1	1	0	50.8 (12.57)	83	6.02
2000	12	6	6	7	0	52.7 (25.55)	89	13.48
2001	15	11	4	0	8	40.1 (6.26)	73	20.55
2002	4	3	0	2	0	37.9 (2.20)	20	20.00
2003	7	4	3	2	2	65.2 (17.58)	29	24.14
2004	6	4	1	1	1	45.9 (21.77)	50	12.00
2005	8	7	1	7	6	41.8 (11.73)	39	20.51

1.3.9. Focal Follows

Focal follows were conducted on the April 5 and 17 2005. Because PCCS does not yet own hydrophones and amplifiers that can be used to record right whale vocalization frequencies, we were only able to make recordings on April 17 when Dr. Clark (Cornell University) joined us on the R/V *Shearwater* with the necessary hydrophones, amplifiers and recorders. On April 5, 12 individual whales were present in CCB, the maximum recorded for any single day in 2005, and most of them were mother/calf pairs feeding in close proximity, rendering focal follow of a single pair or single individual difficult. Later in the day, we encountered a pair of individuals (#1267 and #1122 an adult female and an adult male respectively) that we followed closely for 2.5 hrs. On April 17, we followed a mother/calf pair for 5.1 hours, however, the close follow was broken up in the middle as the R/V *Shearwater* had to retrieve one of the pop-up acoustic buoys. Thus the mother/calf pair was followed closely only for 2.8 hrs. The preliminary results of these focal follows are presented in Table XI. Vocalizations were recorded during 1.2 hours and a total of 77 right whales calls were recorded. Six of these calls were subjectively evaluated to be of sufficient clarity and intensity that they could possibly have been produced by the mother-calf pair (Table XII). However, as the recordings were made using single hydrophone instead of arrays, no information on bearing is available and thus there is no certainty as to the individual making the calls.

Table XI Summary of focal follows

Date	5 April 2005	17 April 2005
Right whales	2 Adults (female+male)	1 Mother/Calf pair
Total time from first to last seen	2.5 hrs	5.1 hrs
Total time close follow	2.5 hrs	2.8 hrs
Total displacement	5.44 nautical miles	1.68 nautical miles
Estimated speed if travel in straight line	2.2 knots	0.34 knots
Proportion time apparent feeding	None?	84%
Proportion time both underwater	73%	16%
Proportion of time the 2 whales were separated (>200m apart)	0%	46%

Table XII Summary of recorded vocalizations

Session	Start	End	Duration (min.sec)	Total # of right whale calls	# of calls possibly emited by mother/calf	Times of calls possibly emited by the mother/calf pair
1	14:56:50	14:58:55	2.1	3	0	-
2	14:59:44	15:16:50	17.1	22	1	14:59:45
3	15:17:24	16:13:55	56.5	39	3	15:29:14
3						15:45:02
3						15:45:27
4	16:38:25	17:10:12	31.8	13	2	16:46:15
4						16:46:26
Totals			**1.2**	**77**	**6**	

From their behavior while in the field, it seemed clear to us that the two adult whales on April 5 were not feeding. When the positions of the pair are plotted every few minutes (Fig. XIII), the path is almost straight, corroborating the field observation that the whales must have been traveling.

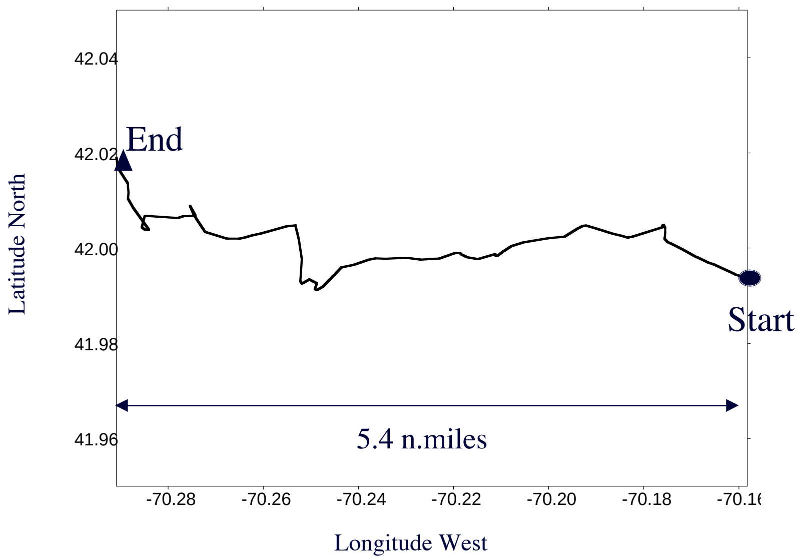


Figure XIII Movement path of the two adults followed closely for 2.5 hours on 5 April 2005.

1.3.10. Monitoring of Entangled Whales

During the 2005 field season, two entangled whales were observed in Cape Cod Bay. Both whales, # 1424 (adult male) and # 2320 (adult female), had been entangled for three years since 2002. Both whales were sighted on only one day. The first entangled whale, # 1424, was sighted during an aerial survey on 7 March 2005 in CCB. This individual looked in good condition, but little of the body could be seen and this whale was not resighted during our field season. The second whale, # 2320 ("Piper"), was observed once by the aerial survey team on 17 April 2005 on track 16 (Fig 1a). The photographs of #2320 have been examined by members of the PCCS disentanglement team and the New England Aquarium right whale research team. It was concluded that the available documentation did not provide enough information to confidently determine the extent of the remaining entanglement; however, no gear was apparent in the images. 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 PCCS disentanglement team (quotes from ongoing case studies).

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." Furthermore, in 2005, no gear was apparent on any photographs.

1.3.11. Distribution of Vessel Traffic

The distribution of vessels by type as recorded during aerial surveys during the 2005 season is plotted in Figure 4. While no direct whale/vessel interactions were observed, there were several instances of whales in close proximity to vessel traffic observed during both aerial surveys and shipboard data collection. On 22 March, a right whale was sighted during an aerial survey feeding beneath the surface in western Cape Cod Bay. The aerial survey team contacted USACE Canal Control via VHF radio to report the sighting, as a southbound tug and barge was approaching the location. USACE relayed the location of the whale to the tug, which altered course to the east to avoid the area. On 13 April, observers on board R/V *Shearwater* documented three mother-calf pairs in areas of high vessel traffic along the eastern margin of Cape Cod Bay within 5 miles of land and in the area between Race Point and Long Point entering Provincetown Harbor. Most of the adults were feeding at or near the surface. On 17 April, the aerial survey team and observers on board R/V *Shearwater* noted a large number of recreational vessels among at least nine right whales (including 4 mothers with calves) off Barnstable Harbor in southern Cape Cod Bay. The whales were difficult to see from R/V *Shearwater* due to their behavior (many were feeding beneath the surface). Some vessels appeared to be engaged in whale watching, while others were traveling at high speed, apparently oblivious to the presence of the whales. Aircraft observers contacted one vessel via VHF that was within 100 meters of a mother-calf pair and informed the operator of the state and federal regulations prohibiting approach within 500 yards. On 19 April, observers on board R/V *Shearwater* sighted a mother and calf in southwestern Cape Cod Bay, and again in proximity to substantial recreational vessel traffic. One vessel that was closely following the pair was contacted via VHF radio and informed of the "500-yard rule". USACE Canal Control was also contacted via cell phone due to the location of the pair near the approaches to the Canal. On 29 April, a private citizen photographed a mother and calf in the eastern (Cape Cod Bay) entrance to the Cape Cod Canal and submitted the photographs to the Cape Cod Stranding Network, which in turn forwarded them to the PCCS team. The photographs were of sufficient quality to permit a match to the catalogue: # 2223 and calf. This was three days after the last right whales were sighted in the Bay by aerial survey. Accounts of right whale sightings in the Canal date as far back as 1957 (Clark 1958) and have been recorded as recently as 2002 (Brown *et al.* 2002). A review of these sightings is currently being compiled, and efforts are being made in cooperation with USACE to raise awareness about the importance of such sightings so that they are promptly reported to marine traffic controllers.

1.3.12. Notification of Agencies and Management Measures

At the completion of each survey and cruise, the information on the number of right whales and their locations 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 and cruises in Cape Cod Bay, the USACE Field Office was contacted directly by VHF radio or cell phone at the time of a sighting in close proximity to traffic exiting or entering the Cape Cod Canal (see above). A total of 64 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/PCCS 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 months of January through March.

A sighting of 9 right whales off the eastern shore of Cape Cod during a PCCS aerial survey on 30 January required consideration by NOAA Fisheries under the Dynamic Area Management (DAM) program. A sighting of three or more right whales within an area of 75 square nautical miles (=139 km^2) such that right whale density is equal to or greater than 0.04 right whales per n.miles^2 (1.85 km^2) may be considered for a DAM action, during which management actions pertaining to fixed fishing gear may be enacted within a zone around the whale sightings (see Atlantic Large Whale Take Reduction Plan - http://www.nero.noaa.gov/whaletrp/). Following consultation with NOAA Fisheries, the PCCS team conducted a focused survey on 2 February (Table 1b, Figure 1b), which indicated that the whales had left the area. No further action was deemed necessary by NOAA Fisheries.

Both DMF and NOAA Fisheries issued an advisory to the maritime community on 14 April due to the high number of right whales in close proximity to areas of high vessel traffic off Provincetown and the approaches to the Cape Cod Canal. 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.

1.3.13. Sightings of Other Species

In addition to right whales, seven other species of cetaceans and two pinniped species were sighted during aerial surveys and vessel cruises (Tables 2 and 3). Fin whales (*Balaenoptera physalus*, 98 sightings) and humpback whales (*Megaptera novaeangliae*, 60 sightings) were the most numerous of the large whales encountered in Cape Cod Bay during aerial surveys. In addition, 24 minke whales (*Balaenoptera acutorostrata*) were sighted during aerial surveys. The spatial distribution of the above three species of balaenopterids is plotted in Figure 5a. Fin whale sightings were largely concentrated toward the eastern side of Cape Cod Bay. When vessel based opportunistic sightings and aerial survey sightings are combined, there was a total of 129 fin whales and 61 humpback sightings. However, most of the large whales sighted by the vessel were also sighted by the plane and thus this number is likely to include many duplicate sightings. Opportunistic identification photographs of humpbacks collected during vessel cruises were contributed to the Gulf of Maine humpback whale catalogue maintained at PCCS by Jooke Robbins. Of the toothed whales sighted during aerial surveys and identified by species, Atlantic white-sided dolphins, *Lagenorhynchus acutus*, were the most common species recorded in Cape Cod Bay (Tables 2 and 3). A large proportion of toothed whale sightings were recorded as "unidentified dolphin" as the species could not be determined without circling to allow examination of morphological features to facilitate identification. The spatial distribution of toothed whales from aerial surveys is indicated in Figure 5b. Harbor seals, (*Phoca vitulina*, 970 sightings) were the most commonly sighted pinniped species during aerial surveys (Table 2). Additional efforts were made in 2005 to photograph aggregations of seals hauled out on ice and sand to allow accurate species identification and counts. Counts and photographs were submitted to colleagues conducting research on pinnipeds in the region, including Stephanie Wood (University of Massachusetts - Boston), Gordon Waring (NOAA Fisheries), and the Riverhead Foundation for Marine Research and Preservation.

1.4. Discussion

1.4.1. Abundance and Residency of Right Whales within CCB

In 2005 only 45 individual right whales were identified within CCB, which is substantially fewer than the mean number of individual identified between 1998 and 2001 ($\bar{x}$=84 ind.), but substantially larger than the mean number of individuals identified between 2002-2003 ($\bar{x}$=25 ind.), and roughly similar to the number of individuals identified in 2004 (n=53 ind.). When residency is also taken into account and thus when number of individual whales are multiplied by the number of days they have been sighted we obtain very similar results: with large numbers of whales*day in 1998-2001 ($\bar{x}$=333 ind*day), low numbers in 2002-2003 ($\bar{x}$=44 ind*day) and 177 ind*day for 2004-2005. This result suggests that there are large variations in the utilization of CCB by right whales between years and it is likely that they are due to variations in food resources. However, due to the complexity and patchiness of the zooplankton, the relationship is not straightforward. In 2005, the zooplankton resource was substantially lower than in 2004 (see section 2), but only eight more individuals were seen in 2004 in comparison to 2005. In 2003, although zooplankton concentration was generally low, it was substantially higher than in 2005, but only 30 different individuals visited the Bay. Furthermore, in 1999, 83 different individuals visited CCB despite a low total copepod density (averaged surface value). These results suggest that the relationship between zooplankton density and whale abundance is complex and may need to integrate species composition density in the entire water column, as well as degree of patchiness. It is also possible that factors other than food resources within CCB are responsible for the number of individual right whales visiting CCB each year.

In 2005, comparable numbers of individuals were seen outside and inside CCB despite a much lower effort in adjacent waters (83% and 17% of effort respectively). However, when residency was taken into account, there were three times fewer whale*day in adjacent waters than within CCB (51 whale*day for outside CCB versus 156 whale*day within CCB). This result suggests that, although adjacent waters played an important role during the 2005 season, CCB was still more heavily utilized by right whales. This result is similar to that found in 2003 and 2002 when a large number of individuals were sighted outside CCB (annual reports 2002 and 2003). However, in all the other years a much lower number of individuals were sighted outside CCB than inside (1 ind. in 2004; 20 ind. in 2001; 8 ind. in 2000 and 2 ind. in 1999; the transect #16 was not flown regularly in 1998 and thus 1998 cannot be taken into account). These results suggest that when food resources are lower than usual in CCB (2002, 2003 and 2005), right whales utilize the adjacent waters more heavily then during years of high food resources within CCB. It would be worthwhile to regularly expand the area of habitat sampling to also include part of track 16 to gain an understanding of this emerging pattern.

Almost half of the individuals that are seen within CCB have been observed there during only 1 year of the project, suggesting that there is little site fidelity for CCB and that it is not always the same 60 individuals that return year after year.

On average, about 18% of the right whale population is observed in late winter-early spring in CCB every year. As roughly ~15% is observed in winter in the SEUS and about 15% of the individuals seen in SEUS are also seen in CCB, we can account for the whereabouts of roughly 28% of the population during winter early spring. Therefore, this also means that the whereabouts of ~72% of the population during these months are still completely unknown. It is clear that, to be able to adequately protect the species, it would be crucial to gain some understanding as to where they might be and why. Individual right whales that are seen outside CCB may provide some insights into the question, as, in general, these whales are not seen within CCB the same year and thus are not on their way to or from CCB. Furthermore, these whales are usually observed during a single day suggesting that they are transiting to another area.

In 2005, the number of right whales increased slowly during the first two months of the season, the number peaked in early and mid April and the peak was followed by an abrupt departure of all whales within a few days at the end of April. This pattern of slow increase, peak in number and ”en masse” departure was consistent with the pattern observed all previous years of the project (except years when whales were particularly scarce as in 2002 and 2003). Although this pattern roughly followed the rise and fall of zooplankton density, the latter cannot fully explain whale movements. For example, in 2004, whales left the Bay in early May while the density of zooplankton (~10,000-11,000 org/m^3) was still above what is considered as the feeding threshold (threshold=~3,750 org/m^3) and was composed almost entirely of *Calanus finmarchicus* which provides the highest caloric value to whales (Mayo *et al*., 2004). Similarly, in 2005, the decline in zooplankton happened slightly after the departure of whales (see section 2 and 3 of this report). This suggests that the decrease in copepod concentration in CCB is not the only factor which triggers the departure of whales and it is possible that, in late-April and early-May, the presence of higher food resources in another habitat (likely the Great South Channel) makes it more profitable for right whales to leave CCB despite high densities of copepods still available in the Bay. Therefore, in order to understand what may trigger their departure from CCB, it would be crucial to investigate food resources in the Great South Channel and adjacent waters before, during and after the “en masse” departure from CCB.

Despite much lower food resources in 2005 (see section 2 of this report) in comparison to 2004, 2001 and 2000, the time period that right whales were present within CCB (86 days) was similar to what was found in these previous years (90, 132, 82 respectively) suggesting that, irrespective of food resources, the first few right whales will arrive at a similar time every year, and some will stay in the Bay despite low zooplankton concentrations. Furthermore, early in the season, a few whales are often seen in the Bay when zooplankton concentration are extremely low and much below the feeding threshold. It is possible that at this time of the year (winter-early spring) few other habitats would be productive enough to support right whale feeding. However, further analyses need to be done in order to test the above hypotheses. Studies in adjacent waters would also help understand what triggers the arrival and departure of right whales in CCB.

1.4.2. Individual Residency and Movements

Although right whales were present in CCB for 86 days in 2005, the average time span between first and last sighting of individual whales was only 13.2 days. This suggests that, during the season, there is a turnover of individuals and none stay in the Bay for the entire season. This time span in 2005 was substantially lower than 2004 (20.8 days) as well as substantially lower than the overall project average (21.4 days), suggesting that when food resources are lower than usual (like in 2005, see section 2 of this report), the time each individual whale spends in CCB is drastically reduced despite a similar number of whales visiting the bay and despite a similar residency period for all whales.

In 2005, based on their sighting history, it seems that about 15% of the whales left and re-entered CCB at least once during their residency period. This percentage is smaller than the average project (1998-2005) percentage (27%), and may be related to the shorter residency period in 2005 in comparison to the other years. These movements in and out of the Bay are crucial to understand, because while transiting in and out of CCB, whales are likely to cross the important Boston shipping lane and thus be very vulnerable to ship strike. These frequent excursions in and out of CCB may serve to assess food resources in other areas. As these excursions happen throughout the field season, it may suggest that some individuals are almost constantly looking for other feeding areas and are coming back to CCB as long as no better resources are found. However, the way the information on food resources could be disseminated amongst individuals resulting in an “en masse” departure at the end of each season is puzzling.

In 2005, most males spent only one day in CCB while the median time span between first and last sighting for mother/calf pairs was 25 days. These results were consistent with what was found during earlier years where mother/calf pairs and single females always had a significantly larger residency time in CCB than males. This discrepancy in residency time between demographic groups suggests that, although as many males as females are visiting the Bay, CCB is a more important habitat for females than for males. This result makes CCB an even more critical habitat as females and mother/calf pairs are the most vulnerable demographic group and as the death of a female is considered more significant to the survival of the population than the death of a male (Fujiwara and Caswell 2001).

1.4.3. Distribution

Right whale distribution within CCB was slightly different in 2005 in relation to 2004, however, except two whales sighted to the west of the Critical Habitat (Fig. 2f), all other sightings were within the Critical Habitat boundaries. This is consistent with what has been found in previous years when only an occasional right whale is sighted west of the Critical Habitat. This result suggests that the boundaries of the Habitat are well suited to protect right whales within CCB. The large proportion of individual right whales sighted in 2005, as well as in 2002 and 2003, east of CCB and thus east of the Critical Habitat suggest that these waters are also important for right whales. However, these whales are usually seen on a single day only and seem to be transiting to or from an other area suggesting that the area east of CCB is important as a "migration route" but likely not as an habitat itself. Nonetheless, due to the high density of whales occasionally found in these waters, further studies including habitat sampling would greatly increase our understanding of the value of this habitat for right whales.

1.4.4. Demographics

Although significantly more females than males were identified in 2005, this sex ratio does not seem to be a rule for CCB as, over the 8 years of the project, there were fewer males than females during four years and fewer females than males during the other 4 years (Table IV). It is possible that 2005 was anomalous for an unknown reason, but it is also possible that this is a start of a new trend and that more adult females and less juveniles of both sexes will be utilizing the Bay.

A strong trend in the proportion of juveniles can be seen in the last 3 years where a substantially smaller proportion of juveniles was identified in CCB and adjacent waters than during the first three years of the project. However, very few calves were born in 1998, 1999 and 2000 thus greatly decreasing the pool of juveniles available in later years, which could partly (but not entirely) explain the scarcity of juveniles in recent years. If this factor plays a role in the low number of juveniles observed in recent years in CCB, we should see an increase in the number of juveniles in the next few years due to the high birth rate in the last five years.

There was a large variability in the proportion of mother/calf pairs observed in CCB in relation to the number of calves born in the SEUS during the entire project. No calves were observed during the first 4 years likely owing to the very low number of calves born in the SEUS. In 2005, there was the largest proportion of mother/calves pairs observed in CCB since 1998, however, due to the high inter-annual variability the difference was not statistically significant. As only an average of 15% of the mother/calf pairs sighted in the SEUS are re-sighted in CCB, this raises the question as to where the other mother/calf pairs are found before they make their way to the Great South Channel and the Bay of Fundy later in the year.

1.4.5. Sightings Between Habitats and Transit Time

Individual right whales took a median of 39 days in 2005 to transit from SEUS to CCB. As there are about 900 nautical miles between the border of Florida/Georgia and CCB, such a transit time suggests that whales were traveling at an average speed of just under one knot.

This is consistent with what one would expect from slow moving right whales, especially if they are foraging on their way. 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 ship collisions on right whales.

1.4.6. Focal Follows

The pilot study of April 2005 showed unambiguously that such a study is feasible and, if conducted over long time period, will yield a wealth of new data on individual behavior and small-scale movements. The acoustic part of the study is promising as well, as the fieldwork showed that it was possible to closely follow whales, recording their behavior as well as recording their vocalizations. However, the use of single hydrophones resulted in uncertainties in calls assignments, and it was difficult to assess whether it was the focal mother/calf calling or individual whales further away. Therefore the data collected on 17 April are not that useful to determine call rates of focal individuals in relation to behavior and demographic group. In the future, we will use hydrophone arrays allowing us to obtain bearing to calls and thus decreasing the uncertainties in call assignments.

The sample size of this study was obviously very small, and does not allow us to make any generalizations. The results of this two-day study showed that the mother/calf pair spent almost half of their time separated (>200m apart), and in 84% of the time one or the other was at the surface and thus vulnerable to ship strike. A calf by itself, especially if separated from its mother, will be hard to see even if a ship has observers on board, making it even more vulnerable. The two adults traveling spent the majority of their time underwater (73%) and were thus likely away from ship's harm. However, little data exist about the depth at which right whales dive when traveling and it is possible that they stay in the upper layer of the surface column, thus unavailable for observation but vulnerable to ship strikes. The only method that would allow us to determine this depth, and thus the vulnerability of traveling whales would be to attach suction cup tags on individuals and to simultaneously record their behavior.

1.5. Conclusion

The results of the 2005 field season continue to support the view that CCB is an important habitat for right whales during winter and early spring, and that this habitat is especially important for single females and for mother/calf pairs. Males seem to visit the Bay only briefly. They also showed the possible relationship between individual residency time and zooplankton densities, although there does not seem to be a very obvious, direct relationship between the overall residency period of right whale in CCB and zooplankton concentrations Our results also demonstrate the frequent whale movements in and out of CCB, movements during which individual right whales may be particularly at risk of collision with ships as they may be crossing the Boston shipping lanes and are traveling in areas devoid of protection. Furthermore, our results suggest that the individuals that are observed in large numbers east of CCB during some years are usually not observed in CCB and seem to be transiting to or from another area.

Table 1A. **Aerial survey track lines flown over Cape Cod Bay, December 2004 to mid-May 2005. For location of track lines, cross-reference by track line number with Figure 1. Cross-leg mileage (between track lines) are not listed for the standard Cape Cod Bay survey (track 1 to 16), as tracks are spaced 1.5 nm apart and the aircraft is turning during at least half of the cross-leg.**

Track line Number	Latitude	Longitude West End	Longitude East End	Track line Length (nm)
1	42 06.5	70 37.9	70 10.0	21
2	42 05.0	70 36.3	70 15.8	15
3	42 03.5	70 36.8	70 17.0	15
4	42 02.0	70 35.7	70 07.7	21
5	42 00.5	70 34.2	70 07.0	20
6	41 59.0	70 34.2	70 06.6	21
7	41 57.5	70 34.2	70 06.6	21
8	41 56.0	70 31.6	70 06.3	19
9	41 54.5	70 30.9	70 06.3	18
10	41 53.0	70 30.0	70 06.1	18
11	41 51.5	70 29.5	70 06.1	18
12	41 50.0	70 30.3	70 06.1	18
13	41 48.5	70 30.2	70 06.1	18
14	41 47.0	70 28.3	70 06.1	17
15	41 45.5	70 26.5	70 11.4	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 (Fig 1).

Table 1B. **Aerial survey track lines flown east of Cape Cod, 2 February 2005. Cross-reference this table with Figure 1. Cross-leg mileage is listed as the track lines are spaced ≥3 nm apart.**

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	70 00.0	69 40.0	15
3	42 02.0	70 00.0	69 40.0	15
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				**172**

Table 1C. **Aerial survey track lines flown northeast of Cape Cod, 8 February and 6 May 2005. Cross-reference this table with Figure 1. Cross-leg mileage is listed as the track lines are spaced ≥3 nm apart.**

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 1D. **Aerial survey track lines flown over the Great South Channel (SCOPEX), 4 May 2005. Cross-reference this table with Figure 1. Cross-leg mileage is listed as the track lines are spaced ≥3 nm apart.**

SCOPEX Track line Number	Latitude West End	Longitude West End	Latitude East End	Longitude East End	Track line Length (nm)
5	41 49.0	69 56.3	42 19.4	68 45.2	61
10	41 43.8	69 55.7	42 15.4	68 42.2	63
15	41 38.8	69 53.4	42 11.2	68 38.9	64
20	41 34.6	69 50.2	42 06.9	68 35.6	64
Total survey with transits and cross-legs					**286**

Table 1E. **Legend of abbreviations and common names for marine mammals 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
Dd	Common Dolphin
Gm	Pilot whales
Pp	Harbor Porpoise
UNDO	Unidentified Dolphin/ Porpoise
Hg	Gray Seal
Pv	Harbor Seal
UNSE	Unidentified Seal

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 during the 2005 season. ES=Eastern Shore of Cape Cod; NE=North East of Cape Cod; GSC=Great South Channel. Species abbreviation are explained in Table 1E.**

Survey#	Date	Eg Sighted	Eg Photo'd	Ba	Bp	Mn	UNBA	UNMW	UNLW	La	Dd	Gm	Pp	UNDO	Hg	Pv	UNSE	Hours Flown	Distance Flown (nm)	Tracks Completed / Area Surveyed
Cape Cod Bay and Track 16																				
CCS347	09Dec04	0	0	3	2	2	0	0	0	30	0	0	0	246	0	0	0	6.3	295	1-14,16
CCS348	18Dec04	0	0	0	15	18	0	0	0	280	0	65	0	20	0	0	0	4.9	295	1-14,16
CCS349	02Jan05	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	3.8	306	1-15,16
CCS350	09Jan05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	306	1-15,16
CCS351	11Jan05	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	3.7	306	1-15,16
CCS352	15Jan05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.5	306	1-15,16
CCS353	30Jan05	12	12	0	0	0	0	0	0	0	0	0	0	0	0	0	1	5	319	1-15,16
CCS354	01Feb05	4	4	0	0	0	0	0	0	0	0	0	2	0	0	340	2	4.6	306	1-15,16
CCS355	02Feb05	4	4	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0.7	23	N/A+
CCS356	07Feb05	3	3	0	0	0	0	0	0	0	0	0	1	0	0	0	103	4.2	306	1-15,16
CCS357	08Feb05	3	3	0	0	0	0	0	0	0	0	0	0	30	0	0	40	3.7	260	1-14
CCS358	09Feb05	2	2	0	0	0	0	0	0	0	81	0	3	0	0	1	1	4.2	306	1-15,16
CCS359	14Feb05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	628	0	3.2	295	1-14,16
CCS360	17Feb05	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	3	4	306	1-15,16
CCS361	26Feb05	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.1	306	1-15,16
CCS362	28Feb05	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3.9	306	1-15,16
CCS363	05Mar05	3	3	0	0	0	0	0	1	0	0	0	0	0	0	0	0	4.8	306	1-15,16
CCS364	07Mar05	8	8	0	0	0	0	0	0	0	0	0	0	31	0	0	1	5.8	306	1-15,16
CCS365	10Mar05	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.4	295	1-14,16
CCS366	11Mar05	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.4	131	1-9,most of 8*
CCS367	13Mar05	0	0	0	0	0	1	0	0	0	0	0	2	0	0	0	5	3.3	295	1-14,16
CCS368	18Mar05	2	2	0	0	0	0	1	0	0	0	0	0	41	0	0	4	2.9	191	1-6,12-14,16
CCS369	20Mar05	4	4	0	1	0	0	0	0	0	0	0	0	0	0	0	2	4.5	295	1-14,16
CCS370	22Mar05	18	18	1	0	0	0	0	0	0	0	0	0	20	0	0	6	5.4	306	1-15,16
CCS371	26Mar05	16	14	0	1	2	0	0	0	0	0	0	0	0	0	0	0	6.7	260	1-12,16*
CCS372	27Mar05	14	14	0	0	1	1	0	0	0	0	0	0	0	0	0	5	5.4	224	3-14*
CCS373	01Apr05	5	5	0	0	0	0	0	0	3	0	4	0	1	0	0	1	3.8	295	1-14,16
CCS374	05Apr05	12	12	1	1	1	0	0	0	0	0	0	3	1	0	0	5	6.2	306	1-15,16

Table 2. Continued

Survey#	Date	Eg Sighted	Eg Photo'd	Ba	Bp	Mn	UNBA	UNMW	UNLW	La	Dd	Gm	Pp	UNDO	Hg	Pv	UNSE	Hours Flown	Distance Flown (nm)	Tracks Completed / Area Surveyed
CCS375	06Apr05	9	9	0	1	0	0	0	0	0	0	0	0	0	0	0	0	4.6	199	5-15*
CCS376	10Apr05	14	14	1	7	0	0	0	0	0	1	0	1	13	0	0	3	6.3	306	1-15,16
CCS377	16Apr05	13	13	2	7	2	0	0	0	0	1	0	0	1	0	0	5	6.5	295	1-14,16
CCS378	17Apr05	22	22	0	10	0	0	0	0	0	0	0	1	20	0	0	12	6.2	306	1-15,16
CCS379	22Apr05	15	15	4	8	5	0	0	0	0	0	0	0	0	0	0	3	7	306	1-15,16
CCS380	26Apr05	6	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.1	17	14*
CCS381	03May05	0	0	5	14	2	0	0	0	0	0	0	0	3	0	0	5	3.7	295	1-14,16
CCS383	05May05	0	0	2	10	4	0	0	0	15	0	0	0	65	0	0	0	4.1	306	1-15,16
CCS385	10May05	0	0	3	11	0	0	0	0	6	0	0	1	0	0	0	18	4.1	306	1-15,16
Total Cape Cod Bay and Track 16		**200**	**198**	**22**	**89**	**37**	**5**	**1**	**1**	**334**	**83**	**69**	**14**	**493**	**0**	**969**	**226**	**164.0**	**10093**	
Adjacent Waters																				
CCS355	02Feb05	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	2	149	ES
CCS357	08Feb05	2	2	0	0	1	0	0	0	0	0	0	0	21	0	0	0	2.4	147	NE
CCS382	04May05	6	5	2	1	6	4	0	0	2	10	0	2	99	1	1	17	3.6	286	GSC
CCS384	06May05	2	2	0	7	16	1	0	1	0	0	0	0	22	0	0	0	2.5	180	NE
Total Adjacent Waters		**10**	**9**	**2**	**9**	**23**	**5**	**0**	**1**	**2**	**10**	**0**	**2**	**143**	**1**	**1**	**17**	**10.5**	**762**	
Total All Surveys		**210**	**207**	**24**	**98**	**60**	**10**	**1**	**2**	**336**	**93**	**69**	**16**	**636**	**1**	**970**	**243**	**175**	**10855**	

+Survey effort during transit to/from survey area outside Cape Cod Bay.
*Survey cut short due to unsuitable weather conditions.

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 2005. Species abbreviation are explained in Table 1E.**

Cruise	Date 2004	Eg Sighted	Eg Photo'd	Ba	Bp	Mn	UNBA	UNLW	La	Pp	UNDO	Pv	UNSE	Hours At Sea
SW515	05Jan05	0	0	0	0	0	0	0	0	0	0	0	0	3.3
SW516	15Jan05	0	0	0	0	0	0	0	0	0	0	0	0	5.8
SW517	22Jan05	0	0	0	0	0	0	0	0	0	0	0	0	6.6
SW519	29Jan05	0	0	0	0	0	0	0	0	0	0	1	1	6.0
SW520	01Feb05	1	1	0	0	0	0	0	0	0	0	0	0	5.0
SW521	08Feb05	0	0	0	0	0	0	0	0	0	0	0	1	7.5
SW522	15Feb05	0	0	0	0	0	0	0	0	14	0	0	6	4.5
SW523	16Feb05	0	0	0	0	0	0	0	0	0	0	0	0	5.0
SW524	24Feb05	0	0	0	0	0	0	3	0	0	0	0	0	6.0
SW525	07Mar05	3	3	0	0	0	0	0	0	2	0	0	2	8.5
SW526	11Mar05	6	4	0	0	0	0	0	0	0	0	0	3	5.0
SW527	18Mar05	4	0	0	0	0	0	0	0	0	0	0	0	8.5
SW528	23Mar05	2	2	0	0	1	0	0	0	0	0	0	0	8.0
SW530	01Apr05	1	0	0	0	0	0	0	0	2	7	1	6	9.5
SW531*	05Apr05	16	9	0	0	0	0	0	0	0	0	0	0	9.0
SW532	06Apr05	2	0	0	1	0	0	1	0	0	0	0	0	5.0
SW533	07Apr05	0	0	0	1	0	0	0	0	0	0	0	0	6.0
SW535	13Apr05	8	8	0	3	0	0	0	0	0	0	0	0	10.0
SW536*	17Apr05	6	6	0	3	0	0	0	0	0	0	0	1	10.0
SW537	19Apr05	2	2	0	1	0	0	0	0	9	0	4	0	7.5
SW538##	22Apr05	2	2	0	0	0	0	0	0	0	0	0	0	6.5
SW539	26Apr05	4	3	1	4	0	1	0	0	0	0	1	0	8.0
SW541	04May05	0	0	0	9	0	0	0	0	7	0	0	1	7.5
SW544	10May05	0	0	0	7	0	0	0	0	3	0	0	0	8.0
SW545	14May05	0	0	0	2	0	0	0	0	1	5	0	0	6.5
Total		**57**	**40**	**1**	**31**	**1**	**1**	**4**	**0**	**38**	**12**	**7**	**21**	**173.1**

* Cruises dedicated to focal folllows and acoustic behavior
Cruise part of the Cornell/Pershing contract

Table 4. Number of survey days, demographic composition and number of right whales identified in all areas (A), in Cape Cod Bay (B) and in adjacent waters (C) from aerial surveys and R/V Shearwater cruises in two-week periods from December 2004 through mid-May 2005. The values in this table represent the minimum number of whales as photo-analysis has not been finalized. The total is lower than the sum of each line as many whales were seen during several 2-week periods. The shaded areas represent 2-week intervals when right whales were observed. The last interval (*) represent only 1 week.

A) All Areas (n=82)

Two week intervals	Dec-04	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 (all platforms)												
Number of survey days	2	4	2	7	5	6	5	6	6	5	2	50
Number of individuals identified	0	0	0	16	3	15	19	25	29	14	0	83
Demographics												
Male	0	0	0	5	0	4	8	7	4	2	0	27
Female	0	0	0	8	3	10	7	11	14	7	0	35
Unknown Sex	0	0	0	3	0	1	4	7	11	5	0	21
Calf	0	0	0	0	0	0	1	4	9	4	0	10
Juvenile	0	0	0	0	0	1	2	1	1	0	0	5
Adult	0	0	0	12	3	13	13	19	17	10	0	59
Unknown Age	0	0	0	4	0	1	3	1	2	0	0	9

B) Cape Cod Bay (n=45) ‡: Number between brackets are the survey days where there were no aerial survey effort (exclusively effort with R/V Shearwater)

Two week intervals	Dec-04	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 (all platforms)												
Number of survey days‡	2	4 (1)	2 (1)	7 (1)	5 (3)	6	5 (1)	6 (1)	6 (2)	4 (1)	2 (1)	48
Number of individuals identified	0	0	0	6	3	15	11	24	17	7	0	46
Demographics												
Male	0	0	0	0	0	4	3	6	3	0	0	13
Female	0	0	0	6	3	10	6	11	8	4	0	23
Unknown Sex	0	0	0	0	0	1	2	7	6	3	0	10
Calf	0	0	0	0	0	0	1	4	6	3	0	6
Juvenile	0	0	0	0	0	1	0	1	0	0	0	2
Adult	0	0	0	6	3	13	9	18	11	4	0	36
Unknown Age	0	0	0	0	0	1	1	1	0	0	0	2

C) Exclusively seen in adjacent waters (n=37)‡: ‡: Number between brackets represent the number of surveys east of CCB and in the GSC

Two week intervals	Dec-04	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)												
Number of survey days‡	2	3	1	6 (2)	2	5	4	3	4	4 (2)	1	
Number of individuals identified	0	0	0	10	0	0	8	1	12	7	0	37
Demographics												
Male	0	0	0	5	0	0	5	1	1	2	0	14
Female	0	0	0	2	0	0	1	0	6	3	0	12
Unknown Sex	0	0	0	3	0	0	2	0	5	2	0	11
Calf	0	0	0	0	0	0	0	0	3	1	0	4
Juvenile	0	0	0	0	0	0	2	0	1	0	0	3
Adult	0	0	0	6	0	0	4	1	6	6	0	23
Unknown Age	0	0	0	4	0	0	2	0	2	0	0	7

Table 5: Sighting records of identified right whales seen in CCB and adjacent waters, December 2004 to mid May 2005. F=female, M=male, J=juvenile, C=calves, U=unknown. "X" denotes the sighting date in CCB and bold "X" in adjacent waters. Brown are survey dates east of CCB and in the GSC. Light blue represent uncomplete surveys due to deteriorating weather. Pink represent dates of only shipboard effort.

Id#	Sex	Age category	2004 9-Dec	2004 18-Dec	02-Jan-05	09-Jan-05	11-Jan-05	15-Jan-05	30-Jan-05	01-Feb-05	02-Feb-05	07-Feb-05	08-Feb-05	09-Feb-05	14-Feb-05	17-Feb-05	26-Feb-05	28-Feb-05	05-Mar-05	07-Mar-05	10-Mar-05	11-Mar-05	13-Mar-05	18-Mar-05	20-Mar-05	22-Mar-05	*23-Mar-05*	26-Mar-05	28-Mar-05	01-Apr-05	05-Apr-05	06-Apr-05	10-Apr-05	*13-Apr-05*	16-Apr-05	17-Apr-05	19-Apr-05	22-Apr-05	26-Apr-05	03-May-05	04-May-05	05-May-05	06-May-05	10-May-05	# days sighted	Time Span: 1st to last sighting
2795	U	U							**X**																																				1	1
3040	M	U							**X**																																				1	1
1317	M	A							**X**																																				1	1
2470	M	A							**X**																																				1	1
2630	M	A							**X**																																				1	1
1027	F	A							**X**								X																												2	28
2460	F	A							X	X	X		X						X	X																			X	X						8	87
2240	F	A							X	X	X	X				X				X																										6	37
2123	F	A							X	X	X	X	X	X																															6	11
1123	F	A							**X**																																				1	1
1901	M	A							**X**																																				1	1
C1MX	U	U							**X**																																				1	1
1503	F	A								X	X							X																											3	28
1301	F	A										X	X	X		X			X	X		X																							7	33
1281	F	A											**X**																																1	1
BK02	U	U											**X**																																1	1
2145	F	A														X												X																	2	38
1249	M	A															X																												1	1
1968	F	A																X	X	X																									3	11
1608	F	A																		X		X		X	X				X																5	21
1507	M	A																		X																									1	1
1817	F	A																		X	X							X	X	X															5	26
1424	M	A																		X																									1	1
1209	F	A																				X				**X**		X								**X**									4	38
2140	M	A																				X			X	**X**																			3	12
3123	F	J																				X																							1	1
1802	F	A																						X																					1	1
2614	F	A																							X																				1	1

Table 5 continued

Id#	Sex	Age category	2004 9-Dec	2004 18-Dec	02-Jan-05	09-Jan-05	11-Jan-05	15-Jan-05	30-Jan-05	01-Feb-05	02-Feb-05	07-Feb-05	08-Feb-05	09-Feb-05	14-Feb-05	17-Feb-05	26-Feb-05	28-Feb-05	05-Mar-05	07-Mar-05	10-Mar-05	11-Mar-05	13-Mar-05	18-Mar-05	20-Mar-05	22-Mar-05	23-Mar-05	26-Mar-05	27-Mar-05	01-Apr-05	05-Apr-05	06-Apr-05	10-Apr-05	13-Apr-05	16-Apr-05	17-Apr-05	19-Apr-05	22-Apr-05	26-Apr-05	03-May-05	04-May-05	05-May-05	06-May-05	10-May-05	# days sighted	Time Span: 1st to last sighting
1980	M	A																							X	**X**																			2	3
2617	F	A																								X			X	X															3	11
1625	M	A																								X																			1	1
3190	U	U																								**X**										**X**									2	27
2615	M	A																								**X**																			1	1
1821	M	A																								**X**																			1	1
1032	M	A																								**X**																			1	1
2027	M	A																								**X**																			1	1
2910	U	U																								**X**																			1	1
3110	M	J																								**X**																			1	1
3180	F	J																								**X**																			1	1
C3MX	U	U																								X		X	X																3	6
1245	F	A																									X				X	X	X	X	**X**			**X**							7	31
1703	F	A																										X			X	X	X	X				X	X						7	39
1409	M	A																										X	X																2	2
1207	M	A																										X	X		X		X												4	16
1427	M	A																										X																	1	1
1131	M	A																										X																	1	1
1328	M	A																										**X**																	1	1
1241	F	A																											X		X		X		X	X	X	X	X						8	31
2223	F	A																											X	X	X	X	X		X	X		X							8	27
2271	M	A																											X																1	1
1122	M	A																													X		X												2	6
1267	F	A																													X														1	1
2350	U	A																													X														1	1
1042	U	A																														X													1	1
1310	F	A																															**X**		X	X		X							4	13
1303	F	A																															X	X	X	X		X	X						6	17
2530	M	A																																	X	X		X							3	7
1204	F	A																																	**X**	**X**									2	2
2320	F	A																																		**X**									1	1
2201	M	A																																		**X**									1	1

Table 5 continued

Id#	Sex	Age category	2004 9-Dec	2004 18-Dec	02-Jan-05	09-Jan-05	11-Jan-05	15-Jan-05	30-Jan-05	01-Feb-05	02-Feb-05	07-Feb-05	08-Feb-05	09-Feb-05	14-Feb-05	17-Feb-05	26-Feb-05	28-Feb-05	05-Mar-05	07-Mar-05	10-Mar-05	11-Mar-05	13-Mar-05	18-Mar-05	20-Mar-05	22-Mar-05	23-Mar-05	26-Mar-05	28-Mar-05	01-Apr-05	05-Apr-05	06-Apr-05	10-Apr-05	13-Apr-05	16-Apr-05	17-Apr-05	19-Apr-05	22-Apr-05	26-Apr-05	03-May-05	04-May-05	05-May-05	06-May-05	10-May-05	# days sighted	Time Span: 1st to last sighting
2413	F	A																																	X									1	1
1706	F	A																																	X									1	1
1632	F	A																																			X							1	1
1133	M	A																																						X				1	1
1320	M	A																																						X				1	1
1151	F	A																																						X				1	1
1125	F	A																																						X				1	1
1814	U	A																																						X				1	1
1013	F	A																																								X		1	1
1245C	U	C																							X				X	X	X	X	X			X							7	31
1703C	U	C																								X			X	X	X	X				X	X						7	39
1241C	U	C																									X		X		X		X	X	X	X	X						8	31
2223C	U	C																									X	X	X	X	X		X	X		X							8	27
2753	F	J																										X															1	1
1310C	U	C																													X		X	X		X							4	13
1303C	U	C																													X	X	X	X		X	X						6	17
1204C	U	C																															X	X									2	2
2413C	U	C																																X									1	1
CT17	U	U																																X									1	1
1632C	U	C																																		X							1	1
3101	F	J																																		X							1	1
1013C	U	C																																							X		1	1

Figure 1a. Cape Cod Bay study area including aerial survey tracks, boundary of Critical Habitat, state waters boundary, and shipping lanes.

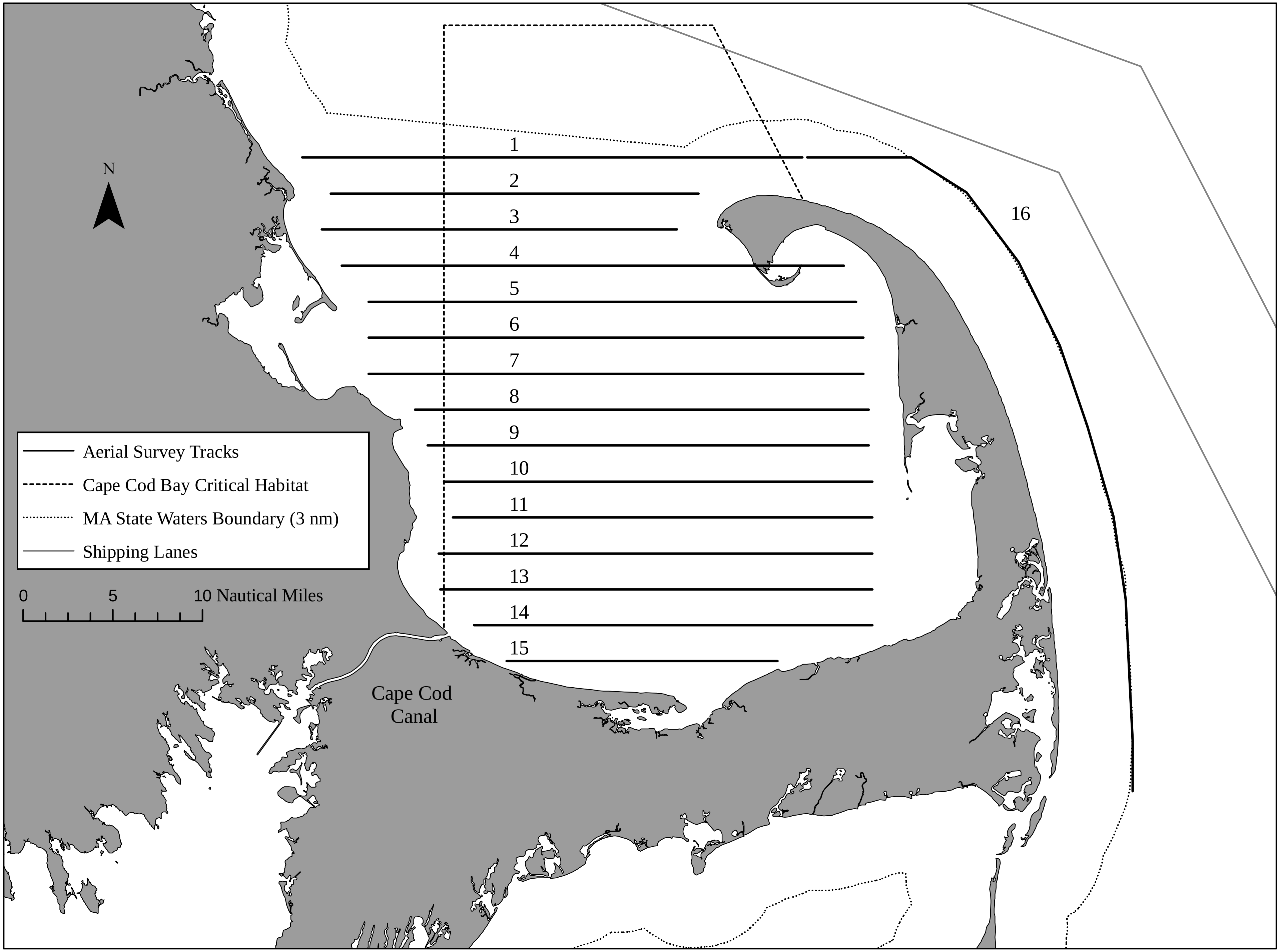


Figure 1b. Aerial survey track lines flown east of Cape Cod, 2 February 2005.

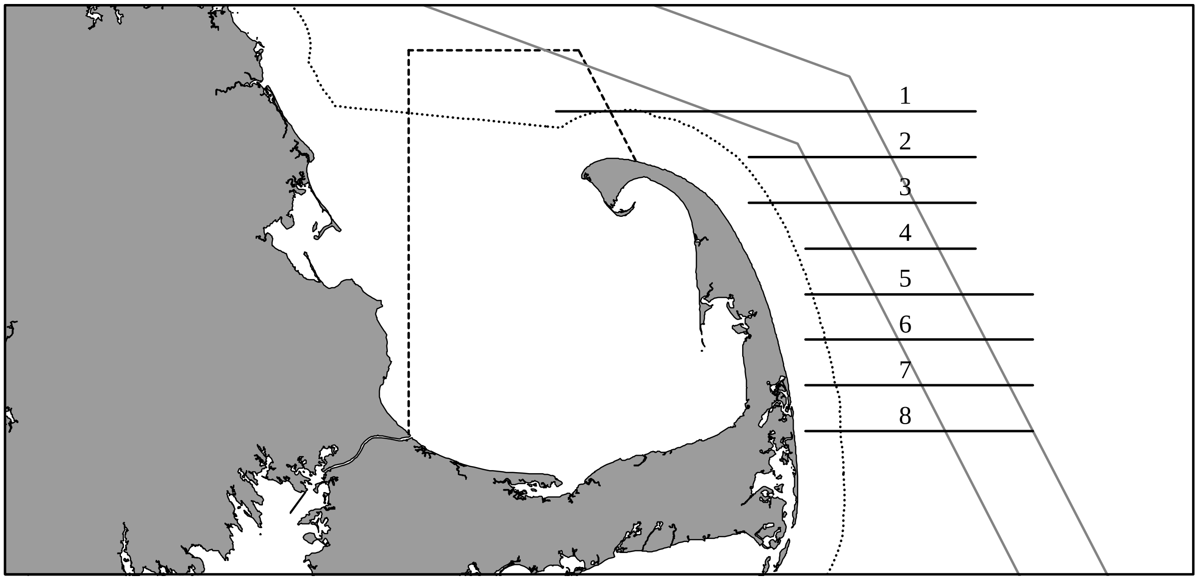


Figure 1c. Aerial survey track lines flown northeast of Cape Cod, 8 February and 6 May 2005.

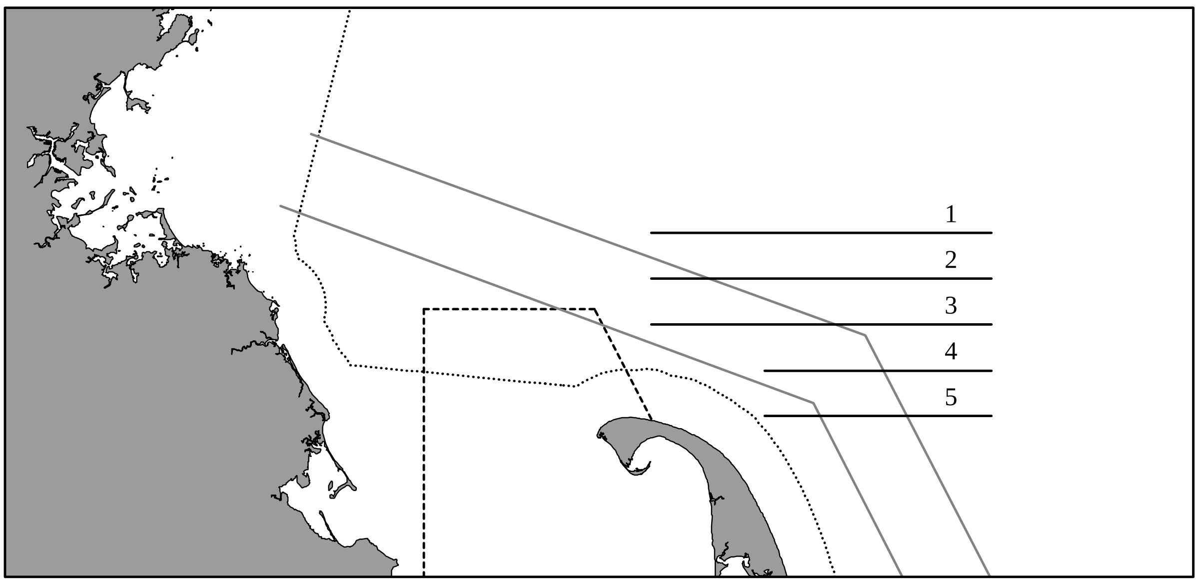


Figure 1d. Aerial survey track lines flown over the Great South Channel (SCOPEX), 4 May 2005.

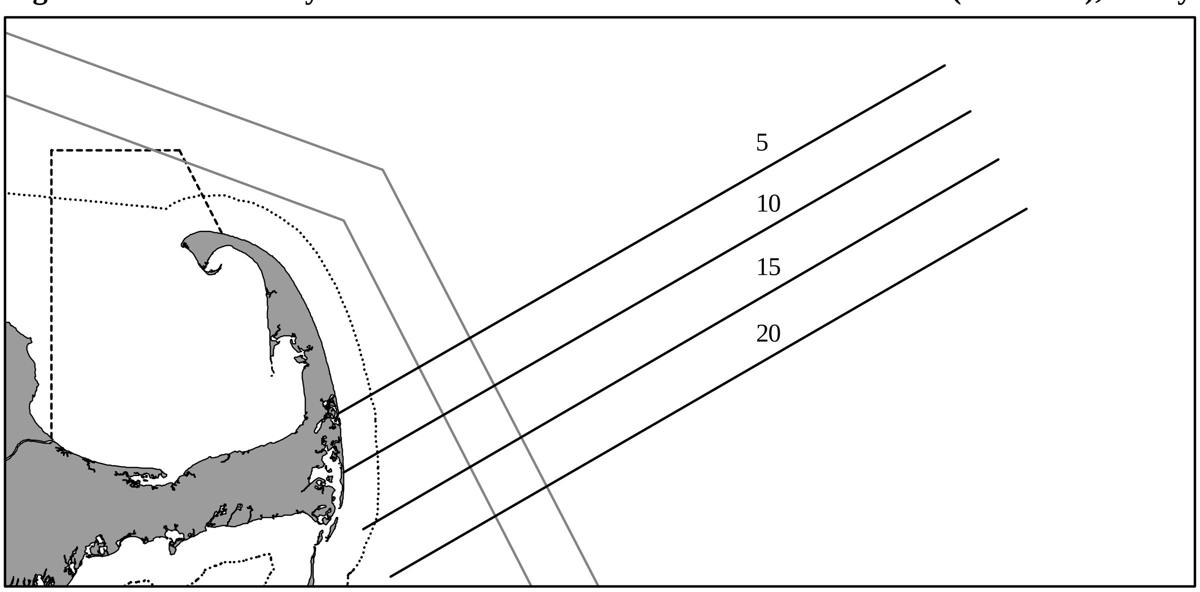


Figure 2a - d. Sightings of right whales from 12 aerial surveys of Cape Cod Bay and adjacent waters, 1 January - 25 February 2005.

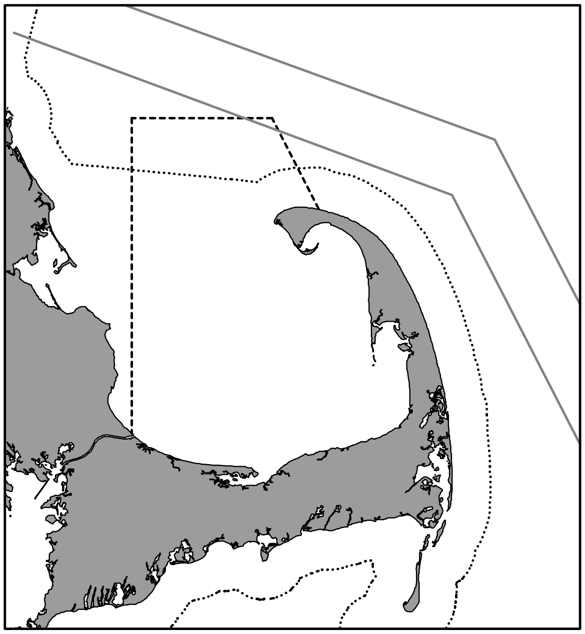


Figure 2a. 1 - 14 January

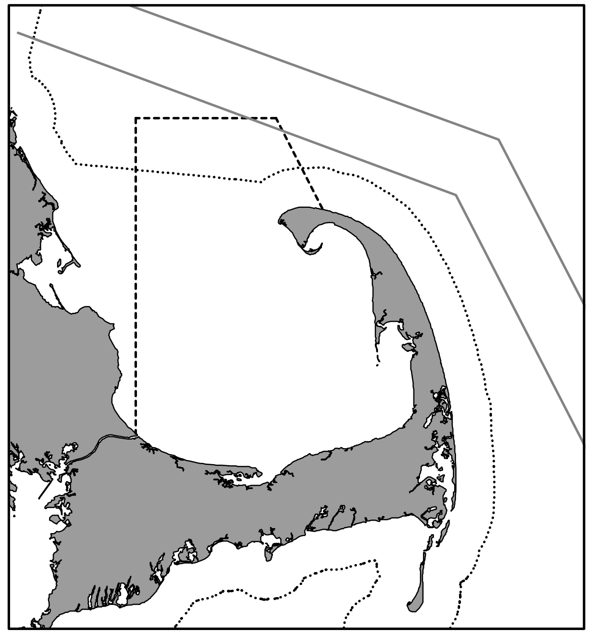
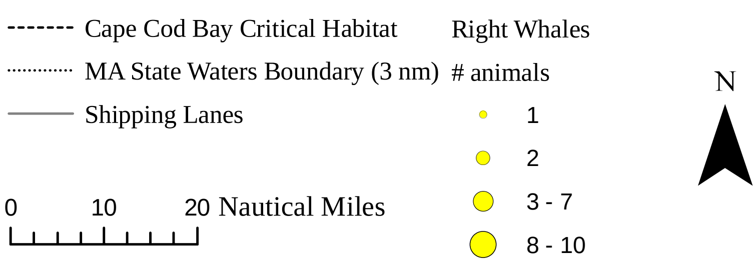


Figure 2b. 15 - 28 January



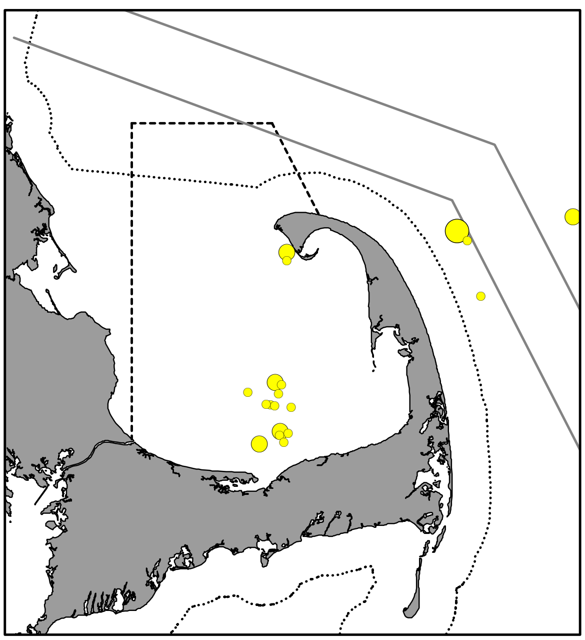


Figure 2c. 29 January - 11 February

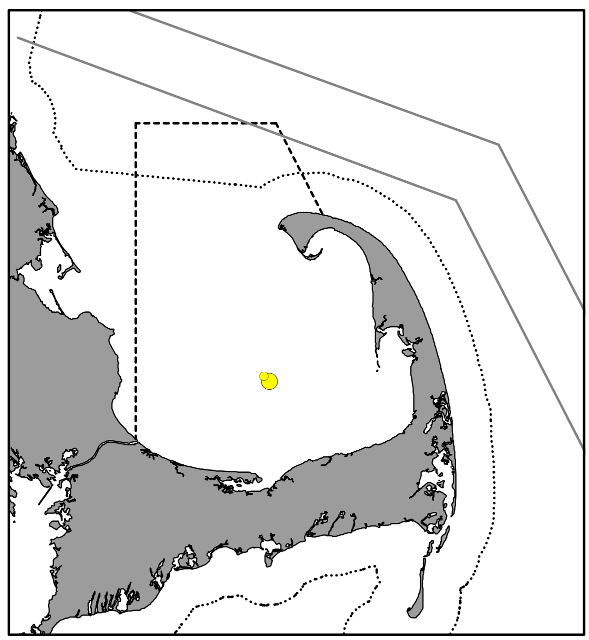


Figure 2d. 12 - 25 February

Figure 2e - h. Sightings of right whales from 19 aerial surveys of Cape Cod Bay and adjacent waters, 26 February - 22 April 2005.

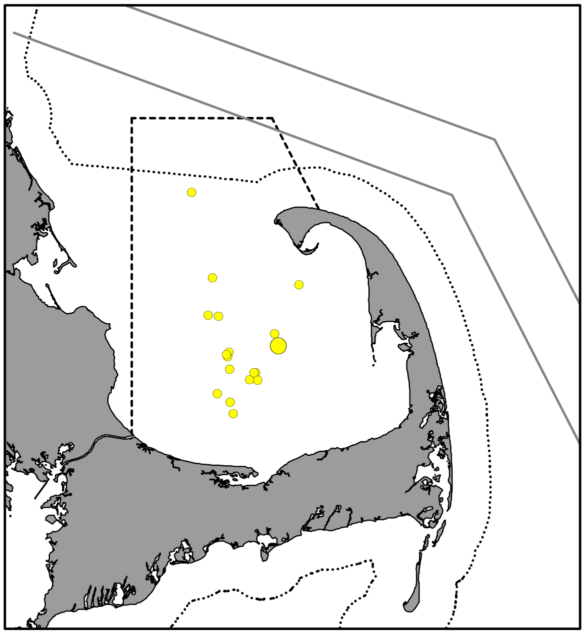


Figure 2e. 26 February - 11 March

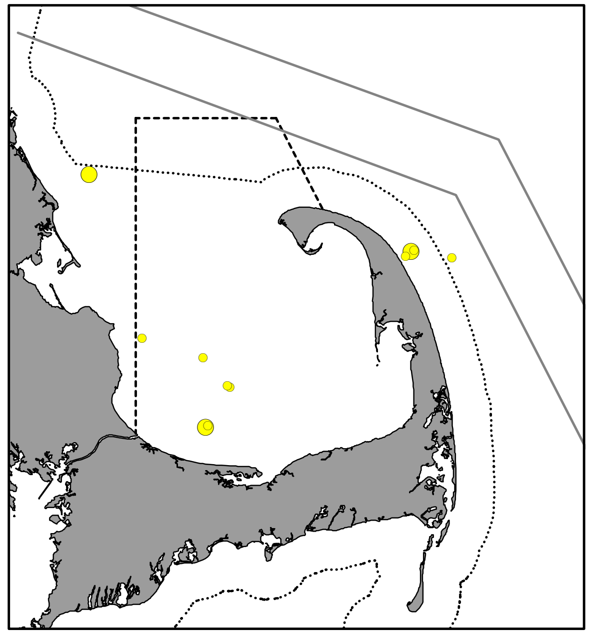
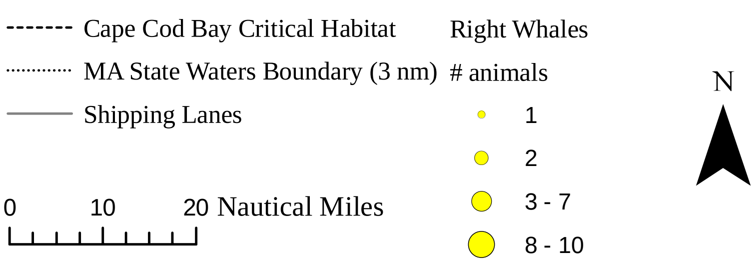


Figure 2f. 12 - 25 March



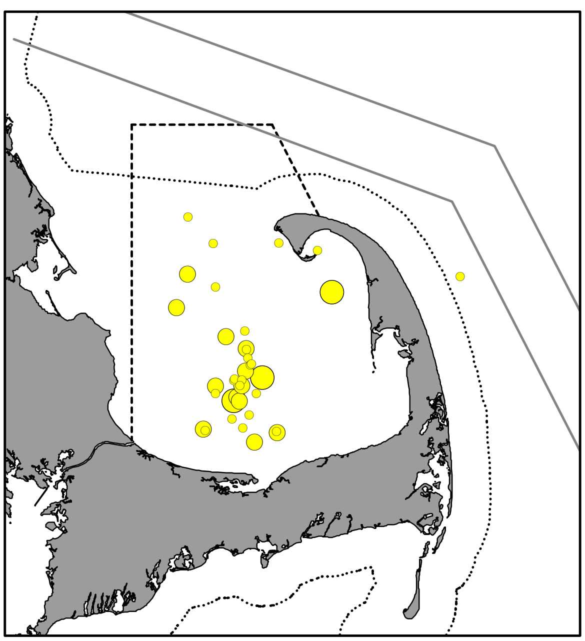


Figure 2g. 26 March - 8 April

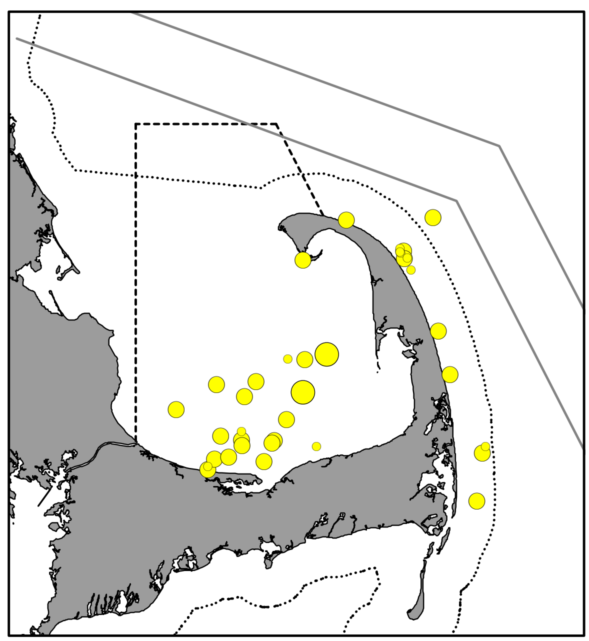


Figure 2h. 9 - 22 April

Figure 2i - j. Sightings of right whales from 6 aerial surveys of Cape Cod Bay and adjacent waters, 23 April - 15 May 2005.

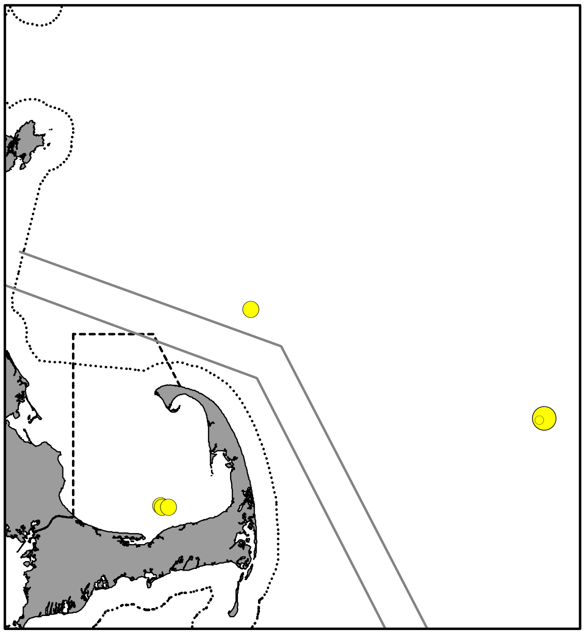


Figure 2i. 23 April - 6 May

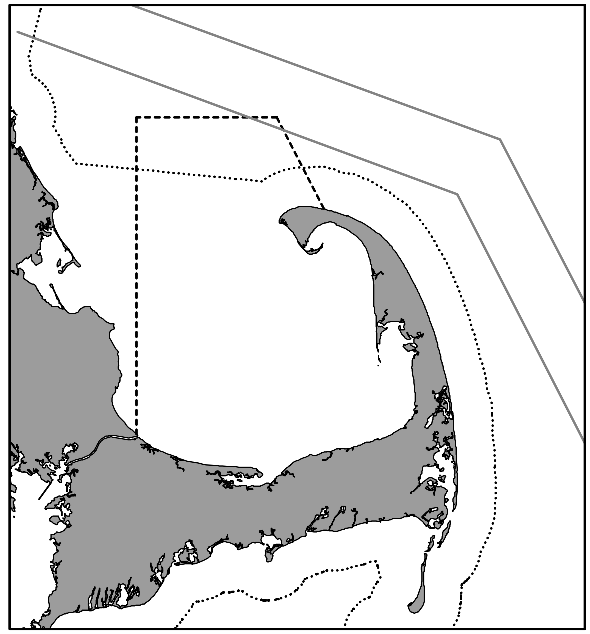


Figure 2j. 7 - 15 May

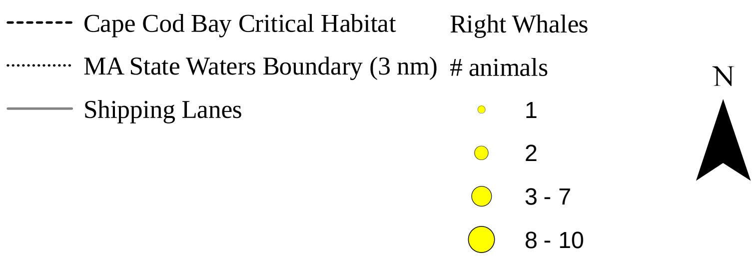


Figure 3a. Sightings of right whales from 41 aerial surveys of Cape Cod Bay and adjacent waters, 1 January - 15 May 2005.

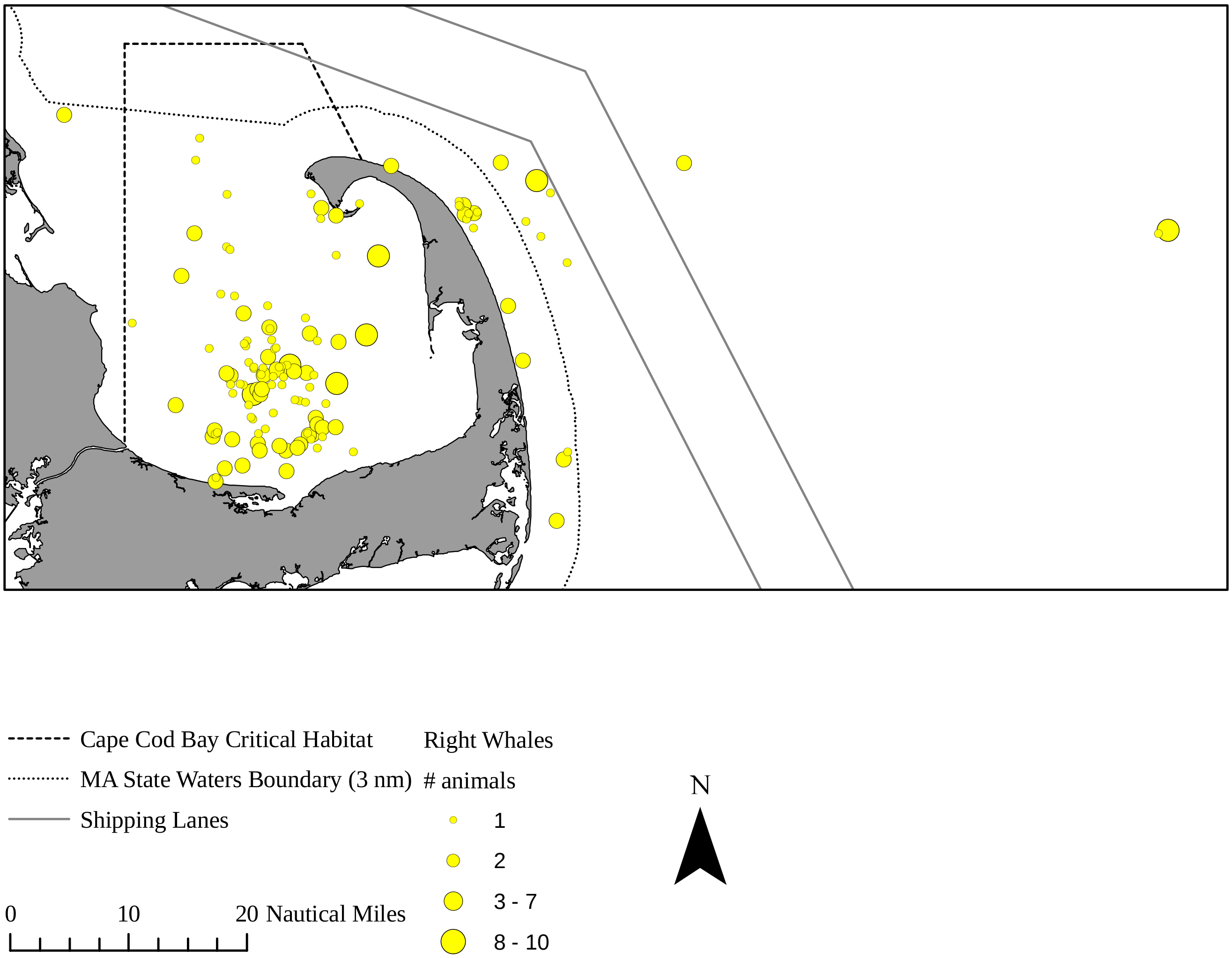


Figure 3b. Sightings of right whales from 2004 season (shown in red) over 2005 season sightings.

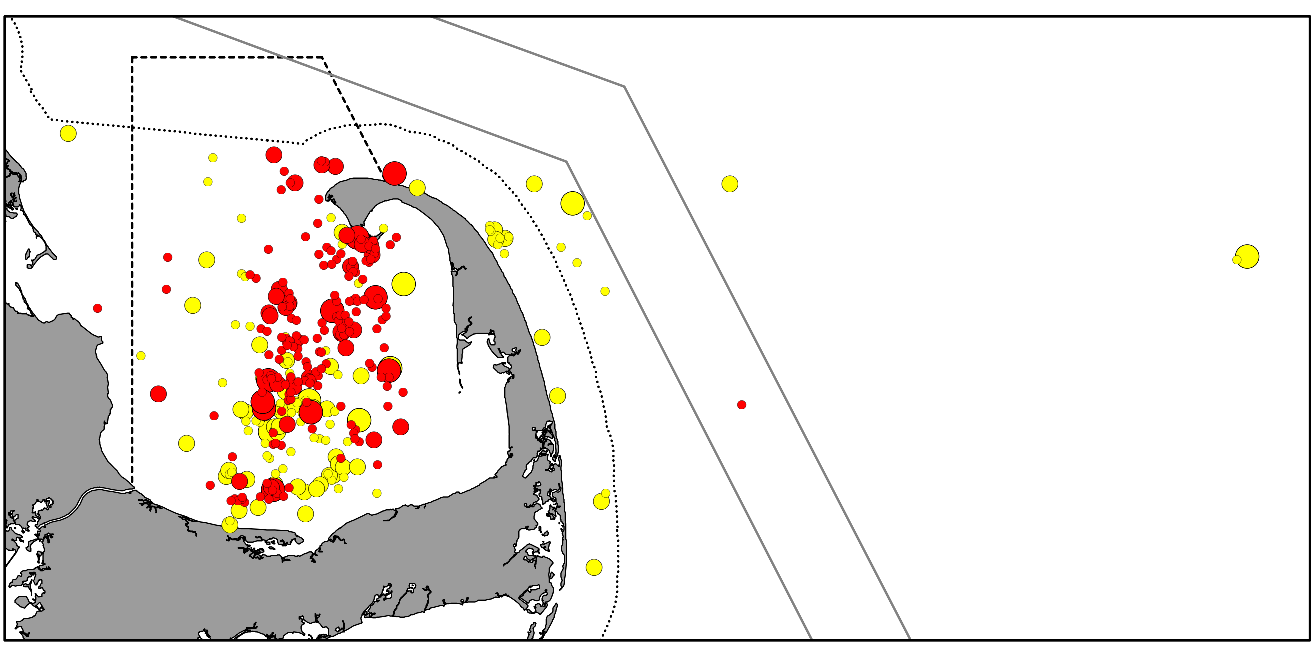


Figure 4. Sightings of vessels from aerial surveys of Cape Cod Bay and adjacent waters, 9 and 18 December 2004 and 1 January - 15 May 2005.

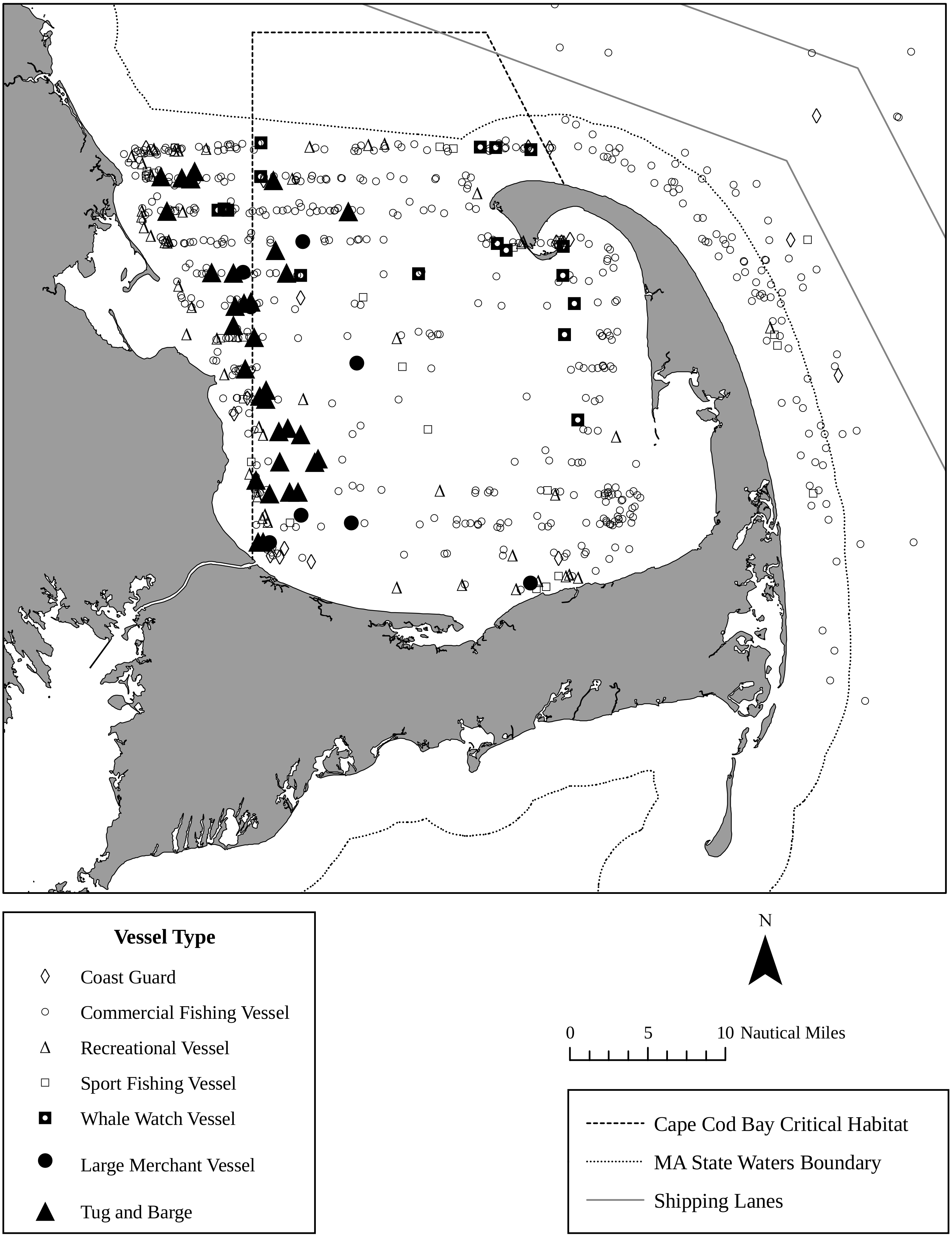


Figure 5a. Sightings of balaenopterid whales from aerial surveys of Cape Cod Bay and adjacent waters, 9 and 18 December 2004 and 1 January - 15 May 2005.

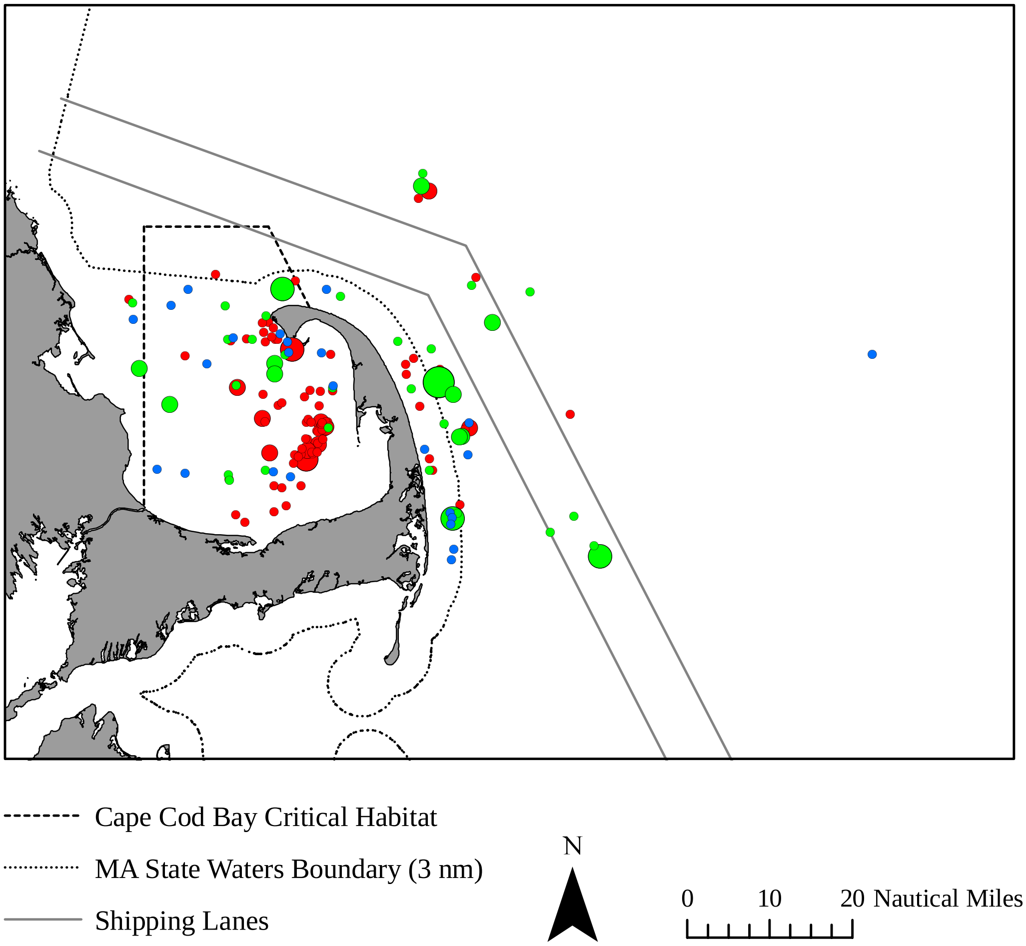
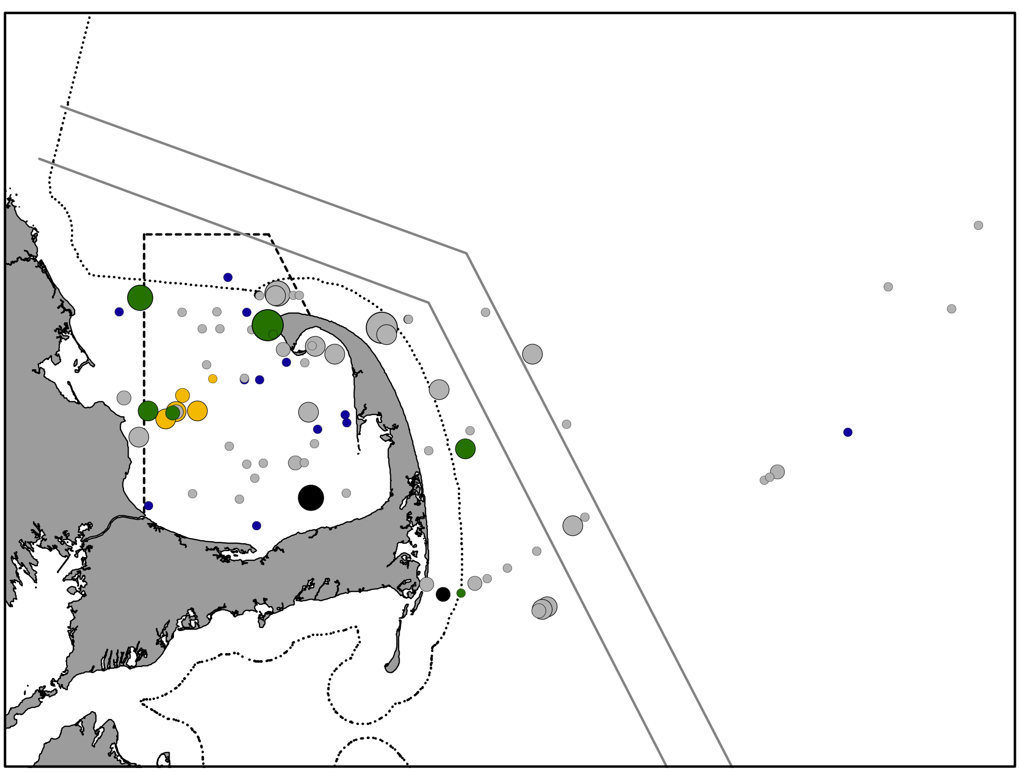
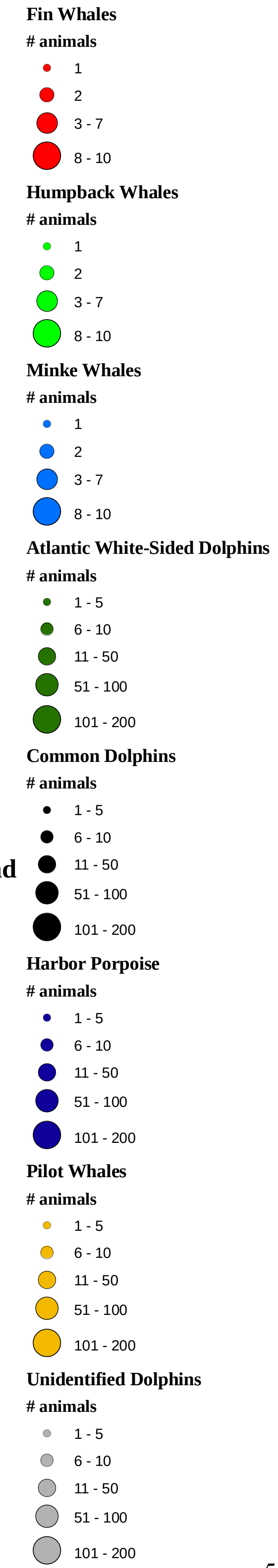


Figure 5b. Sightings of toothed whales from aerial surveys of Cape Cod Bay and adjacent waters, 9 and 18 December 2004 and 1 January - 15 May 2005.





Appendix I

Confirmed right whale identifications in Cape Cod Bay and adjacent waters 1998-2005 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	Y2005
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	G
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	MG
1032	M	F		F	F			GF	F	GF	GF	F	F	F	F	F	F	F	MF	F	GF	OF	F	GF	GMF		G
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	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	M
1123	F																										G
1125	F																										G
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		M
1133	M		GF		B	BF	MG		B	GB	B			F	MF		M	F	F	AF	GN	M			MO		G
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	G
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		
1204	F																										G
1207	M	A	G	G	GB			A		GB	B	F	G	F	F	J	F	SF	F	N	GF	F	G	OG	J	M	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	MG
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		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	MG
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	M
1267	F			J	F			GBF	B	BF	GFB	FS	M		MF	MF	MF	SMF	MF	MF	MGF	GOF	MSF	MGFJ			M
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	G
1301	F				MF	AM		MB		BS	SF	M	B	BS		F	MF	MF	FS	SAF	MF	MGBS	SGF	MGS	SF	SM	M
1303	F	F			MF	F		B			GF				SF	F	MF	MF	MF	JF	GF	GFS	SAGF	MGFS	SF		M
1306	M				MF		F	G	M	GF	GF	B	B	F	F	F	F	SFO	F	F	GF	MGOF	MG	MGF	F		

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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	MG
1311	M				GF		M	GB		GB	B		B	SB	F	MF	F		M		G	SMG	MG	MG	G		
1317	M				SM	MBJ		GB	B	M	SB		B			OF	F	F	MF	F	MGF	MGF	MG	F	GO		G
1320	M	O	G		B		G	B	B	M	SB	B	B		F								G	G	GMJ		G
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	G
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	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	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		M
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	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	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		M
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		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		G
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	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	G
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	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		

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1812	F									B	B		B		SF	F	F	S	F		MGF	MOGBF		SG	G	S	
1814	U																										G
1817	F									B	SB		S	S	SF	SF	FS	SF	F	S	G	MFS	SMGF	MGFS	SMF	SM	M
1820	M									B	B	B	B		M	F		SMF	MF	M	MF	MOF	MG	G		M	
1821	M									B	B											G		MG			G
1901	M										SGF		S	SF	SF	SF	SF	SMF	SMF	F	MGOF	SOFB	SMGFO	MGF	GOF		G
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	M
1970	F										B							S		O		S	A	MG			
1971	M										F	F		F	F	F	F	F	GF	F	GF	MSAOB	GOF	MF	SGF	M	
1980	M										B							SM		M		SMG			GM	M	MG
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			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	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		MG
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	M
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			G
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	M
2240	F													SF	SF	F	F	SFO	GF	MG	OGF	MOF	SGF	SGF	S	M	M
2271	M													SF	F	F	F	SMOF	NF	M	MGF	AMGOF	MF	OGF	M		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	G
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	M
2406	M														A	SMF	M	F	F	MF	MGF	MGOF	MGF	G	SGM		
2413	F																										G
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	M
2470	M															F	F	MF	F	MF	MGF	MGF	SF	MGF		M	G
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			

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2530	M																F	F	F	N	F	GF	GF	G	M	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		
2611	F																	SF	F	AF	F	F	GFO	F	AGM		
2614	F																	SMF		M	GF	F	GF	F		S	M
2615	M																	SF	F	AF	F	OF	GF	F	G		G
2617	F																	SF	SF	F	F	MF	MOF	SF		M	M
2630	M																	S	F	MAF	MF	GF	GF	G			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	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			
2795	U																										G
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		G
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			
3040	M																										G
3101	F																										G
3102	F																						SMGF	SM			
3103	F																					S	SMGF	MF	M		
3109	M																						SAN	MF	SMGF		
3110	M																					S	SMG	SAF			G
3123	F																						SOF	SF	M	S	M
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		G
3181	M																					S	SMF				
3190	U																					S	SGF	OGF		M	G
3240	F																							SAJGFC	GF		
3302	U																								SGF	SM	
3308	U																								JMF	S	
3317	U																							S	SMF	S	
3343	U																							S	SMF		
3351	U																							S	SMFJ	S	

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1145ca																								M			
1246ca																								G			
1310ca																								M			
1503ca																									SM		
2145ca																										SM	
2460ca																										M	
01-03																							G				
02-120																								M	G		

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Appendix II

Acoustic Detections of Northern Right Whales in Cape Cod Bay,

Sampled 29 October 2004 - 31 May 2005

Christopher W. Clark, Cornell Bioacoustics Research Program, 607-254-2405 cwc2@cornell.edu

There is good evidence from previous studies to support the assumption that passive acoustic methods could 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 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 two periods during this past season, starting in late October 2004 and ending in late May 2005, four moored auto-detection buoys were installed; three in Cape Cod Bay and one to the east of the Truro highlands. Each of these buoys was equipped with an electronic package to automatically detect right whale contact call and send detection data back to Cornell via a cell phone link.

For Cape Cod Bay, this applied research continued in 2004-2005 in collaboration with the Center for Coastal Studies[1]. The research expanded with the addition of the auto-detection buoys and the recognition that more information was needed on the specific relationships between food availability, the calling behavior of individual animals, and the density/distribution of animals in the Bay. 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 2004 and through spring 2005, the Cornell Bioacoustics Research Program deployed pop-ups in Cape Cod Bay. The first pop-up was deployed in ca. the middle of the Bay on 29 October 2004 in conjunction with the installation of three auto-detection buoys. The auto-detection buoys failed at slightly different times in January 2005 in association with extreme weather conditions. The single pop-up was recovered and replaced on 26 January 2005. Five more pop-ups were deployed on 31 March 2005. The three auto-detection buoys were replaced on 1 April 2005. Three more pop-ups were deployed on 17 April in conjunction with a CCS focal-follow cruise. All pop-ups were successfully recovered on 6 May 2005. The auto-detection buoys continued to operate until 31 May when intermittent transmissions started to occur due to exhausted batteries and operation. Pop-up positions of the full 9-element configuration established by 17 April are shown in Figure 1.

During the focal-follow of the mother-calf pair on 17 April 2005, a total of 1.2 h of single hydrophone recording was collected between 14:57 – 17:10 (local). There were 75 right whale calls detected. As many as six (6) of these calls were subjectively evaluated to be of sufficient clarity and intensity that they could possibly have been produced by the mother-calf pair.

[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 the Northern Right Whale Grant program and the Division of Marine Fisheries.

Figure 1. Positions of nine pop-ups and four auto-detection buoys deployed in Cape Cod Bay and to the east of Truro highlands. These devices were used to detect the calls of right whales during the 2004-2005 season.

**SECTION 2: MONITORING THE HABITAT OF NORTH ATLANTIC RIGHT WHALES IN CAPE COD BAY –
2005**

2.1. Introduction

This section addresses 2005 habitat sampling results in the context of Objective IV (see General Introduction) of the PCCS/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. The continually growing zooplankton database 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 2005 season was to continue the innovative technique developed in 2003 and further modified in 2004: the 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 (see Appendix II at the end of this section).

2.2. 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, a vertical plankton pump, and beginning in 2005, an Optical Plankton Counter (OPC) on loan from MA DMF. The equipment available has been refined to allow an accurate assessment of the resource with consideration of right whale feeding behavior in the vertical and horizontal planes. See Section 4 for discussion of the CTD and OPC sampling.

Zooplankton samples were collected at fixed stations and in the vicinity of whales both horizontally and obliquely using standard 333-micrometer (μm) mesh conical nets 30cm or 60cm in diameter fitted with a General Oceanics helical flow meter. This net collection technique has been employed since 1984 and therefore provides the most useful comparative measure of the conditions that support the feeding activities of right whales in Cape Cod Bay (CCB). 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 sampled was recorded using a 1" water meter. Field samples were kept in seawater on ice on board the vessel. In the laboratory the zooplankton samples were preserved in 6-8% formalin and settled overnight in graduated cylinders. 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). The settled volume was recorded and estimates of the caloric capture were made from the zooplankton density estimated from enumeration.

2.3. Results and Discussion

The supporting data for Sections 2, 3, and 4 of this report, including detailed counts of zooplankton to the lowest taxon for each plankton sample, multi-variable data from all CTD and OPC 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 Provincetown Center for Coastal Studies. Any data not reproduced in the Sections 2, 3, 4 or Appendices (described below) of this report are available to DMF upon request.

- ♣ Appendix I: System Data Record with Inter-annual Comparisons- 2005

  Figures of 2005 zooplankton densities, caloric densities, species composition, and interannual trends using various spatiotemporal treatments. Some figures follow formatting from 2004 or previous years and are updated to include 2005. All figures are self-explanatory, support conclusions drawn later in this section, and contribute to the characterization of the environment that in the winter and spring of 2005 supported 45 right whales in Cape Cod Bay (see Section 1) individually identified by the PCCS survey teams.

- ♣ Appendix II: System Assessment and Prediction- 2005

  Three examples (SW516- January 15, SW525- March 7, and SW545-May 14) of the early-, mid- and late-season 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 third year of this distribution list, and the number of subscribed individuals has grown to 60. As described in this report last year (2004), near real-time GIS plots of whale occurrence from PCCS aerial surveys with mean oblique zooplankton densities from recent cruises have been added to each assessment package. Additionally, these assessments have included data from the real-time automatic buoys constructed at the Bioacoustics Laboratory at Cornell University whenever available. These auto-buoys recorded and uploaded right whale calls in Cape Cod Bay during the 2005 season.

The 2005 right whale habitat field season began on 5 January and continued through 14 May with a total of 22 cruises in Cape Cod Bay. Two additional cruises in the bay during the month of June were dedicated to fine-scale field testing and calibration of the new Optical Plankton Counter. On 29 July, an additional cruise aboard R/V *Ibis* was added in response to recent sightings of right whales reported in the northwestern corner of Stellwagen Bank. Two zooplankton samples were collected in the vicinity of a mother calf right whale pair during this cruise.

As in 2004, eight stations (weather permitting) were sampled on every cruise. The configuration of stations changed slightly at the end of January 2005 when station 8N was replaced with station 9N to provide more even geographic coverage of the western bay.

The total number of zooplankton samples collected (Table 1) from surface tows, oblique tows, and vertical pump casts during 2005 was comparable to that from 2004: 434 and 484, respectively. The difference of 50 samples results from fewer 2005 vertical pump casts and is explained by an increase in casts in 2004 due to an exceptionally widespread, durable, and concentrated mid to deep water zooplankton resource.

Zooplankton densities throughout Cape Cod Bay in surface and oblique net tows, when analyzed over the entire field season, were notably lower than the previous season and many prior years as well (Figure 1, note this figure is reproduced in Appendix I). For much of the 2005 season, stations in the eastern and western halves of the bay often displayed daily opposing highs and lows in copepod concentrations, but were comparable in total zooplankton density when data from each half of the bay were averaged over the entire season. Additionally, no individual stations or quadrants showed mean seasonal densities that were measurably higher or lower than the bay-wide average. This relatively uniform distribution of zooplankton in the bay is not a typical annual occurrence; often certain stations, quadrants, or halves of the bay produce higher densities consistently throughout the season. Generally, a higher rate of right whale sightings is associated with these areas. The lower total zooplankton densities in 2005 were primarily a result of reduced contributions from Centropages spp. and Pseudocalanus spp., the usual early and mid- season dominant copepod taxa in CCB. The seasonal progression of dominant taxa (Centropages spp. to Pseudocalanus spp. to Calanus finmarchicus) observed annually in CCB began earlier than in previous years, resulting in a shorter period of peak Centropages spp. and early increases in Pseudocalanus spp. and C. finmarchicus in the mid and late season, respectively.

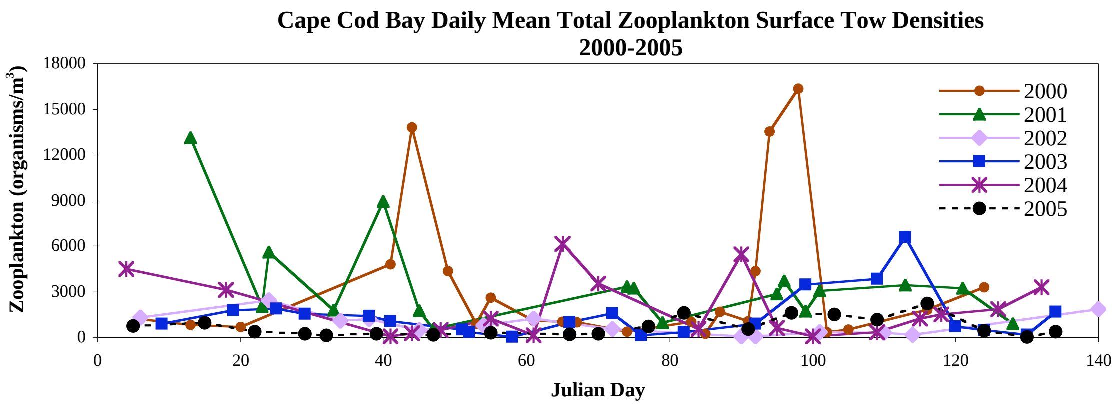


Figure 1. Daily mean surface layer zooplankton densities in Cape Cod Bay 2000-2005.

2.3.1 Surface Tows

Unless noted otherwise, all graphs in this report displaying zooplankton data are based on samples collected at the eight fixed 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.

The mean daily pattern of surface total zooplankton densities in 2005 mirrored that seen in 2003. In both years initial densities measured on the first cruises of the season decreased at the end of January and continued to be low until late March or early April, when zooplankton concentrations increased and maintained consistent levels for roughly a month, decreasing again at the end of April and remaining low through the end of the season. However, mean densities in 2003 were much greater than in 2005, with the peak of the season approximately three times higher. The 2003/2005 pattern of changes in the surface zooplankton was not observed in 2004. The 21 cruises undertaken that year showed more daily high to low variation in densities, with three "peaks" of high densities: early January, late March, and the last day of sampling, 11 May. Additionally, daily means of all samples collected were much higher in total zooplankton densities than in either 2003 or 2005. Figure 1 above shows that 2005 mean daily densities were almost always lower than the previous 5 years, and even with the increase recorded in the 3rd week of March mean zooplankton values often remained generally below 2000, 2001, 2003, and 2004 levels. The 2005 surface layer abundance of the three primary copepod taxa (*Centropages* spp*.*, *Pseudocalanus* spp. and *Calanus finmarchicus*) known to be fed upon by right whales in CCB is discussed in more detail below.

- ♣ *Centropages* spp.: None of the samples primarily composed of either of the two *Centropages* species seen in CCB, *C. typicus* and *C. hamatus,* contained densities over the 3,750 organisms/m^3 right whale feeding threshold. Also, none of the samples collected in the vicinity of presumed or confirmed feeding right whales were dominated by *Centropages* spp. When compared with a treatment only available for the past two years, the 2005 seasonal peak *Centropages* spp. density was roughly six times lower than in 2004. This peak, which always occurs in January, was followed in both years by a rapid decline starting in the third week of the month and continuing until the end of the season. This general decline was punctuated by brief periods of higher densities in the third week of February and the second week of March. When measured by age, late stages (V-VI) of *Centropages* spp. are always more abundant than early stages (I-IV). In the past two years few or no early stage *Centropages* spp. were collected during the period from the third week in March until the second week in May, at which time low numbers again appeared in the collections. To analyze patterns of abundance in greater detail, comparison of 2005 *Centropages* spp. densities with the prior six years (1999-2004) can be made by two-week increments. Resulting data also show 2005 densities lower than other years, see Figure 2.

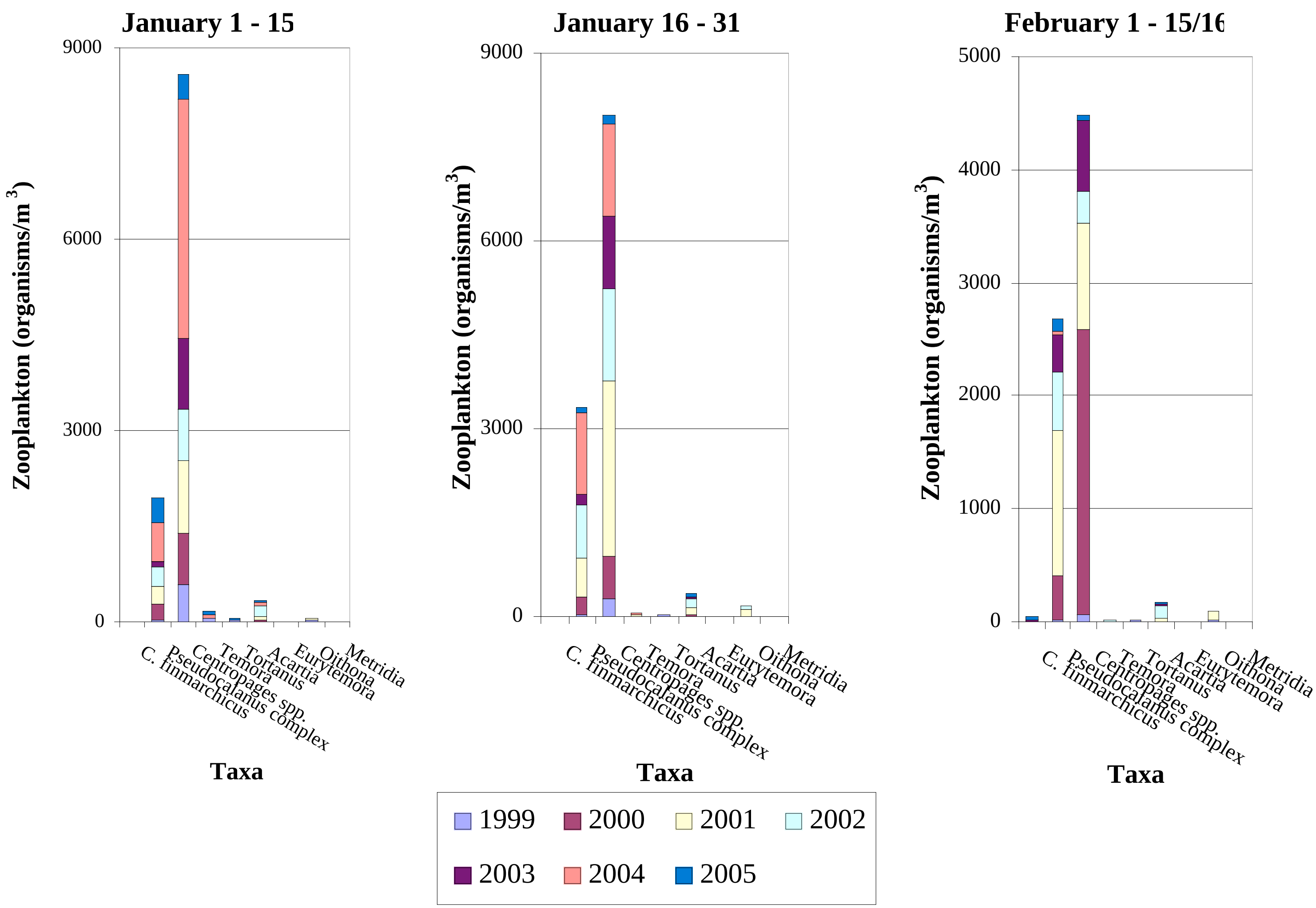


Figure 2. Surface zooplankton densities of nine common Cape Cod Bay copepod taxa during two- week periods 1999-2005. Note scale differences among graphs. Legend shown applies to all graphs.

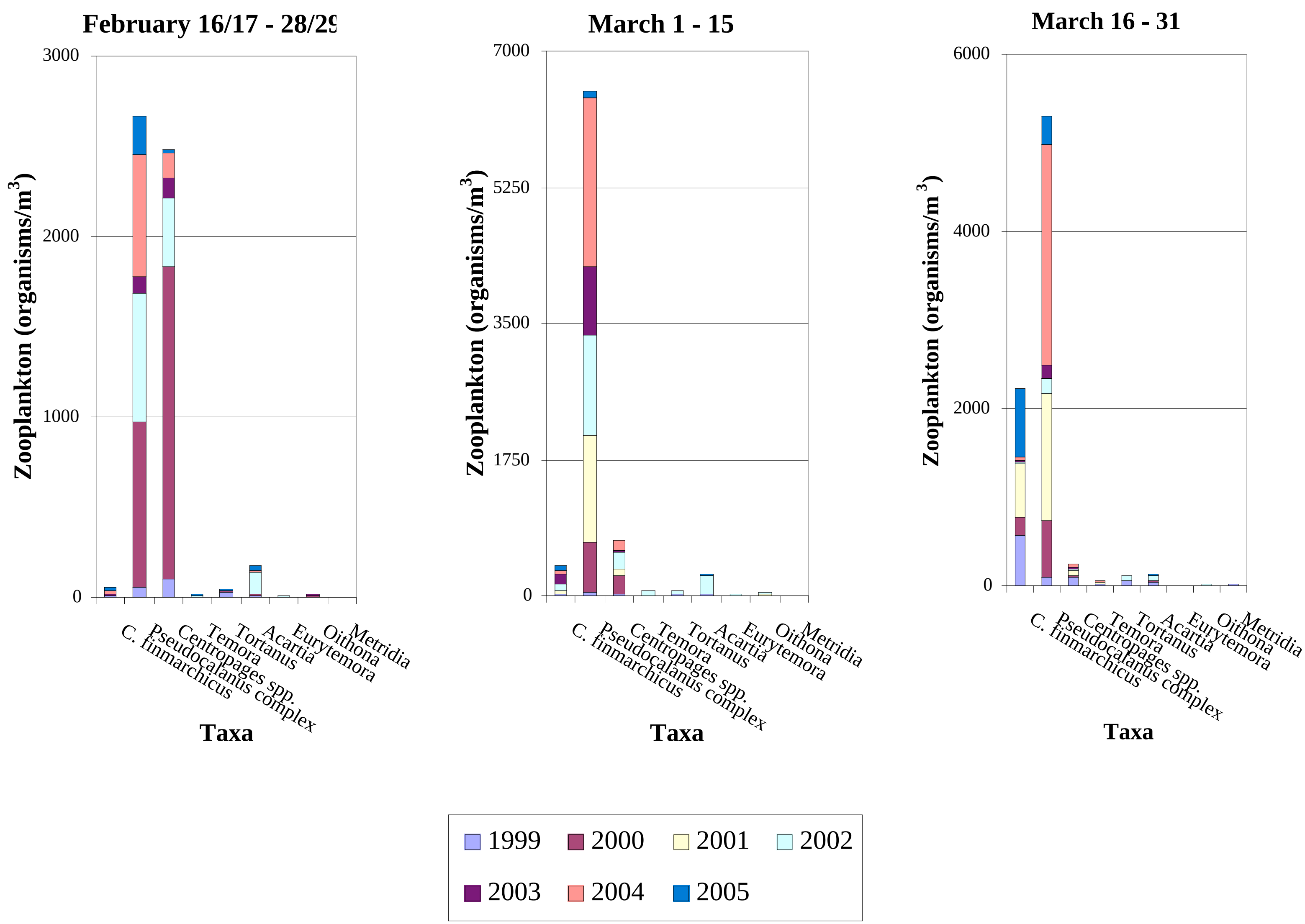


Figure 2 continued. **Surface zooplankton densities of nine common Cape Cod Bay copepod taxa during two- week periods 1999-2005. Note scale differences among graphs. Legend shown applies to all graphs.**

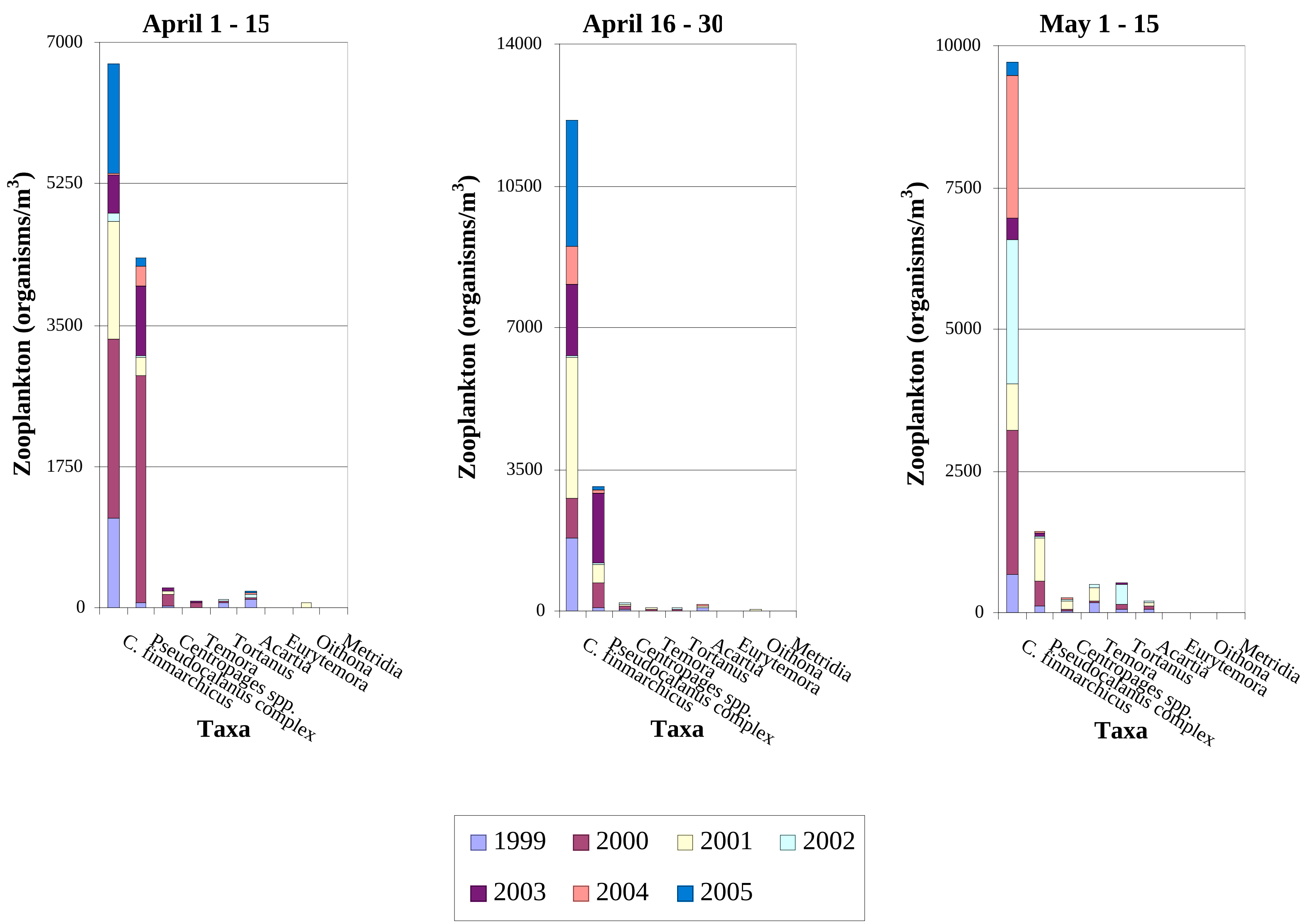


Figure 2 continued. **Surface zooplankton densities of nine common Cape Cod Bay copepod taxa during two- week periods 1999-2005. Note scale differences among graphs. Legend shown applies to all graphs.**

When the contribution of *Centropages* spp. to the total zooplankton resource in the month of January is compared to the past, the relative composition was much lower (47%) than any of the other years this treatment is available (70% - 80% in 1999 -2004). Among those years, the January copepod species composition in CCB in 2005 was most similar to that of 2002. The relative monthly percent composition of *Centropages* spp. through the subsequent four months of the season remained low, often the lowest of the previous six years. Likely as a result of large scale environmental and oceanographic processes occurring throughout the Gulf of Maine, the 2005 surface abundance of *Centropages* spp. in CCB was significantly lower than in recent years.

♣ *Pseudocalanus* spp.: The highest daily mean surface density of *Pseudocalanus* spp. (also referred to as *Pseudocalanus* complex) was found on 23 March, with an unusually early secondary peak on 15 January. The timing of the highest mean density is just a week earlier than in 2004, although there was a secondary peak the second week in March during 2004. The month of March is the period of highest *Pseudocalanus* spp. production in CCB, even though there is variation in exact timing of maximum densities. Data have shown large fluctuations in bay-wide daily density measurements from January until early or mid April, when abundance of *Pseudocalanus* spp. drops off consistently and rapidly. Comparison of surface densities between 2004 and 2005 shows a decrease in most daily means by an order of magnitude in 2005, an event likely of significant consequence to right whales feeding in the bay. The same distinction in early and late stages previously described for *Centropages* spp. can also be applied to *Pseudocalanus* spp. Late stages of *Pseudocalanus* spp. are always more abundant in PCCS 333 µm surface net tows. In contrast to data from 2004, when the abundance of early stages gradually tapered off as the season progressed, there was no seasonal pattern to the variation of early and late stage abundance in 2005.

The month of January displayed the highest percent composition by count of *Pseudocalanus* spp. (38%) measured since 1999. This is a consequence of the low densities of *Centropages* spp., the normally dominant taxa during January, combined with the unusual brief rise in *Pseudocalanus* spp. densities during mid- January discussed above. February's relative percentage was within the normal range and exactly matched that seen in 2002, while March showed an extremely low relative percentage of *Pseudocalanus* spp. (31%, compared to a range of 65% to 95% generally seen). Because samples with the highest densities of *Pseudocalanus* spp. are usually collected in March, this reduction in relative abundance exemplifies a decrease in the biomass and available caloric energy for right whales. The contribution of *Pseudocalanus* spp. relative to other copepod taxa remained weak through the end of the 2005 season. As compared to the previous six years (with the exception of 2003 which was also a year with low *Pseudocalanus* spp. densities), the abundance of *Pseudocalanus* spp. was only within the expected range during the first two weeks in January, while the remainder of the season resulted in comparatively low densities.

- ♣ *Calanus finmarchicus*: The presence of *C. finmarchicus* in surface samples collected from CCB spanned a longer time period than in most prior years. Samples taken on every cruise of the season had at least some *C. finmarchicus* present. This is unusual, especially during the months of January and February. Densities began to rise rapidly on 18 March, and with the exception of a brief drop on 1 April, rose to a peak mean daily value on 26 April. After this peak, densities decreased steadily through the end of the season, on 14 May. This period of high *C. finmarchicus* densities occurred approximately one month earlier than in 2004, when the increase began on 24 April, and peaked on 11 May, the last day of sampling for the season. Although the duration of highest densities was shorter and the timing earlier, the mean surface density measurements of *C. finmarchicus* were comparable to those at the late April peak in 2004. When analyzed in two-week increments, the last two weeks in April contained the highest densities of the season. This is consistent with most other years from 1999-2004. Additionally, during the entire month of April, 2005's densities were higher than those recorded from the previous three years. However, in May these values decreased to levels below those observed in 1999-2004.

  Although *C. finmarchicus* was collected on every cruise during the first two months of the season, these early season densities were extremely low. Even though from 5 January through 11 March the majority of *C. finmarchicus* were late stage and therefore more calorically rich, these low densities likely contributed to the lack of right whales seen in the bay. Once densities started to rise in mid March, the age composition shifted to nearly 90% early stages. This pattern has been observed during the last few years when samples have been staged. Many sample densities were over the right whale feeding threshold, yet sightings of right whales remained low. Most *C. finmarchicus* seen during this period were stages III and IV; a less rich and hence less attractive food item for right whales.

  The pie charts displaying the relative percent composition of copepod taxa in Appendix I show graphically the results discussed above. The percentage of *C. finmarchicus* as compared to other copepods was a record high for the months of January, February, March, and April, and was second only to 2004 during the month of May. The unusually low densities of *Centropages* and *Pseudocalanus* spp. contributed to these high percentages during the 2005 season.

2.3.2 Oblique Tows

Tows with the oblique net consistently result in higher densities than those performed with the surface net. However, occasional exceptions to this rule can occur in discrete patches of a concentrated layer of surface zooplankton. Oblique densities are higher as a result of both the wider mouth diameter of the oblique net and the greater depth of collection (19 meters). Depending on the behavior of right whales, either tow type can be extremely valuable in characterizing the food available to the whales. In 2005, mean values from oblique tows were approximately two times higher than those from surface tows. The similarity between 2003 and 2005 mentioned in section 2.3.1 is also present in oblique tows, however in 2003 densities in January were much higher than in 2005.

Unlike surface tows, which have been conducted regularly at PCCS since 1984, oblique tows have only been consistently performed since January 2003, and therefore comparative analysis is limited to a three year period. However, similarities in seasonal abundance patterns between surface and oblique tows are commonly seen.

- ♣ *Centropages* spp.: In oblique tows, 2005 mean densities of *Centropages* spp. were about five times lower and appeared to weaken a little earlier than in 2004. The seasonal pattern of abundance and stage composition was similar to that described for surface tows, although the densities were slightly higher. It is difficult to compare *Centropages* spp. densities with those from 2003, as oblique tows were not performed during the first three and a half weeks of that season, a critical time for *Centropages* spp.
- ♣ *Pseudocalanus* spp.: The mirroring of surface and oblique zooplankton densities seen in 2004 was present again in 2005. However, 2005 *Pseudocalanus* spp. mean oblique densities were an order of magnitude lower than 2004. Oblique densities during 2005 were approximately twice as high as surface densities. The seasonal peak in oblique *Pseudocalanus* spp. densities was early (15 January, before any right whales had been sighted in CCB), but similar densities were recorded two weeks later on 1 February when a small area near feeding right whales in the southeastern quadrant of CCB was sampled. This was the only day that right whales were observed feeding on patches of zooplankton primarily composed of *Pseudocalanus* spp. during the entire season. Yet relatively low sample densities (~1000 organisms/m^3) likely prevented this area from supporting feeding by a higher number of whales or for a longer period of time.
- ♣ *Calanus finmarchicus*: The pattern of *C. finmarchicus* densities in oblique tows differed between 2004 and 2005. Abundance at the season's end remained high in 2004, but in 2005 was quite low on the last few cruises. However, this low abundance in oblique tow during May matches the 2005 surface tow abundance pattern. Also, the stage composition was similar between oblique and surface tows, with late stages dominating the early season, and early stages more common during the later season. In 2005, oblique densities were consistently higher than surface densities. This is consistent with right whale behavior recorded during cruises: whales were seen more often on long dives than engaged in surface skim feeding. The trend of increasing densities started during the second week of March, earlier in oblique tows than in surface tows. The brief drop in surface density on 1 April was not observed in oblique tows, although a drop was recorded on 6 April. The peak mean oblique daily density occurred on 19 April, and then immediately began to decline. Coincidentally, this same day also logged highest seasonal oblique *C. finmarchicus* densities in 2003 and 2004. Finally, the occurrence of increasing *C. finmarchicus* densities seen in oblique tows a week or two before surface tows was also recorded in 2004.

2.3.3 Vertical Profiles (pump samples)

Less than 20% of all samples collected through the vertical pump system in 2005 were within 2nm of right whales, and none of these whale samples contained densities over the 3,750 organisms/m^3 right whale estimated feeding threshold. The only vertical pump sample with a density above the threshold was collected on 1 April at station 7M, at a depth of 34m (bottom depth ~34.5m) and was 4,210 organisms/m^3. Although no right whales were present at this station, whales were seen by the PCCS aerial survey team approximately 8nm to the south on this day. Most of the samples from the water column (1-28m) were dominated by *C. finmarchicus*, but it is worth noting that the samples from 31 and 34m, including the sample with a total zooplankton density above feeding threshold, were composed primarily of *Pseudocalanus* spp. Results from oblique and surface net tows on 1 April did not show comparable densities of *Pseudocalanus* spp. During the 2005 season, this was the only occurrence of an engybenthic layer of *Pseudocalanus* spp., yet during mid February and early March 2004 near station 6M a layer of *Pseudocalanus* spp. was observed near the bottom that occasionally reached densities greater than 90,000 organisms/m^3.

2.3.4 Samples Collected in Right Whale Presence

In 2005, thirteen surface tows were conducted with right whales present within approximately 2nm. Of these, whales were observed surface skim feeding on only one day, subsurface feeding with mouth visible and open on three days, engaged in long dives on five days, and of undetermined behavior on one additional day. Eighteen oblique tows met the same criteria of whale presence, six days with whales on long dives (implying, but not confirming feeding), one day of undetermined behavior, and three days of shallow subsurface feeding described above.

Figure 3 (A and B) displays total zooplankton sample densities in context with associated right whale behaviors when whales were within 100m of the collected sample. In Figure 3A, surface tow data, the sample with the highest total zooplankton density is labeled "P", a designation that describes how the sample was collected: from the path of the mouth of a whale as it was shallow subsurface feeding. Two other samples, labeled with a "2" and "1" were collected on the same day in the same area where whales were believed to be feeding on euphausiids which successfully escaped capture in the plankton net. As these whales were surface skim feeding, densities would likely be higher if the targeted zooplankton were the less-evasive copepods. Sample "2" contains a higher density because it was collected with a wider diameter net towed horizontally at the surface, making escape by euphausiids slightly more difficult. Finally, the low density of sample "3" is surprising because a whale was subsurface feeding, presumably on a patch near or above the feeding threshold, while the net captured water from the same depth. A possible explanation for this may be related to the dynamic nature of zooplankton patches, constantly changing size and shape and therefore creating patches of varying densities even within 100m. In Figure 3B, oblique tow data, sample "4" near a feeding whale has a surprisingly low density possibly as a result of sea conditions, Beaufort 4, which may cause patches to be highly unstable and short-lived.

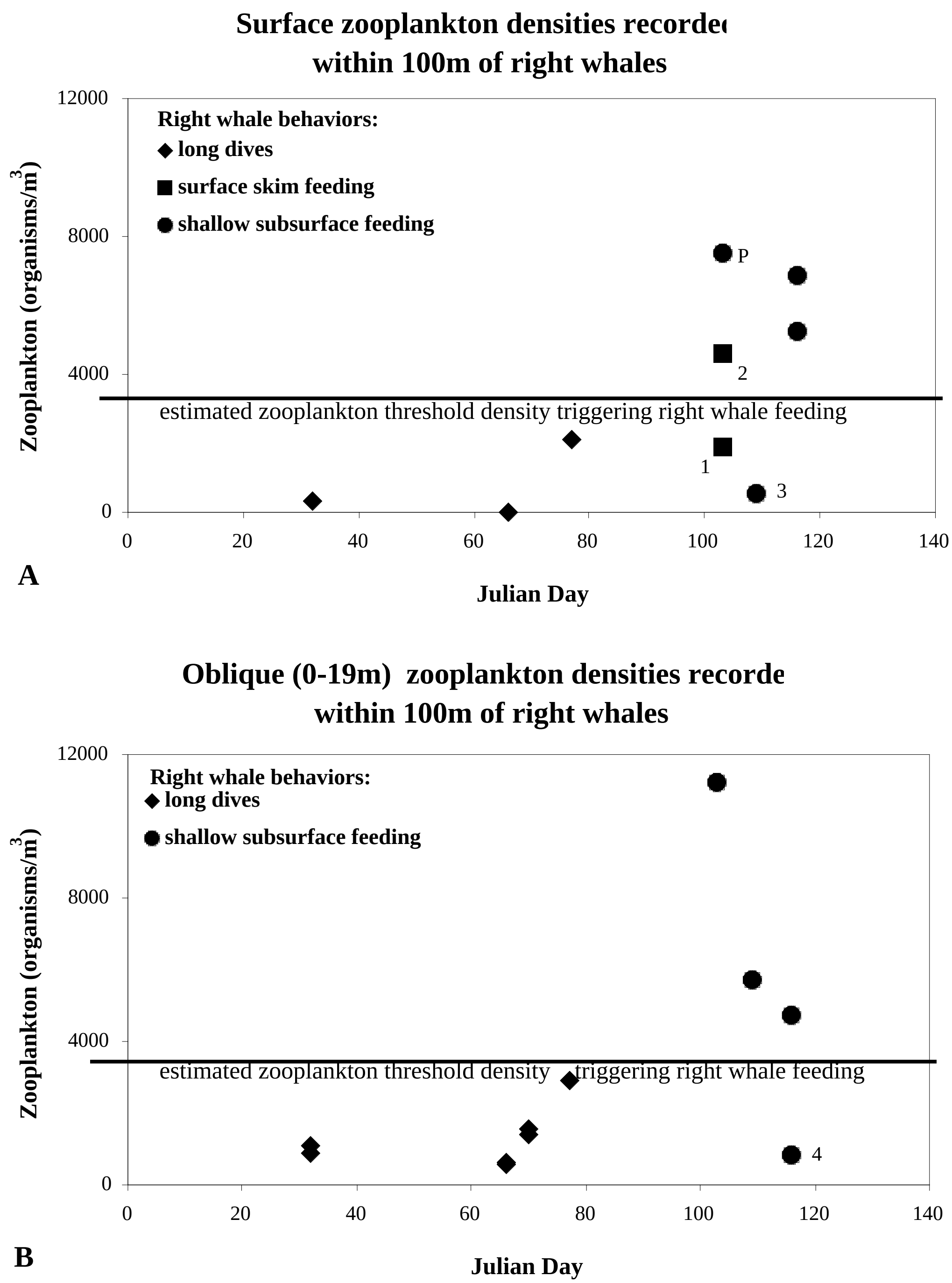


Figure 3. **Zooplankton densities collected either by surface net tow (A), or oblique net tow (B) when right whales were present within 100 meters. Whale behaviors are described in the legend. Samples with a corresponding number or letter (P, 1-4) are described in the text.**

2.4 Conclusion

The zooplankton abundance in Cape Cod Bay during the January through mid-May 2005 field season has been analyzed in great detail through multiple comparative measures in the preceding pages of Section 2. It is necessary to consider and combine all of these views, including but not limited to sample collection type, zooplankton seasonal abundance patterns, comparison to previous years, and fine-scale detail of densities in particular geographic regions of the bay, to attempt to understand the composition and density of zooplankton patches affecting the residency, aggregation, and behavior of right whales in CCB.

Summary data from surface and oblique net tows and vertical pump samples show 2005 as a year of lower zooplankton densities than many prior years, especially of the copepod taxa *Centropages* spp. and *Pseudocalanus* spp. General seasonal patterns of increases and decreases in total densities more closely matched 2003 than 2004, although most sample densities were higher in 2004 than 2003. Low initial surface and oblique densities increased slowly during the months of February and March to reach highest values in April, then dropped off quickly and remained low through the end of sampling on 14 May. With one exception, all samples collected near feeding right whales were primarily composed of *Calanus finmarchicus*. The durable and extremely rich engybenthic layer of *Pseudocalanus* spp. preyed upon by right whales in 2004 was not observed at any time during the 2005 season. It is likely that the decrease in duration of individual right whale residency in Cape Cod Bay measured in 2005 (see Section 1) resulted to some degree from the patterns of zooplankton composition and density explained above.

Table 1. **2005 Cape Cod Bay Habitat Cruises and Collected Samples.**

		PLANKTON SAMPLES: Zooplankton					
Cruise	**Date**	**On Station Surface Tows**	**Off Station Suface Tows**	**On Station Oblique Tows**	**Off Station Oblique Tows**	**Vertical Samples**	**Total**
SW515	5-Jan	2	.	1	.	.	**3**
SW516	15-Jan	7	.	7	.	.	**14**
SW517	22-Jan	8	.	8	.	.	**16**
SW519	29-Jan	8	.	8	.	.	**16**
SW520	1-Feb	1	1	1	2	21	**26**
SW521	8-Feb	8	.	8	.	14	**30**
SW522	15-Feb	4	.	5	.	11	**20**
SW523	16-Feb	4	.	4	.	.	**8**
SW524	24-Feb	6	.	6	.	.	**12**
SW525	7-Mar	8	1	9	2	11	**31**
SW526	11-Mar	3	.	3	5	3	**14**
SW527	18-Mar	8	1	8	1	17	**35**
SW528	23-Mar	8	.	8	.	.	**16**
SW530	1-Apr	10	.	11	.	27	**48**
SW532	6-Apr	4	.	4	.	12	**20**
SW533	7-Apr	4	.	4	.	.	**8**
SW535	13-Apr	8	3	8	1	.	**12**
SW537	19-Apr	7	1	7	1	.	**16**
SW539	26-Apr	8	1	8	1	.	**18**
SW541	4-May	8	.	8	.	11	**27**
SW544	10-May	8	.	8	.	10	**26**
SW545	14-May	8	.	8	.	.	**16**
SW549*	3-Jun	.	.	.	.	.	**0**
SW552*	16-Jun	.	.	.	.	.	**0**
IB033**	29-Jul	.	1	.	1	.	**2**
	Totals	**124**	**8**	**142**	**13**	**137**	**434**

**** designates cruises dedicated to use of the Optical Plankton Counter(OPC)***

***** designates a post-season, non-assessment, opportuntistic sampling cruise***

Appendix I

System Data Record with Inter-annual Comparisons – 2005

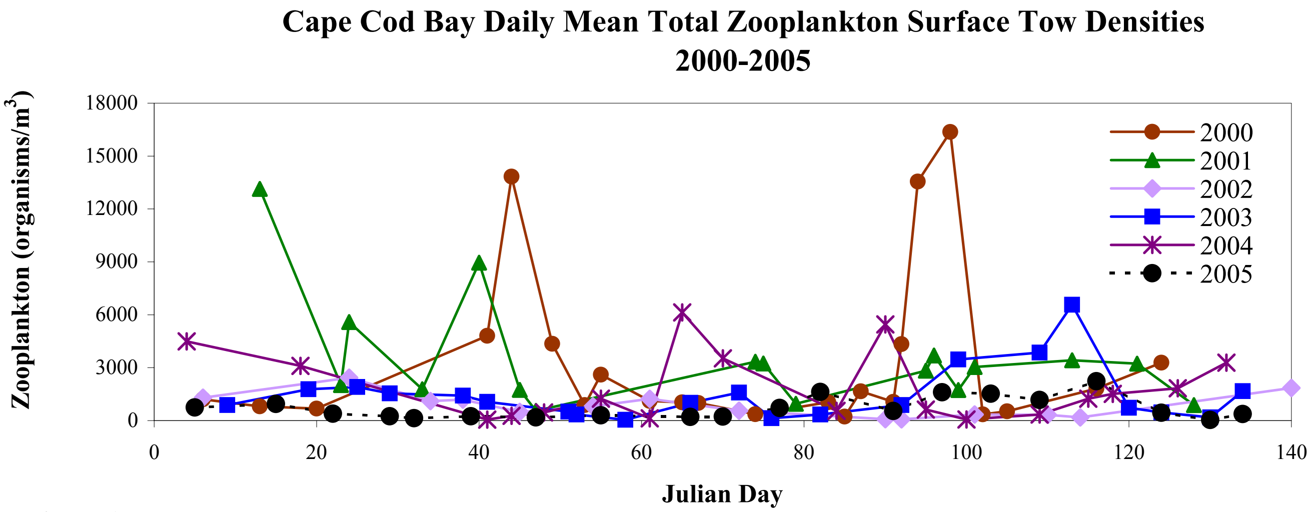


Figure 1

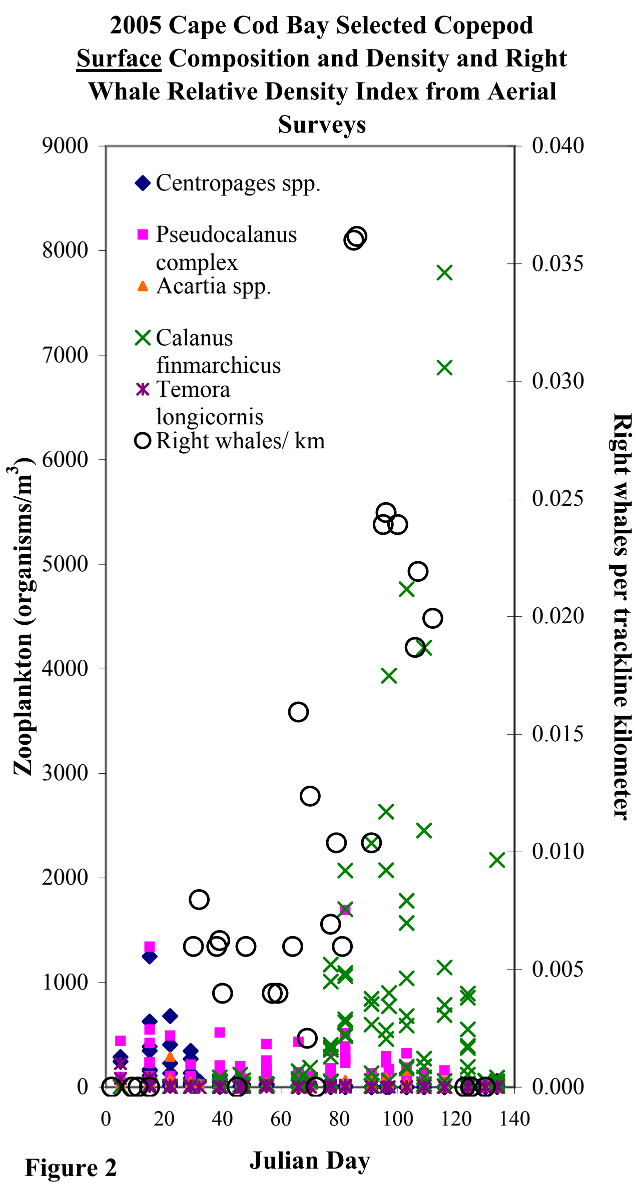


Figure 2

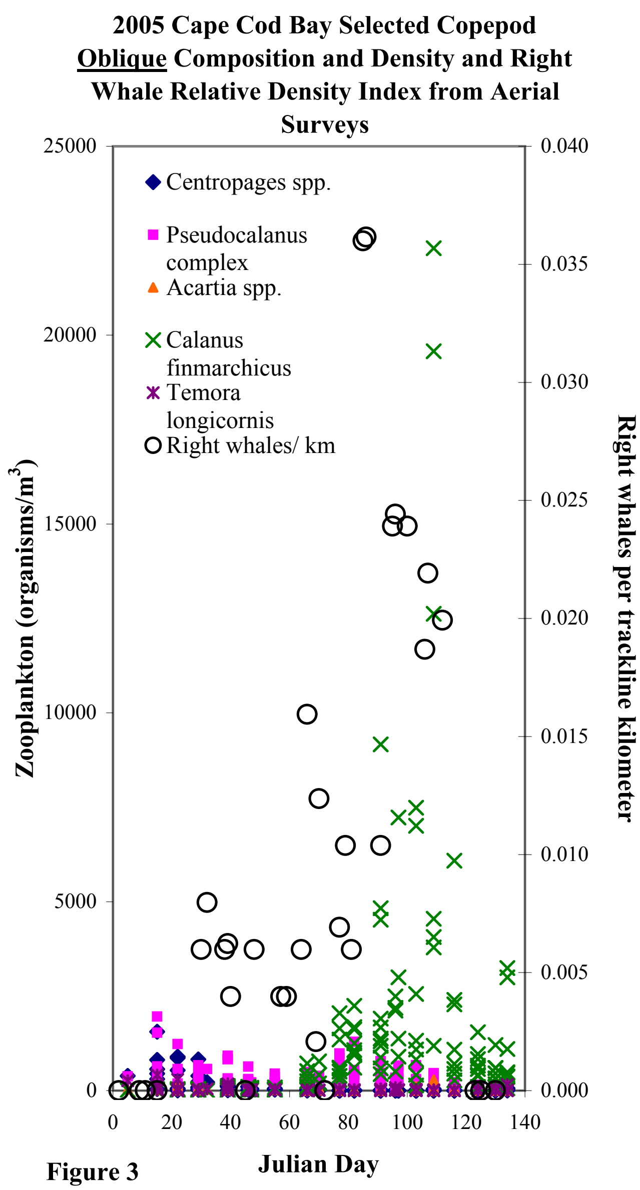


Figure 3

Cape Cod Bay surface layer copepod composition averaged for the month of January, 2000-2005.

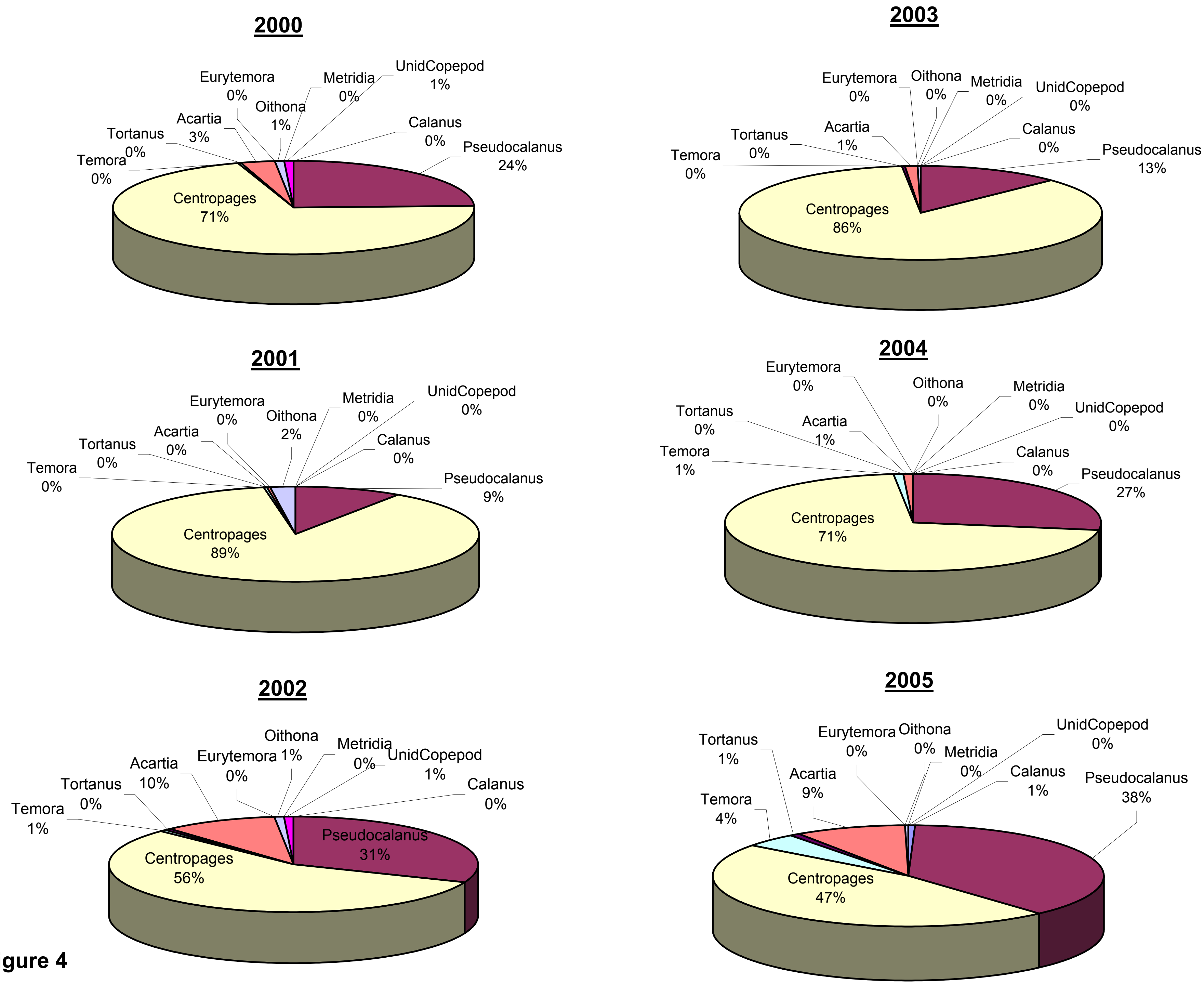


Figure 4

Cape Cod Bay surface layer copepod composition averaged for the month of February, 2000-2005.

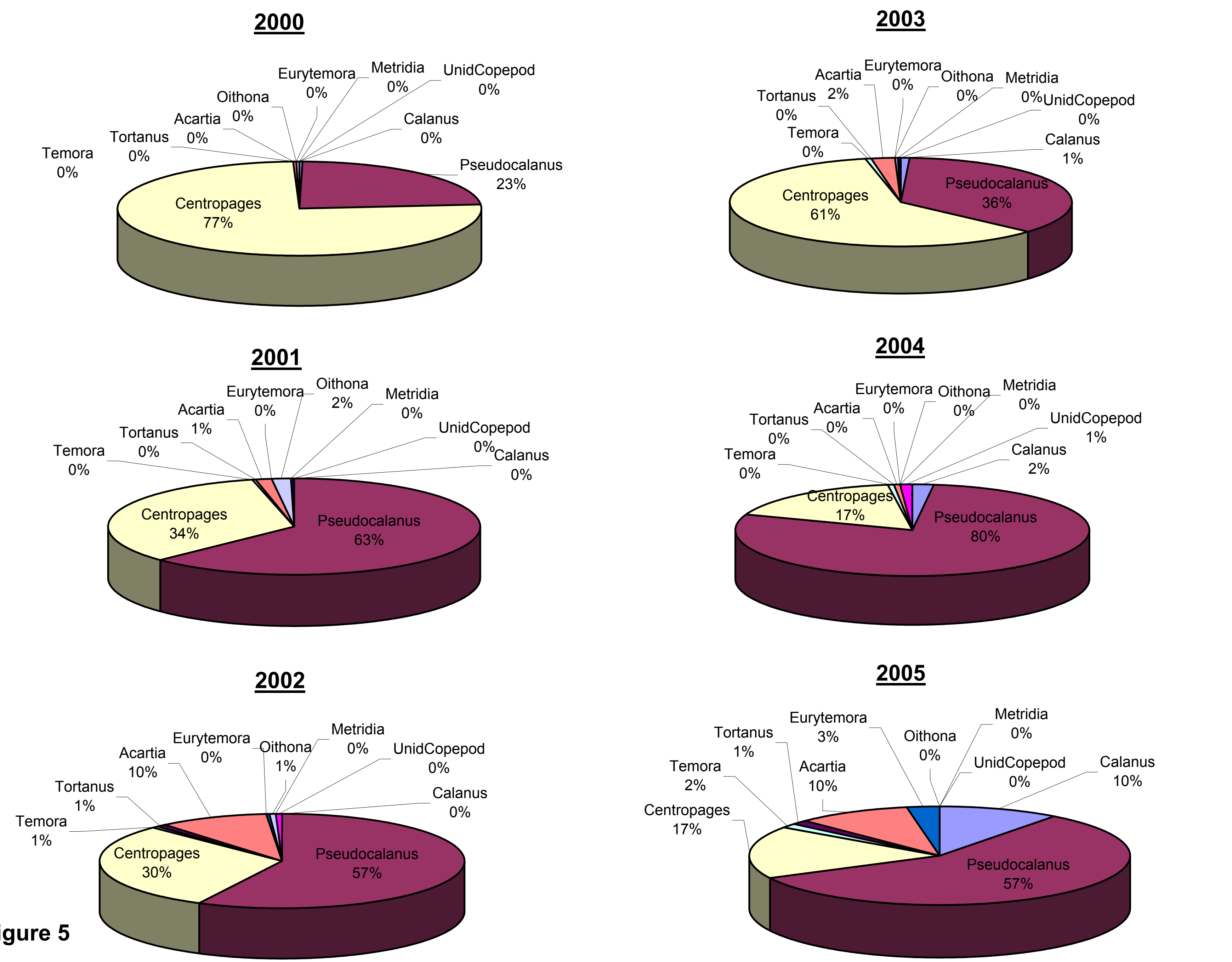


Figure 5

Cape Cod Bay surface layer copepod composition averaged for the month of March, 2000-2005.

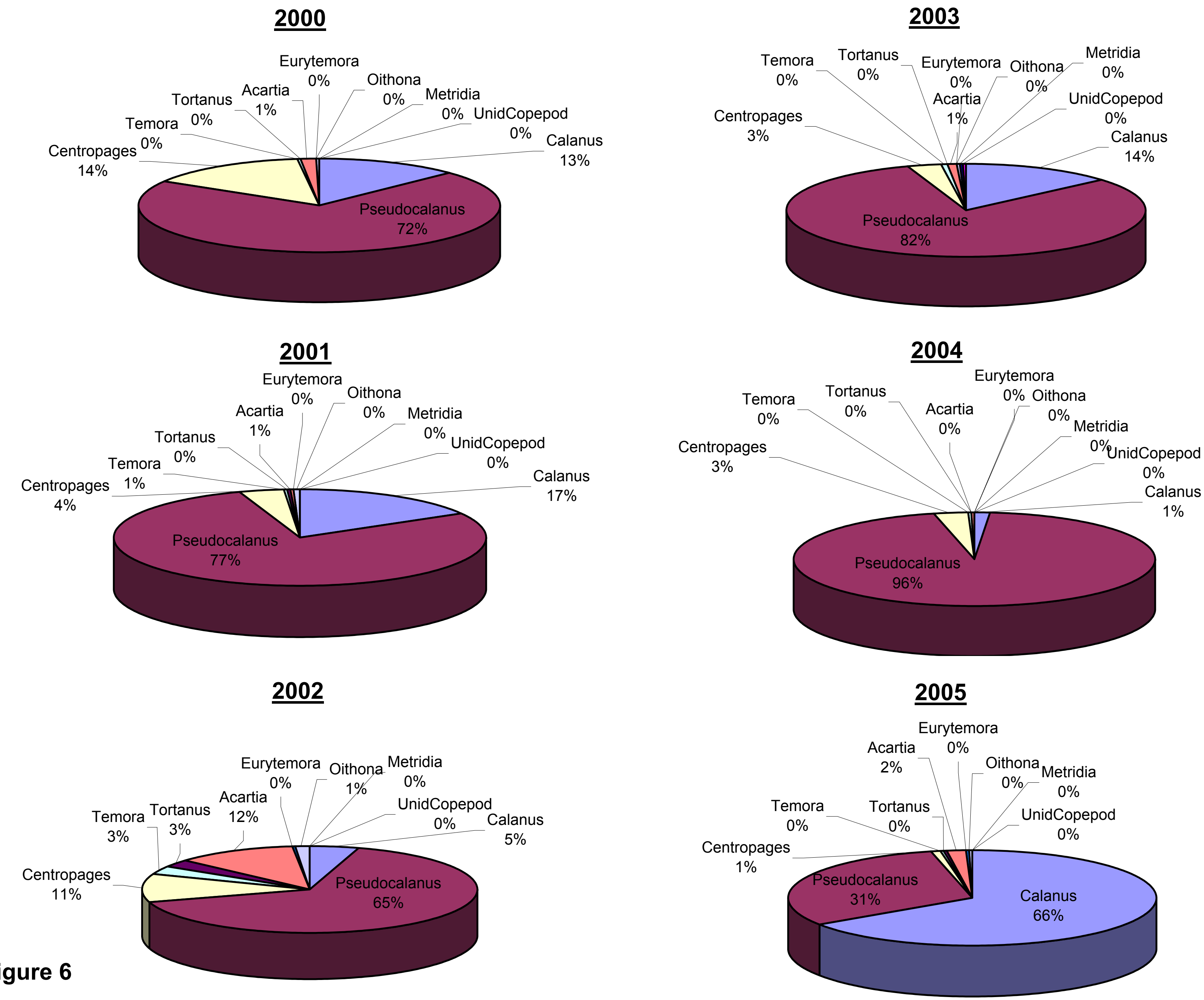


Figure 6

Cape Cod Bay surface layer copepod composition averaged for the month of April, 2000-2005.

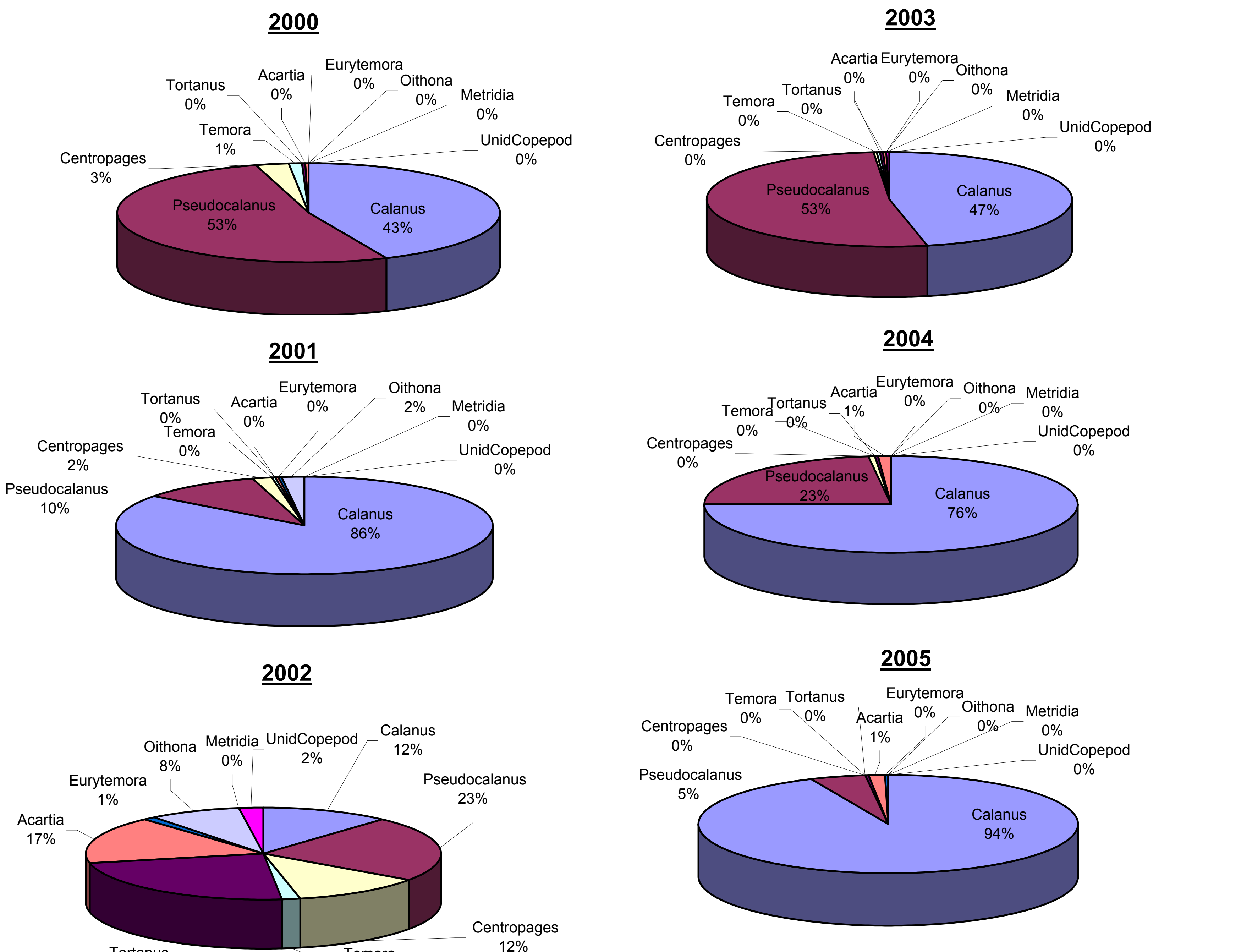


Figure 7

Cape Cod Bay surface layer copepod composition averaged for May 1-15, 2000-2005.

Figure 8

Cape Cod Bay 2005 Average Zooplankton Density Graphs for early and late-stage *Centropages* spp.

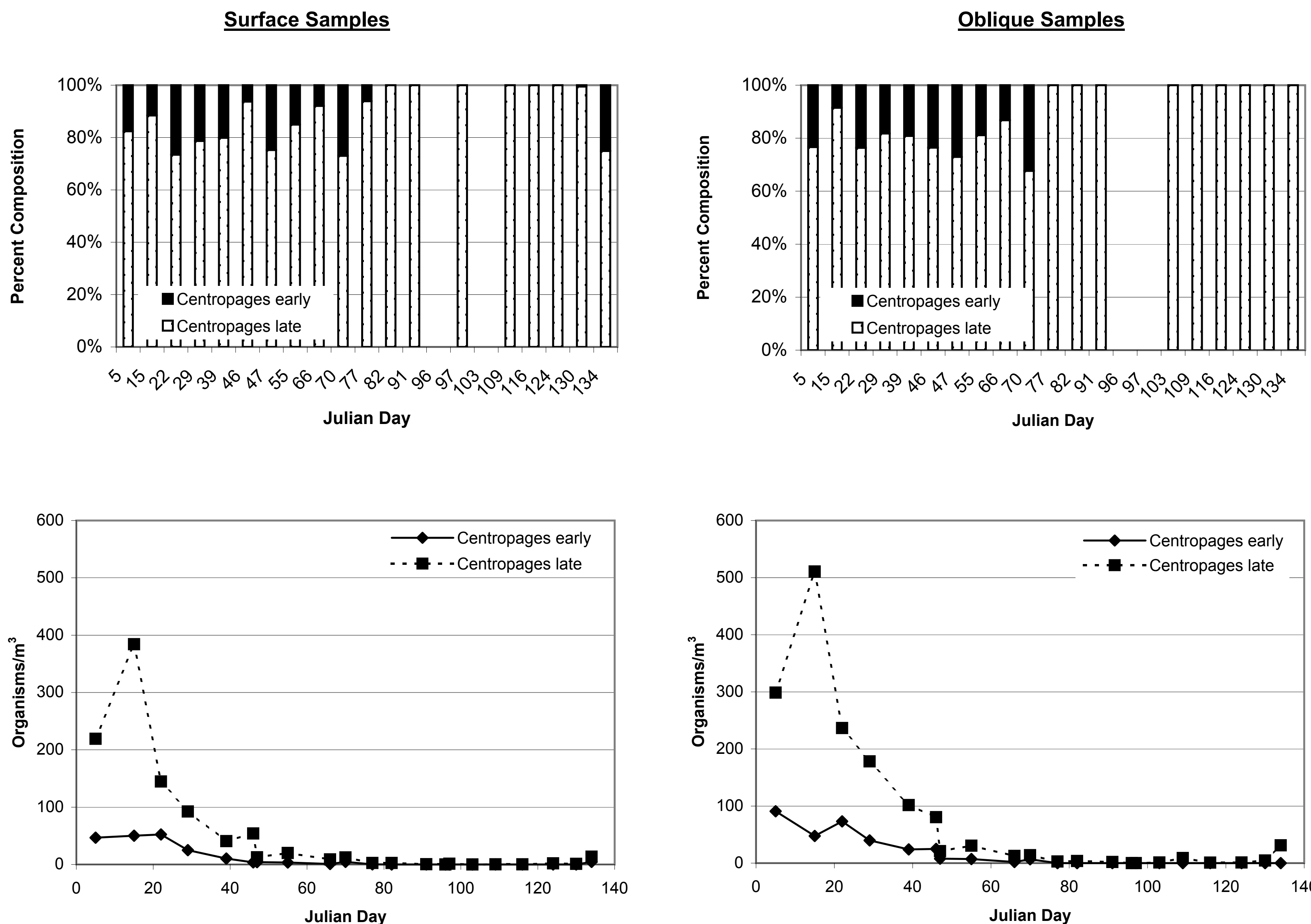
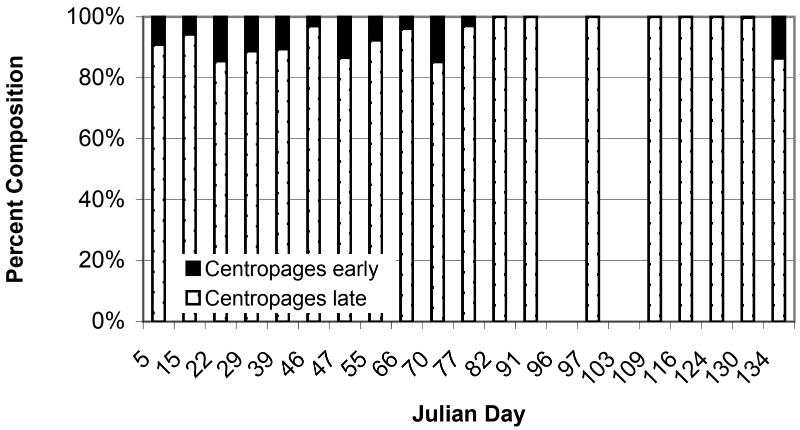
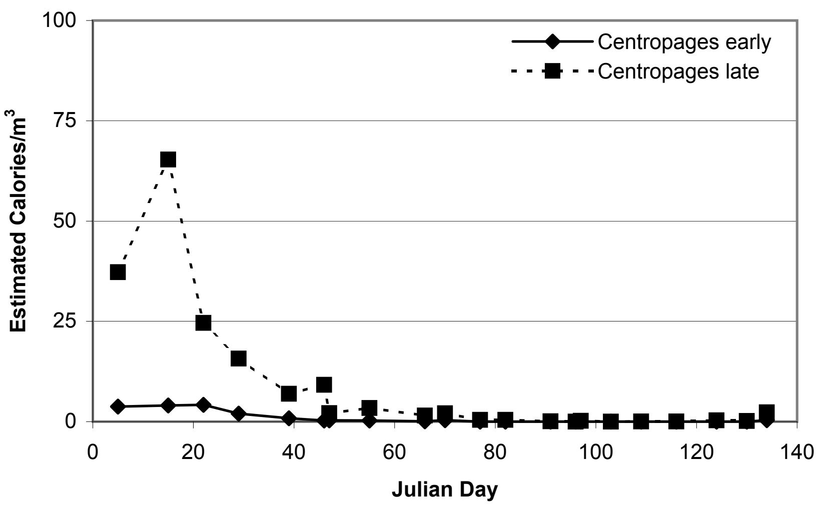


Figure 9

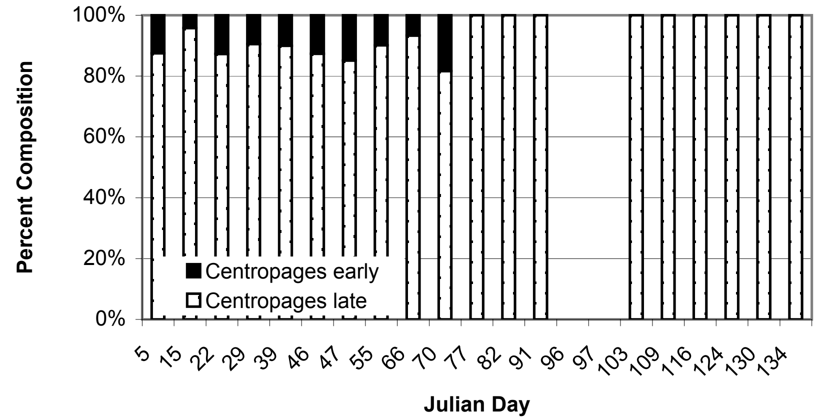
Cape Cod Bay 2005 Estimated Caloric Density Graphs for early and late-stage *Centropages* spp.

Surface Samples





Oblique Samples



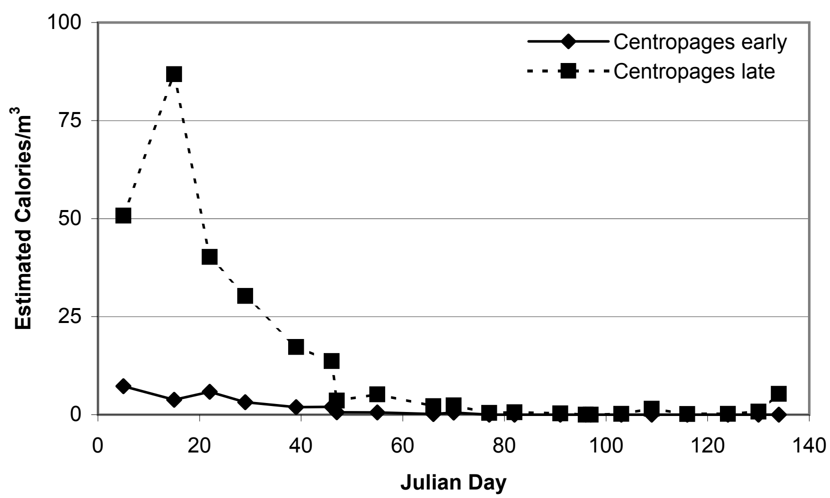


Figure 10

Cape Cod Bay 2005 Average Zooplankton Density Graphs for early and late-stage *Pseudocalanus* spp.

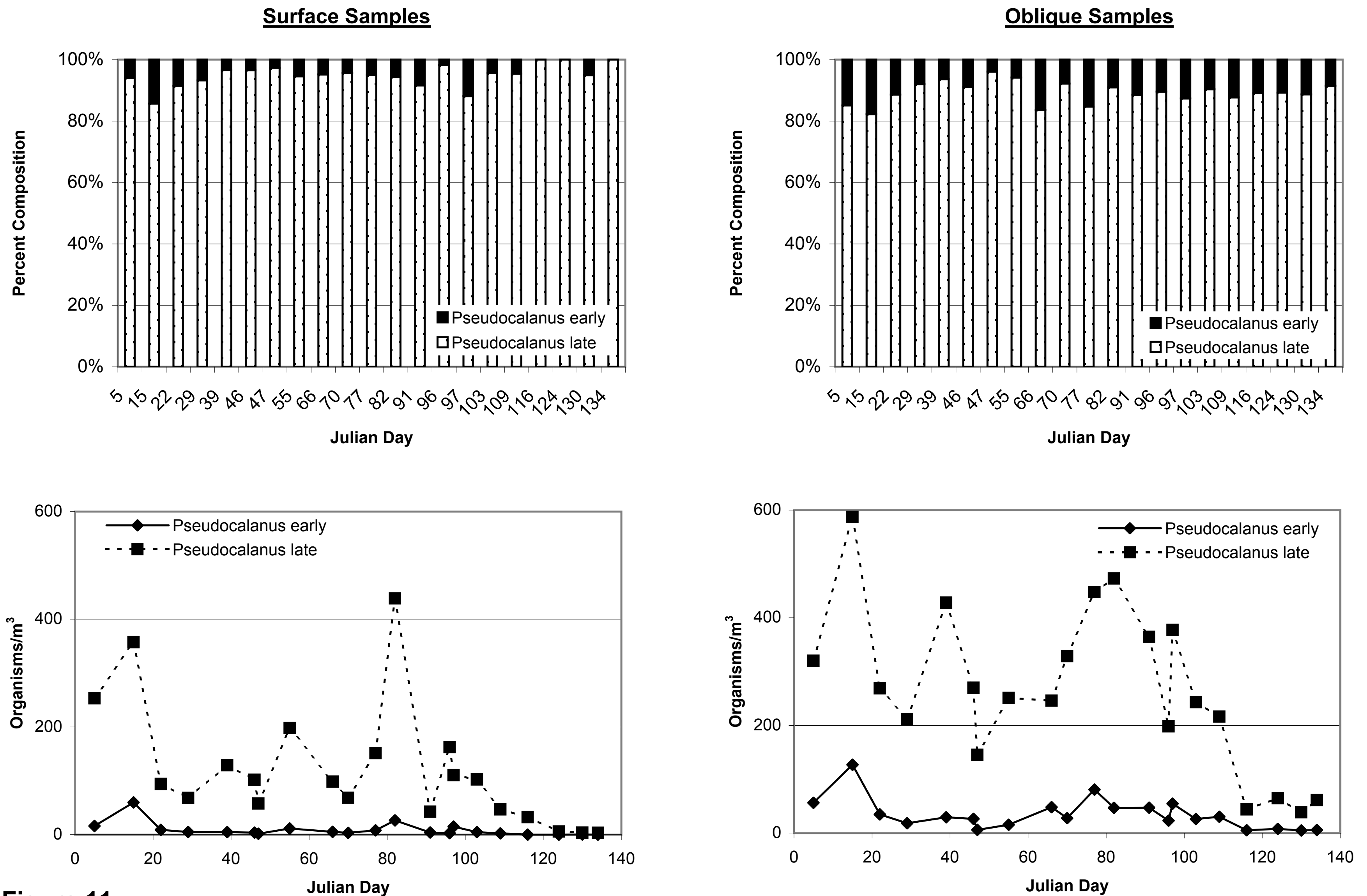


Figure 11

Cape Cod Bay 2005 Estimated Caloric Density Graphs for early and late-stage *Pseudocalanus* spp.

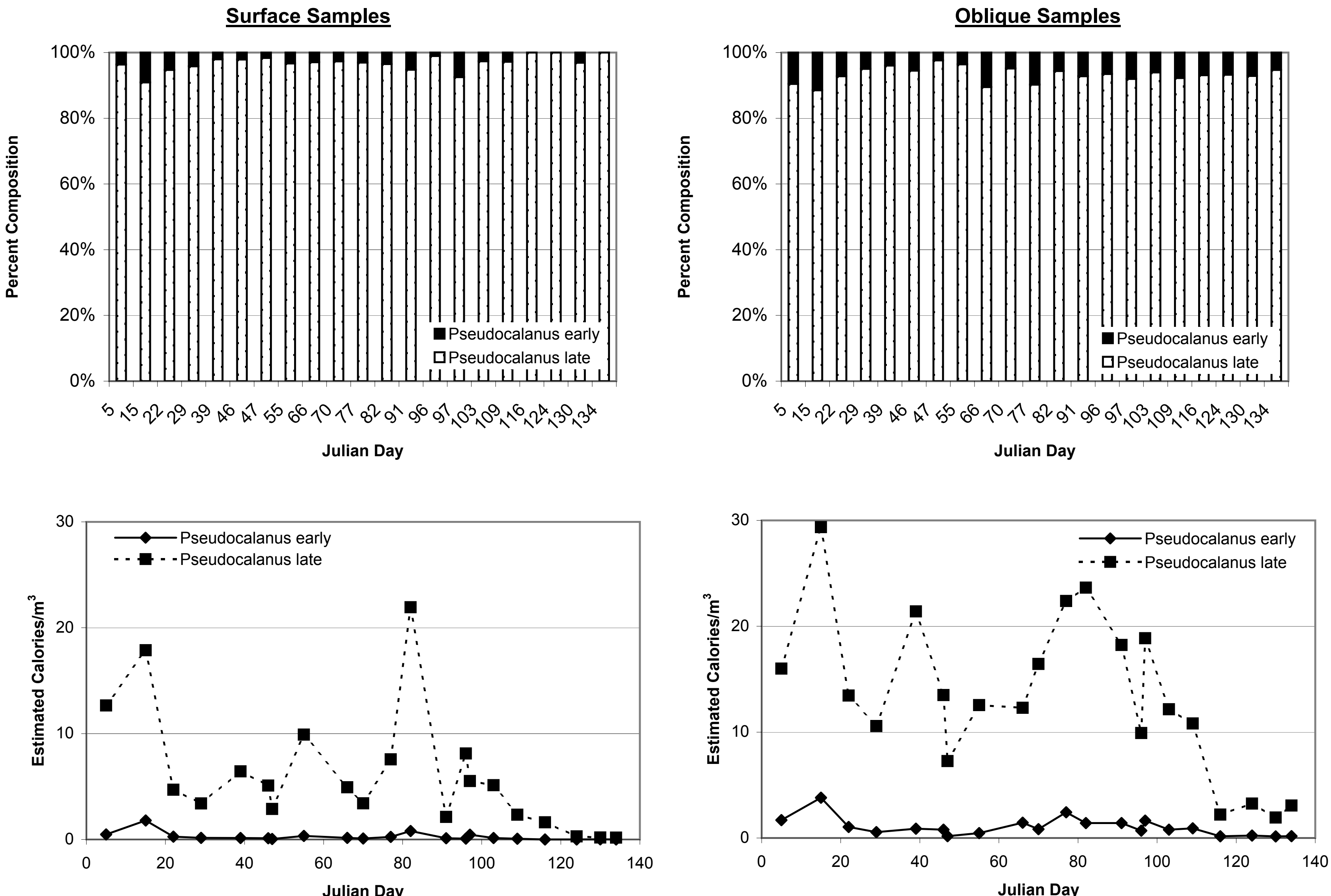
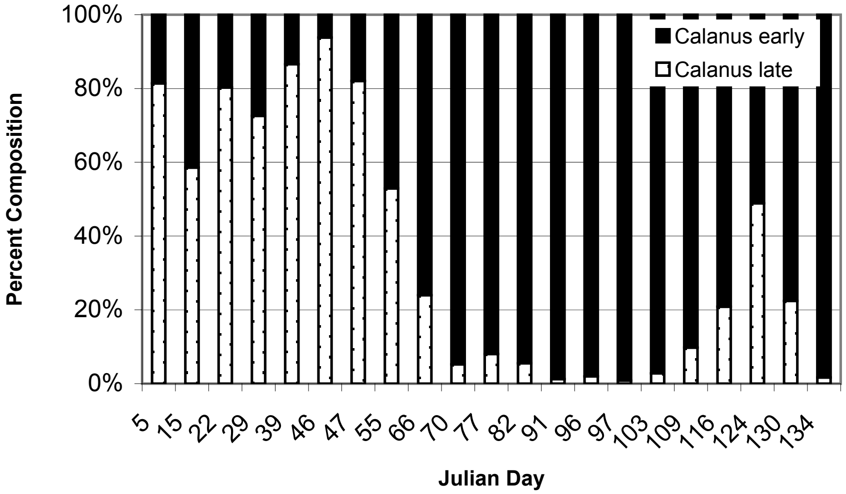


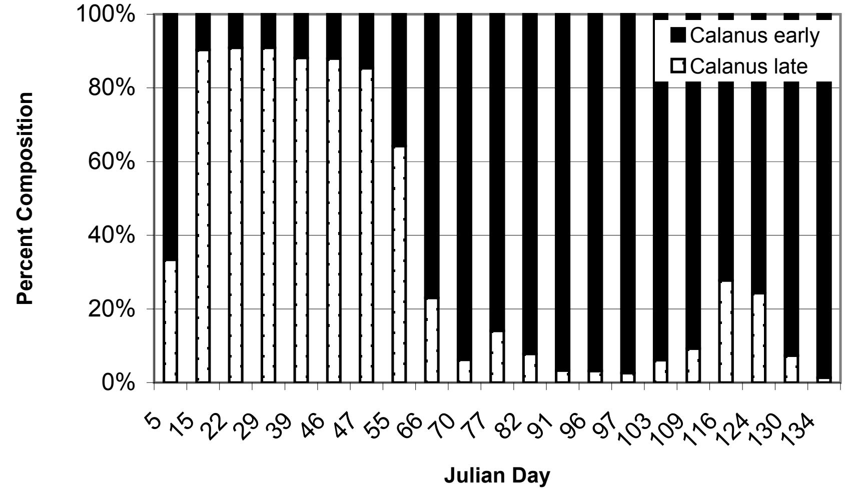
Figure 12

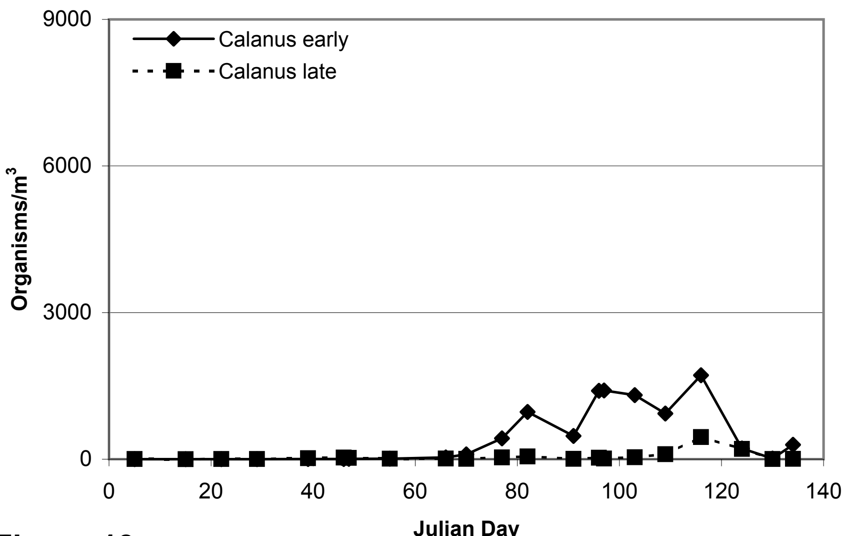
Cape Cod Bay 2005 Average Zooplankton Density Graphs for early (I-IV) and late stage (V-VI) *Calanus finmarchicus*

Surface Samples



Oblique Samples





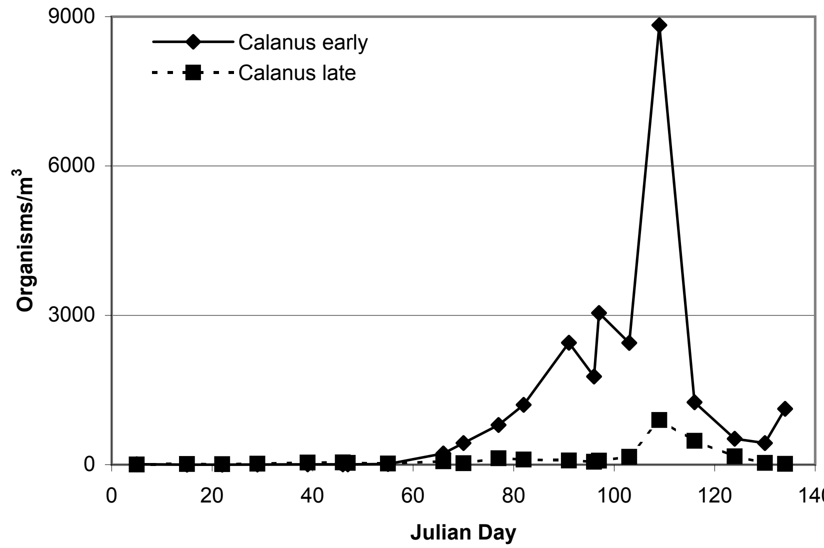
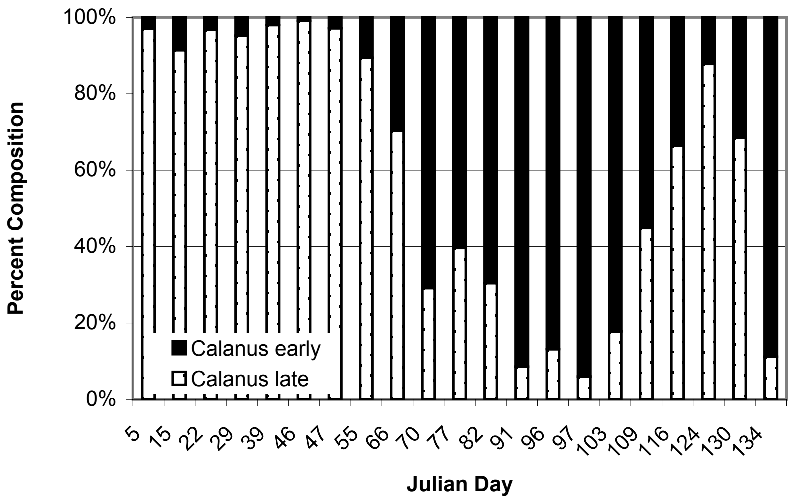


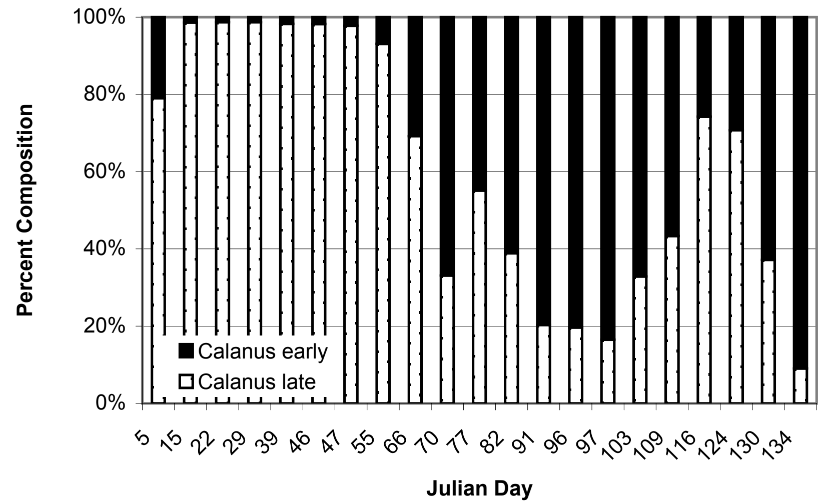
Figure 13

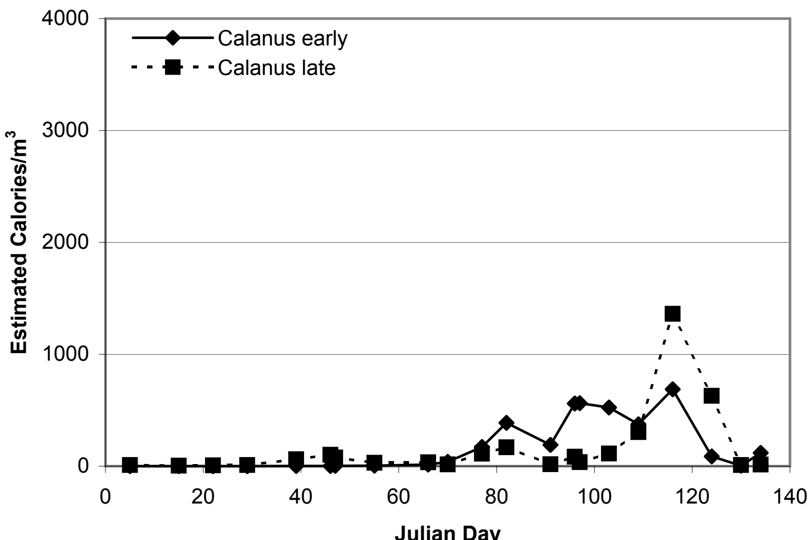
Cape Cod Bay 2005 Estimated Caloric Density Graphs for early stage (I-IV) and late stage (V-VI) *Calanus finmarchicus*

Surface Samples



Oblique Samples





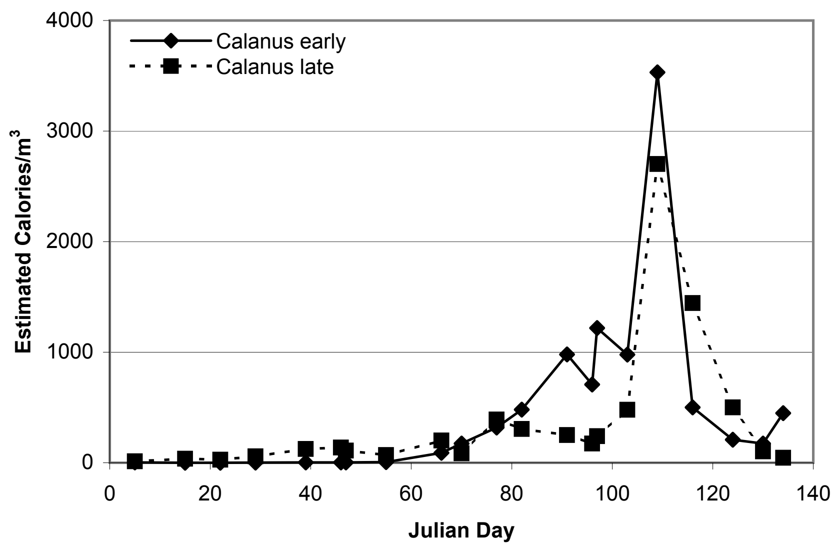
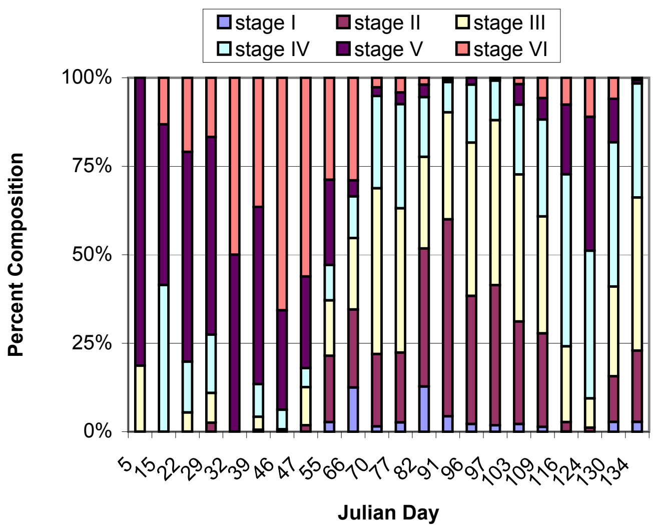


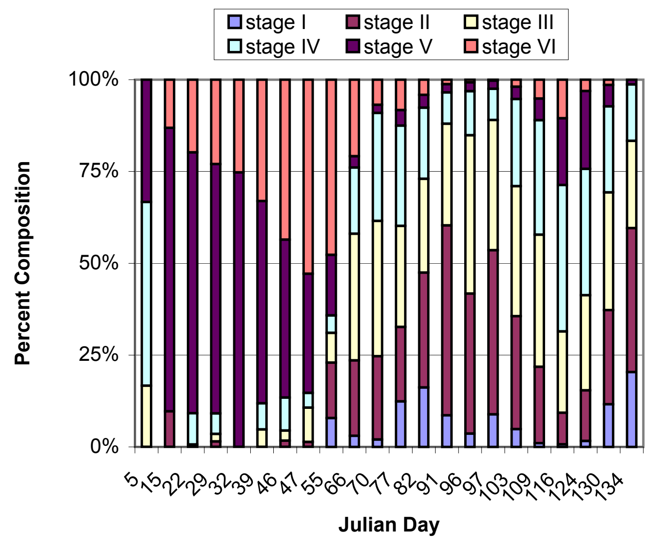
Figure 14

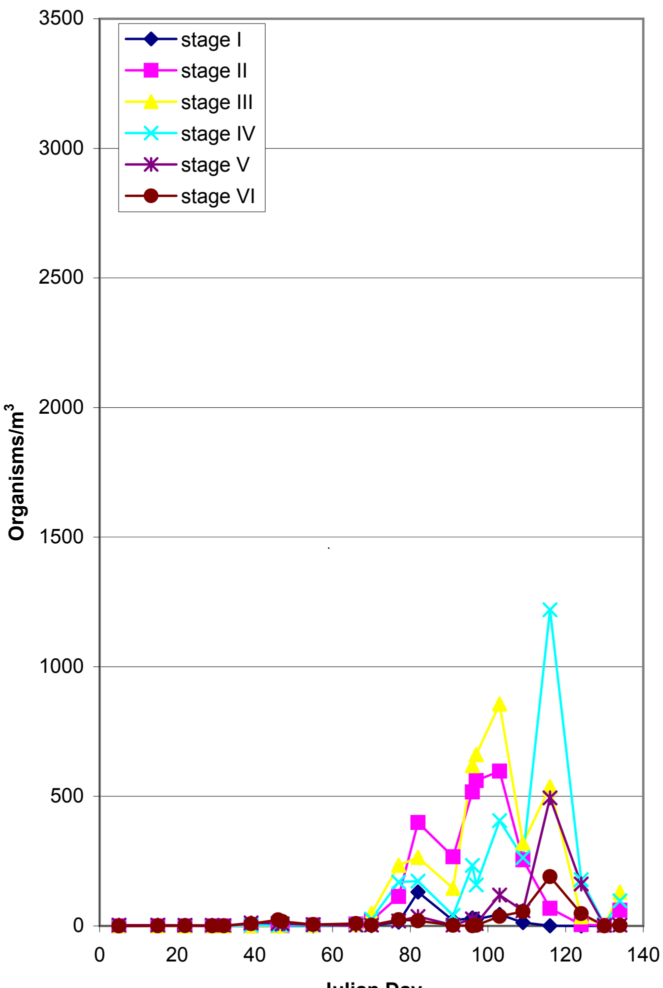
Cape Cod Bay 2005 Mean Daily Density Graphs for individual stage *Calanus finmarchicus*

Surface Samples



Oblique Samples





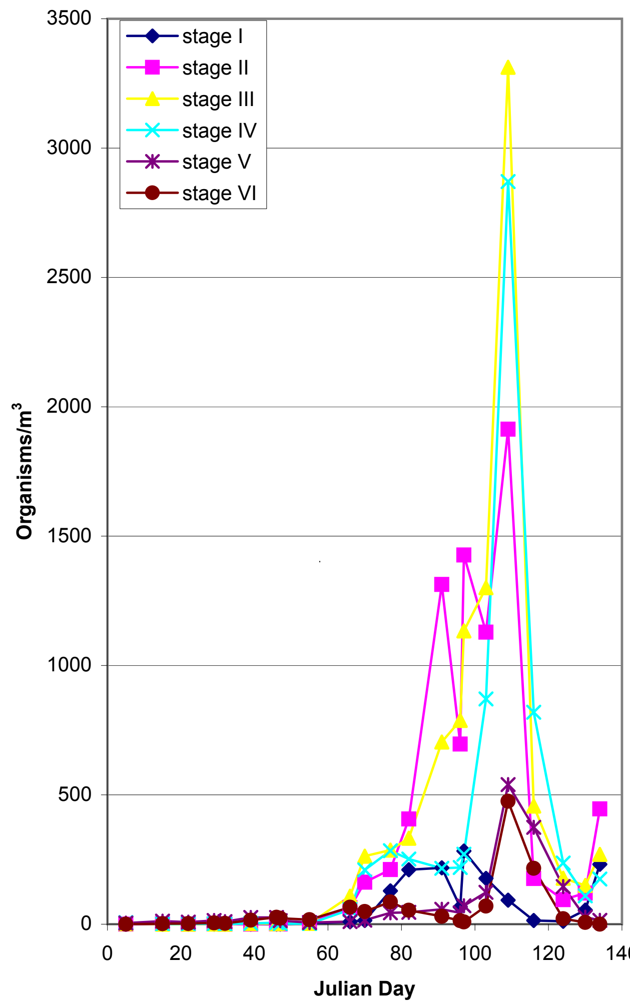


Figure 15

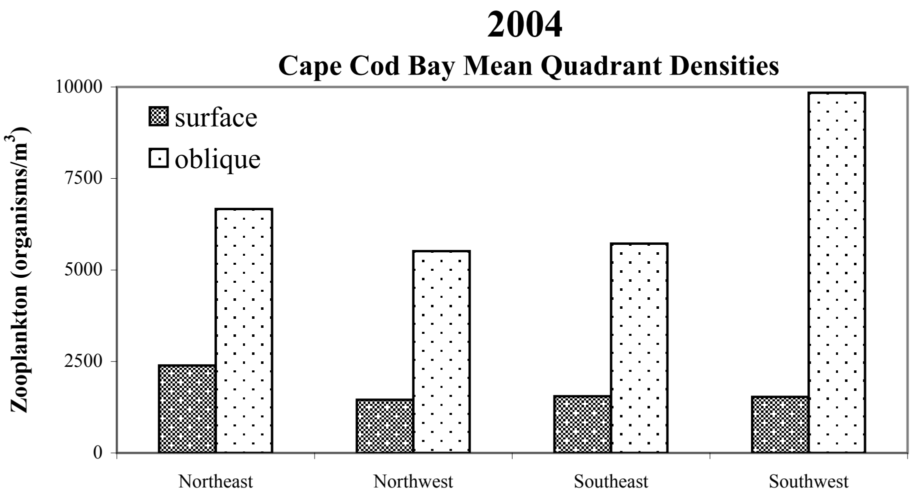


Figure 16

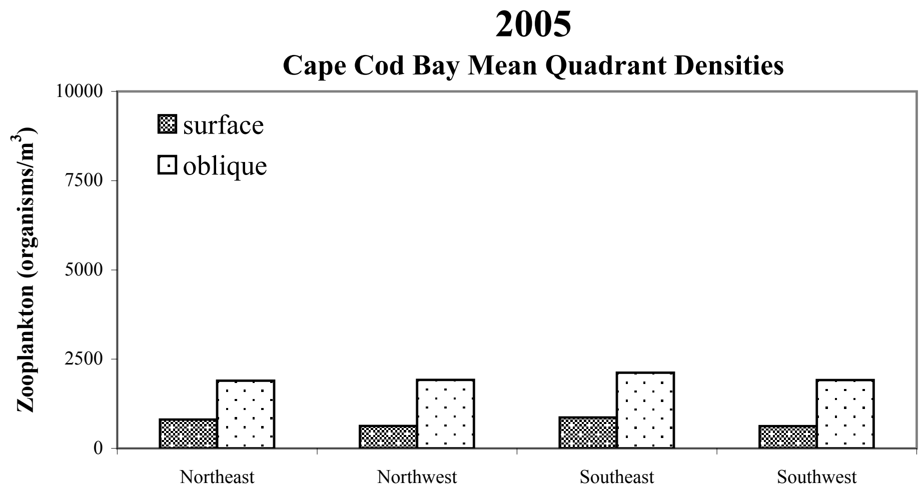


Figure 18

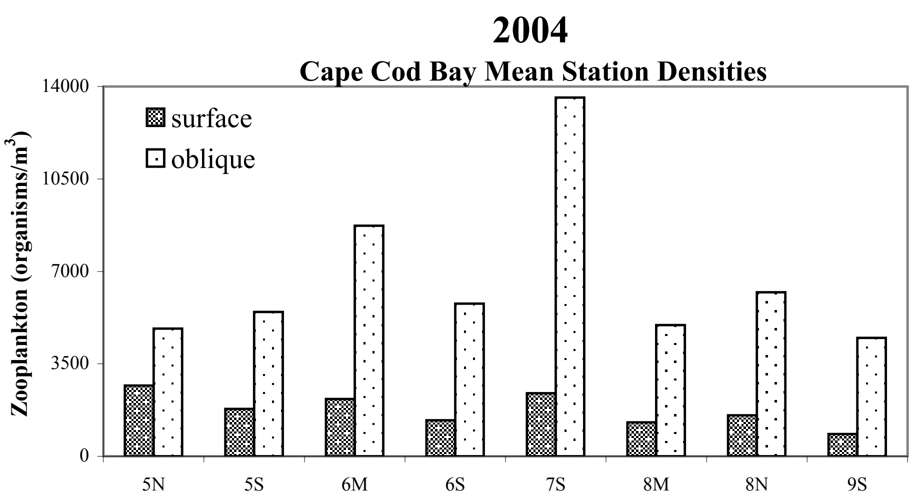


Figure 17

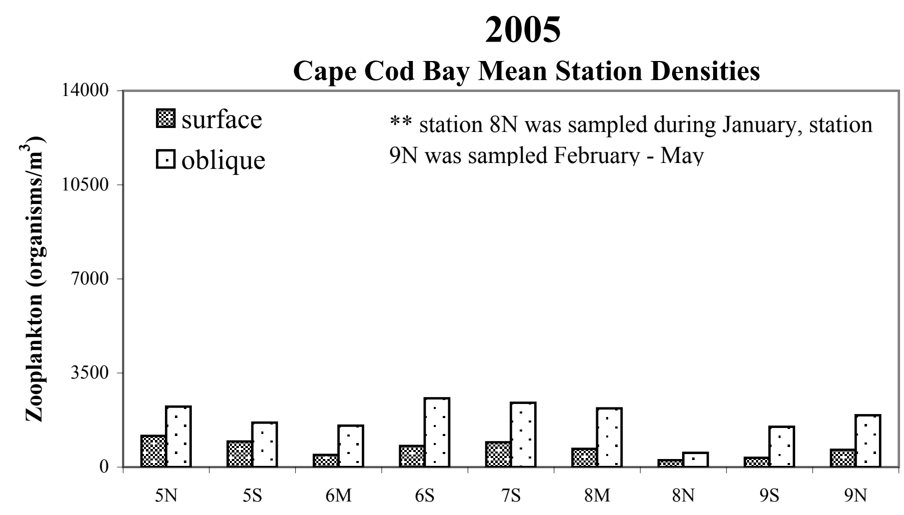


Figure 19

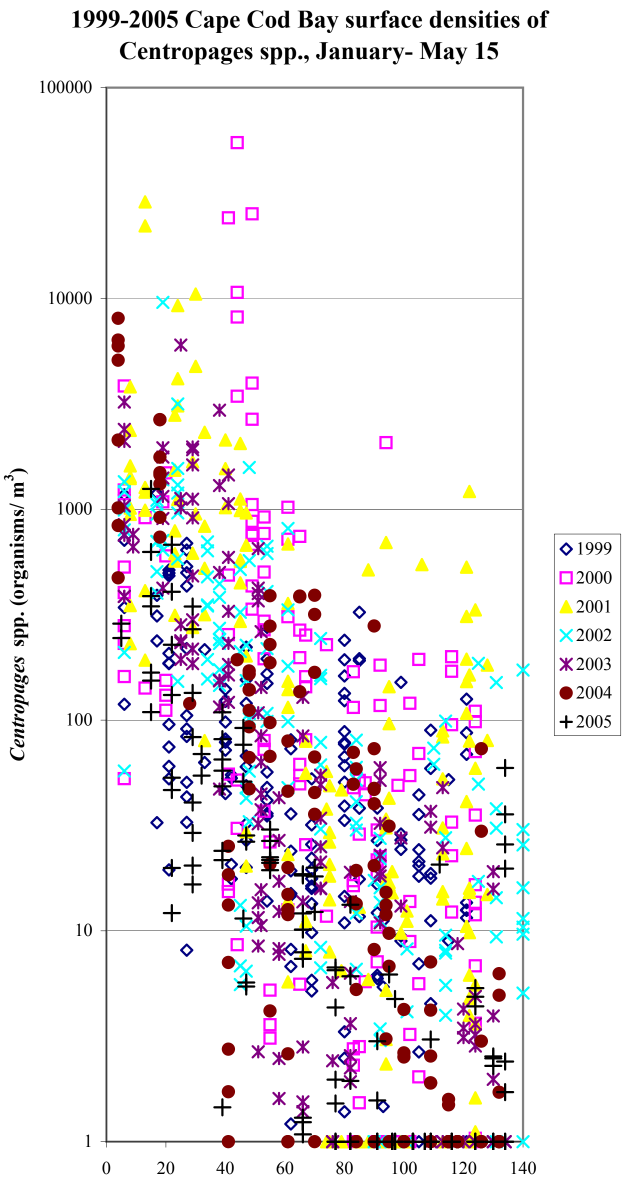


Figure 20

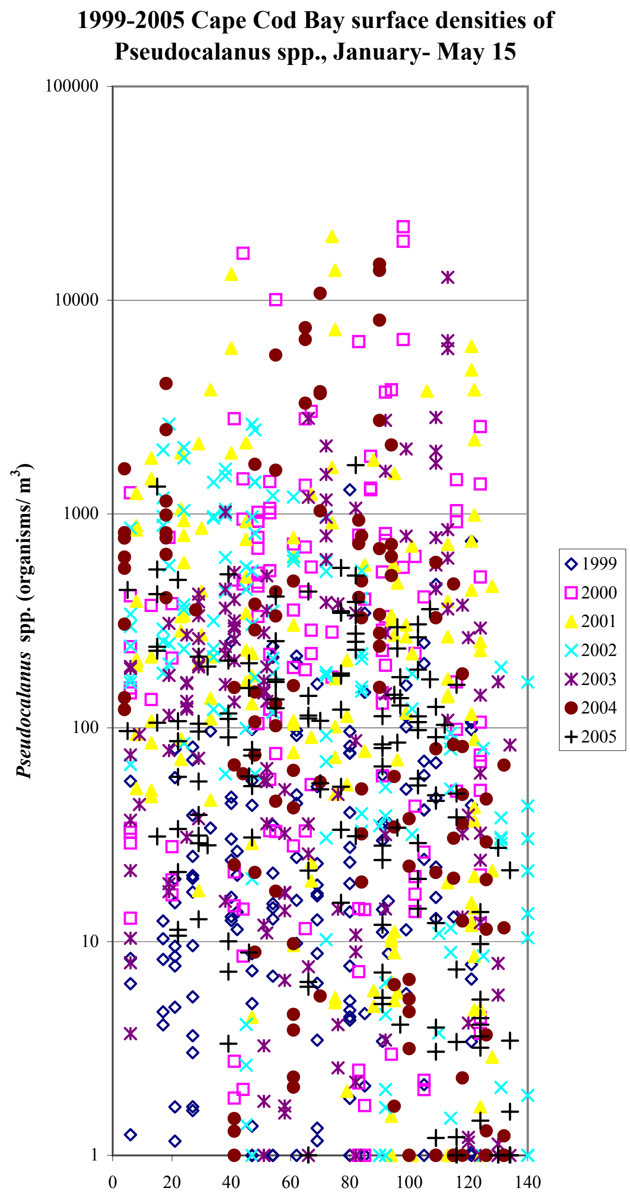


Figure 21

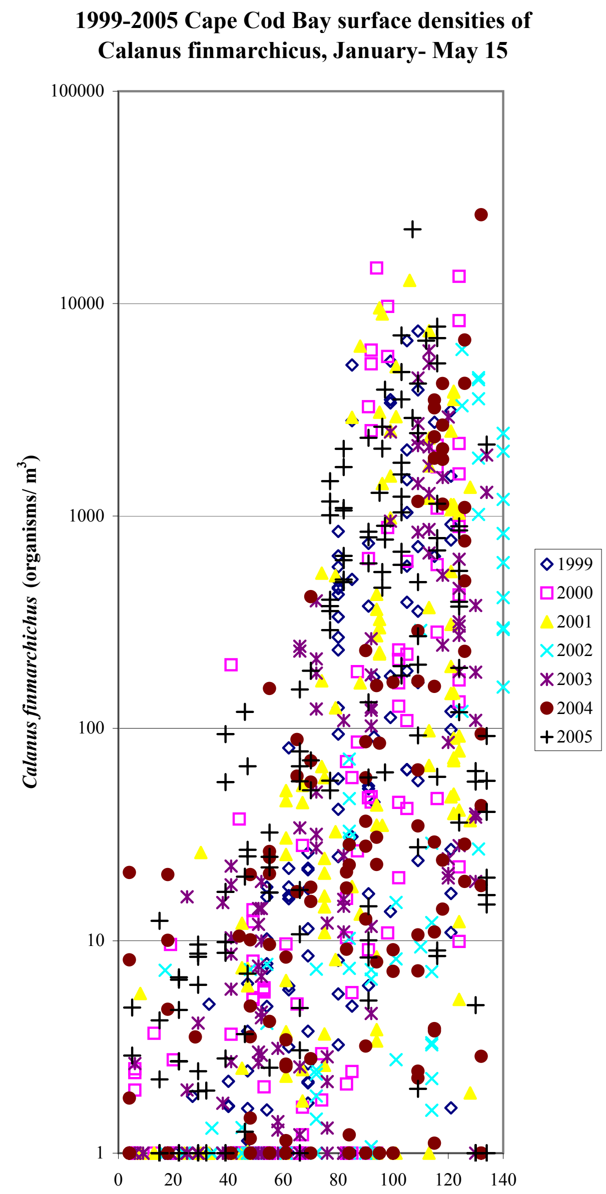


Figure 22

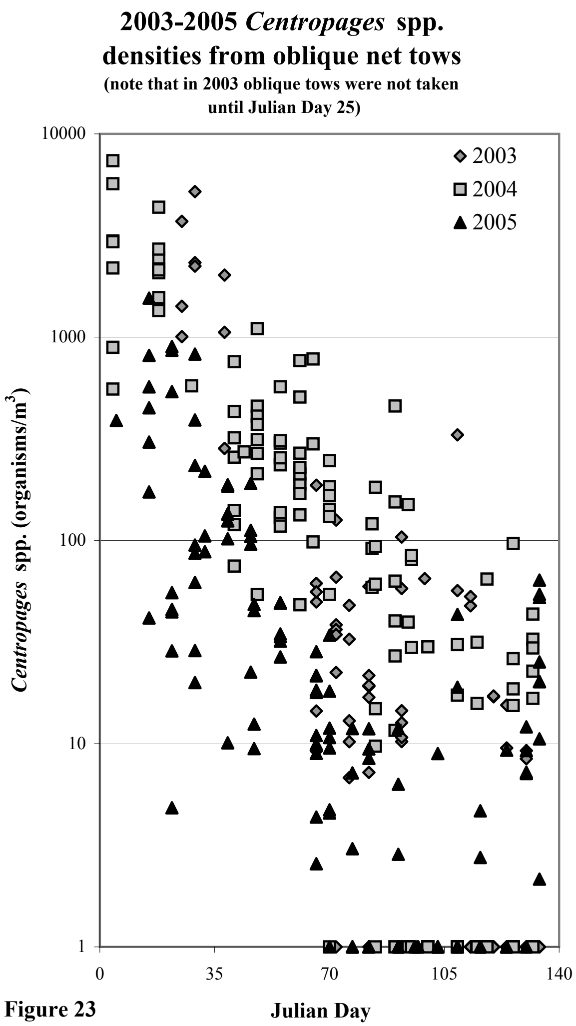


Figure 23

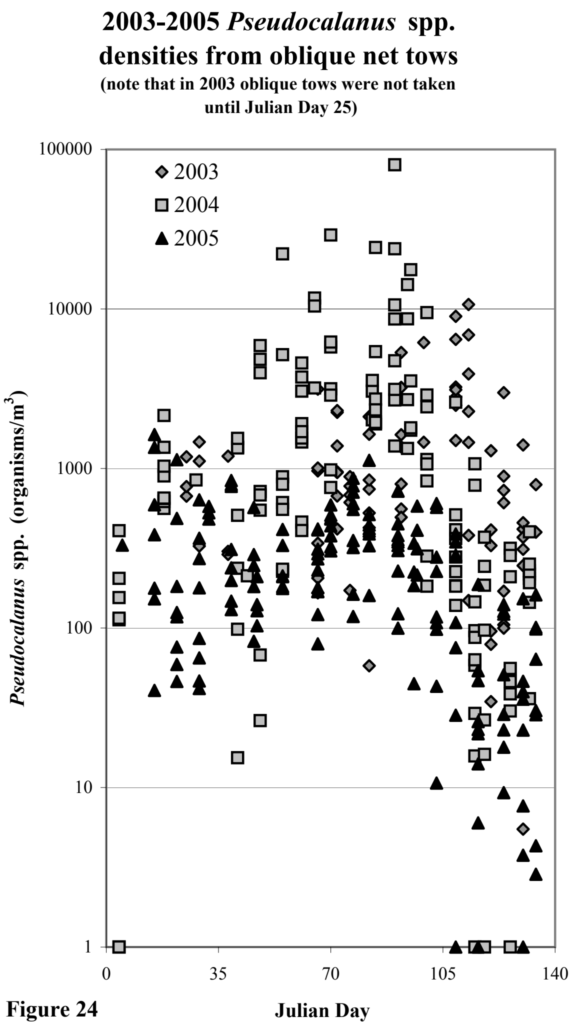


Figure 24

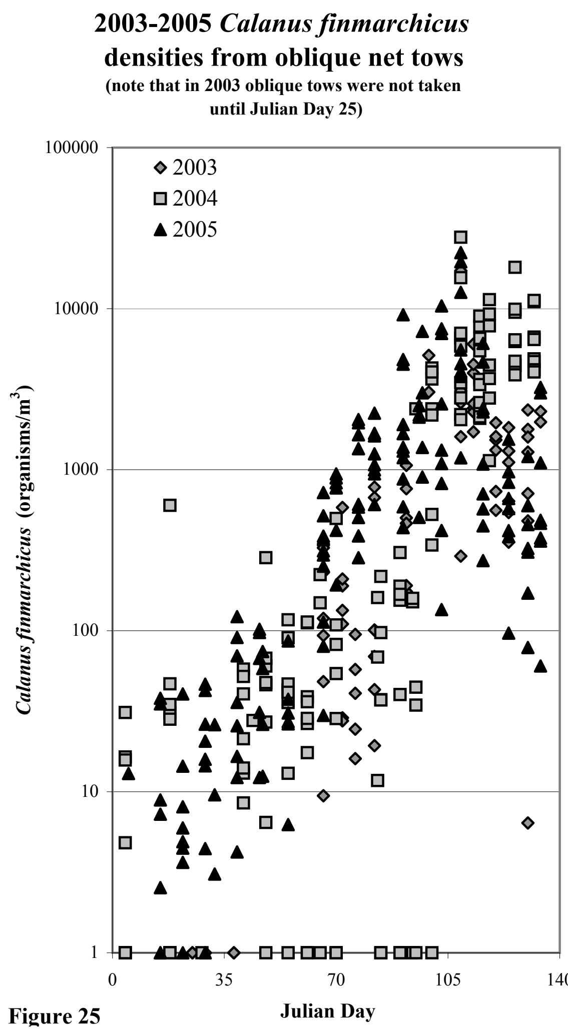


Figure 25

Appendix II

System Assessment and Prediction:

Examples from early, mid and late-season 2005

Cruise Assessment

Seven of the eight regular Cape Cod Bay (CCB) stations were sampled on the second 2005 right whale habitat studies cruise on January 15th. Although sea conditions prevented the use of the vertical pump water column profiling system, surface and oblique net tows were conducted at 2 stations each in the northeastern, southeastern, and southwestern quadrants, and at one station in the northwestern quadrant. As in 2004, detailed results from these tows in various tables, pie charts, and scatter plots follow this interpretation. Visibility on this cruise was unlimited, but no marine mammals were sighted. Please note at the end of this document a new section titled "Aerial Surveillance", documenting recent Center for Coastal Studies CCB flights and the number of right whales seen. This year we are also adding a GIS plot of zooplankton densities from oblique tows at each station overlaid with right whale distribution as seen from air surveys. 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.

Due to the relative shortness of our first cruise (SW515 on Jan. 5: only 3 samples collected in one quadrant), few comparisons can made about the species composition and densities of the zooplankton of CCB from the period from 1 to 15 January. Instead, observations in this assessment as based on samples from SW516 and comparisons are drawn to the same time period from 2004 and 2003.

Surface Layer Assessment

The bay-wide mean surface layer density of 944 organisms/m^3 lies well below the 3,750 organisms/m^3 estimated feeding threshold for right whales in CCB. The individual station densities, however, ranged broadly from just above 400 to over 2000 organisms/m^3. The highest counts were in the easternmost areas of the bay (stations 5N and 5S). Densities at all stations are well below those from cruise SW391, on Jan. 18 2004 (see table on page 2 for all interannual comparisons). During the first 4-6 weeks of the right whale CCB study period (Jan. 1 into February), we closely monitor the densities of the copepod genus *Centropages* spp., as this is usually the dominant taxon, and in suitable numbers is known to induce feeding in right whales. A breakdown of the mean copepod composition at all stations on SW516 displays only slight dominance by *Centropages* spp. (46%) over the mid-season (late February and March) dominant copepod genus, *Pseudocalanus* spp. (41%) in the surface layer. This may indicate an earlier than usual transition in the annual species progression of the copepod community: at this time in 2004 & 2003 the mean surface composition was 52% & 91% *Centropages* spp. and 34% & 8% *Pseudocalanus* spp. respectively. In addition to total density, another of the four zooplankton measures we monitor is an estimate of total available calories for each sample based on its unique species composition. Studies have shown different species of copepods are more or less “calorically rich” depending in part on their overall body size and oil content. The attractiveness to right whales of an individual copepod patch from a nutritional standpoint is likely a combination of total density and caloric density. Although in the southern part of CCB (stations 5S, 6S, 7S and 9S) we are seeing a greater proportion of *Pseudocalanus* spp. (which have a higher caloric content than *Centropages* spp.) than at this time last year, lower densities of both genera in 2005 result in lower caloric densities as compared to 2004.

An additional characteristic of the surface layer on SW516 was the alteration in relative abundance of the two species of *Centropages*: *typicus* and *hamatus*. In CCB, *C. typicus* generally dominates, while the more estuarine and slightly smaller *C. hamatus* is present in reduced numbers. With the exception of station 6M (northeast quadrant, near center of CCB), densities of *C. hamatus* were greater than for *C. typicus*. The significance of this observation in relation to right whale feeding is unknown at this time.

<u>Oblique (surface to 19m) Assessment</u>
Total zooplankton densities from oblique tows followed a consistent interannual pattern of being generally higher than corresponding surface tows. As in surface tows, the mean density for the bay was again lower than at this time in 2004, and the highest densities were in the eastern bay. The species composition from these tows also mirrored that seen in the surface tows, but with an even stronger disparity between *Pseudocalanus* spp. (43%) and Centropages spp. (38%). The dominance of *C. hamatus* over *C. typicus* at all stations except 6M was again noticeable.

<u>General</u>
Results from surface and oblique zooplankton tows at the seven sampled stations were similar in both total density and copepod species composition. No samples contained densities above the estimated feeding threshold for right whales in CCB. The lack of vertical sampling prevents us from assessing the quality of the deep and engybenthic layers that sometimes influence whale distribution in the early season. In addition to the species shown in the following pie charts, samples also contained the copepods: *Eurytemora* spp., *Metridia* spp., and *Oithona* spp., along with barnacle larval stages, fish larvae, Chaetognaths, Hyperiid and Gammerid amphipods and cyphonautes.

Interannual Comparisons:

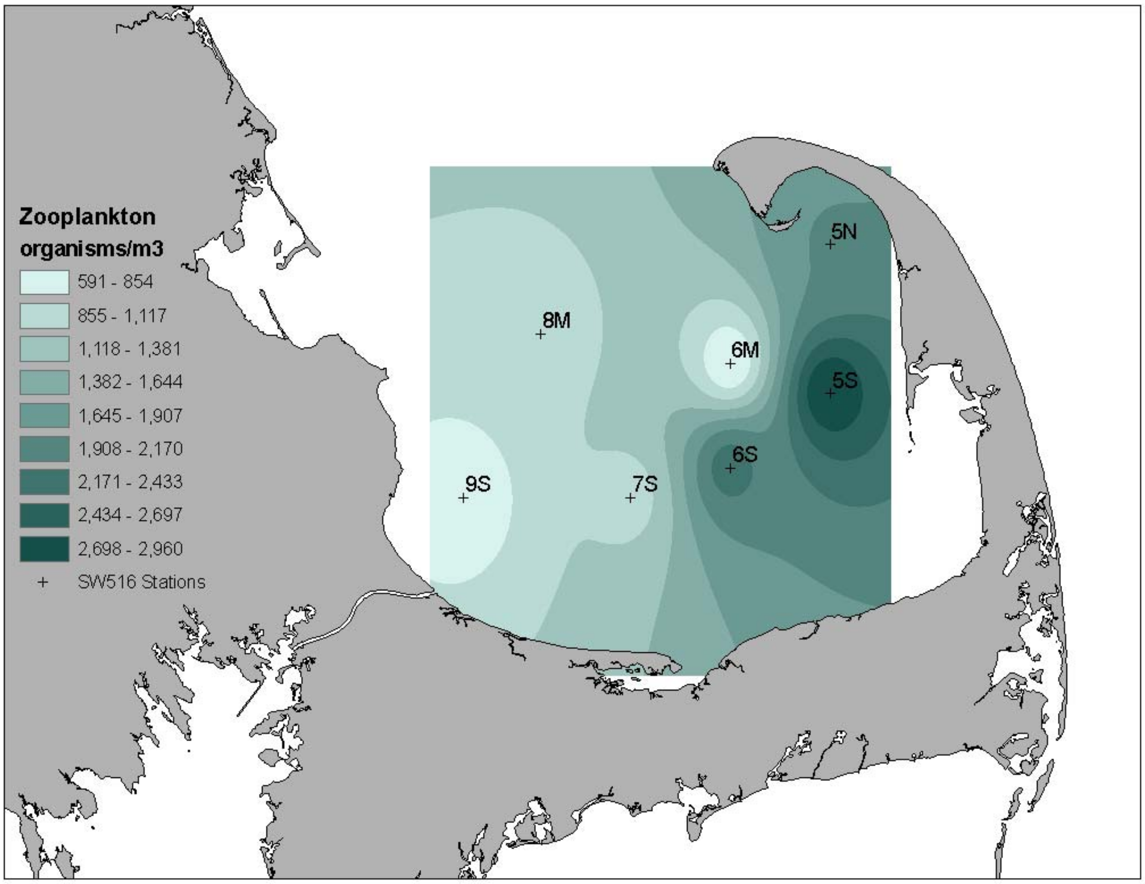
Year	Date	Cruise	Organisms/m^3 (cruise means)	Tow Type
2005	Jan. 15	SW516	944	Surface
2005	Jan. 15	SW516	1489	Oblique
2004	Jan. 18	SW391	3104	Surface
2004	Jan. 18	SW391	4495	Oblique

<u>Interpreted Likelihood (1-10) of:</u>
Aggregation: Low (2)
Residency: Low (2)
Near-surface Feeding: Very Low (1)
Feeding in the Water Column: Low (2)
Trends in Above: N/A
Quadrant Quality/ Attractiveness: NE (2); SE (3); SW (2); NW (1)

Aerial Surveillance

The CCS/DMF aerial surveillance team has completed four surveys of Cape Cod Bay since the beginning of the year. The first survey was conducted on Jan. 2, and the most recent survey was flown on Jan. 15. Despite ideal aerial survey conditions on all flights, no right whales have been sighted to date.

Plot of Zooplankton Densities from oblique net tows on SW516



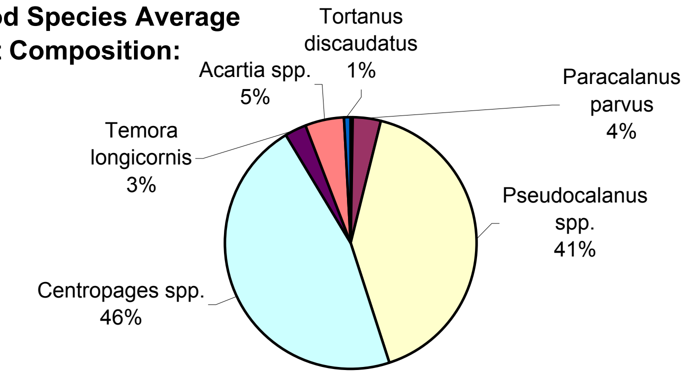
Surface Zooplankton Assessment: SW516 (1/15/2005) Julian Day 15

DMF-funded CCS aerial right whale sightings: 0 whales on 1/15 *SW516 vessel sightings: 0 right whales*

MEASURES:

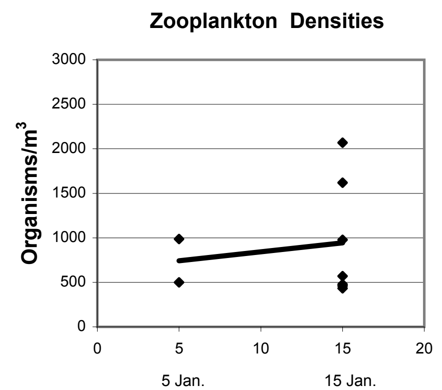
Technique	Station	Total Zpl/m^3	Settled Vol/m^3	Total Calories/m^3	Total Dry Wt./m^3
Surface Tow	5N	1619.15	0.76	223.13	0.04
Surface Tow	5S	2068.90	0.53	164.80	0.03
Surface Tow	6M	432.33	0.31	58.89	0.01
Surface Tow	6S	978.59	0.34	92.98	0.02
Surface Tow	7S	570.67	0.19	50.14	0.01
Surface Tow	8M	478.44	0.15	45.99	0.01
Surface Tow	9S	460.04	0.12	47.80	0.01
Cruise Average:		**944.02**	**0.34**	**97.67**	**0.02**

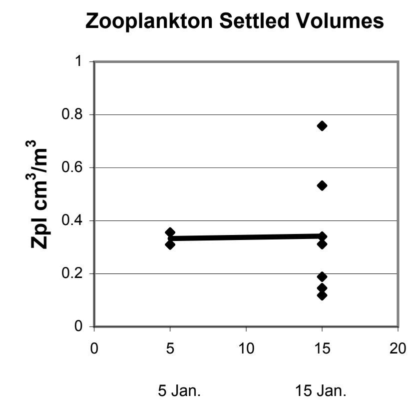
Copepod Species Average Percent Composition: SW516

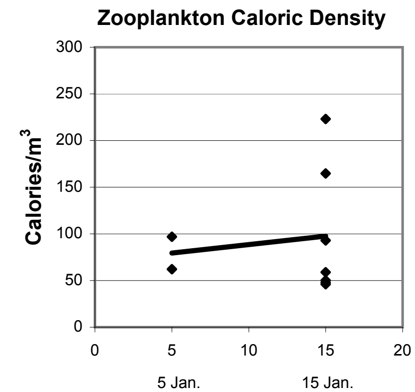


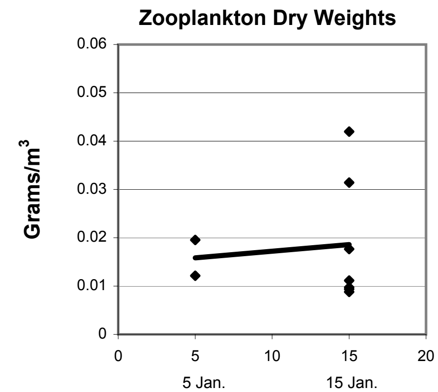
2005 SEASONAL TRENDS: x-axis values are expressed as Julian days in all graphs

Entire Cape Cod Bay:

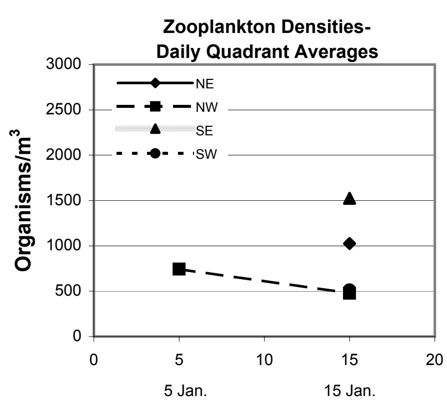


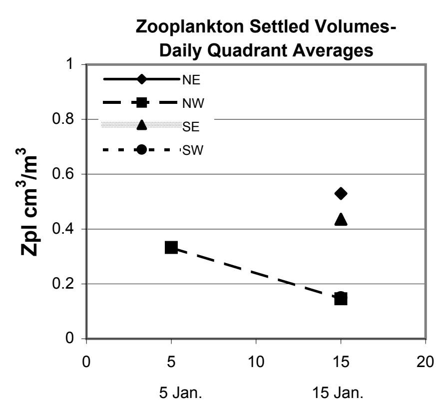


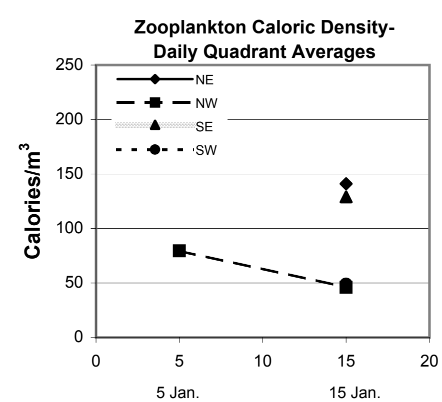


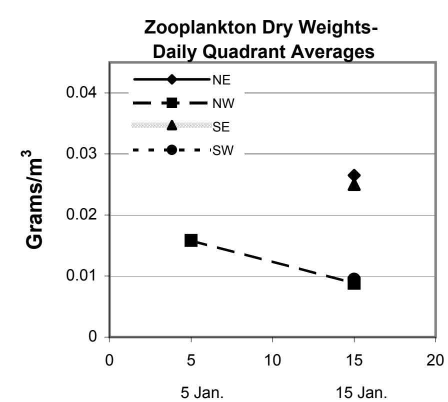


Geographic Quadrants:









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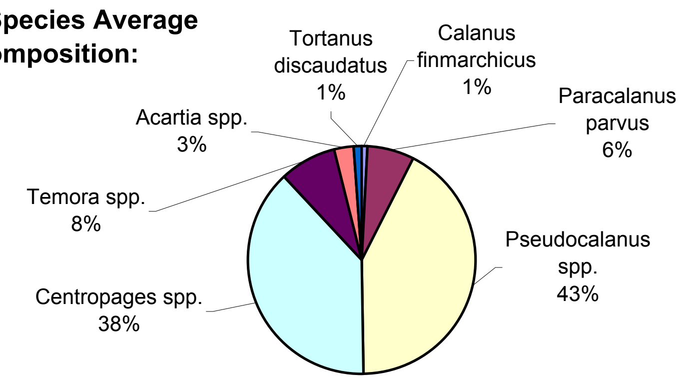
Oblique Zooplankton Assessment: SW516 (1/15/2005) Julian Day 15

DMF-funded CCS aerial right whale sightings: 0 whales on 1/15 *SW516 vessel sightings: 0 right whales*

MEASURES:

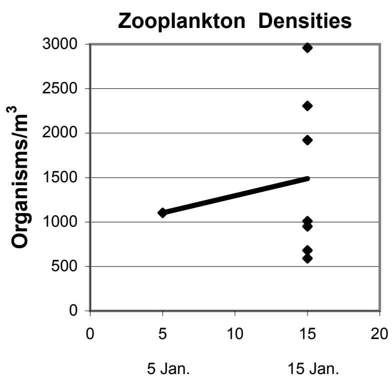
Technique	Station	Total Zpl/m^3	Settled Vol/m^3	Total Calories/m^3	Total Dry Wt./m^3
Oblique Tow	5N	1921.58	0.93	275.43	0.05
Oblique Tow	5S	2960.09	0.97	229.25	0.04
Oblique Tow	6M	591.09	0.45	80.80	0.02
Oblique Tow	6S	2306.81	0.75	213.24	0.04
Oblique Tow	7S	1009.69	0.44	113.14	0.02
Oblique Tow	8M	950.82	0.35	103.25	0.02
Oblique Tow	9S	682.01	0.28	68.27	0.02
Cruise Average:		**1488.87**	**0.59**	**154.77**	**0.03**

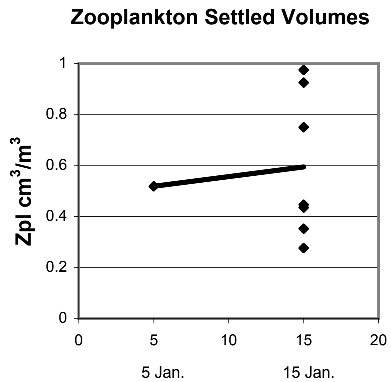
Copepod Species Average Percent Composition: SW516

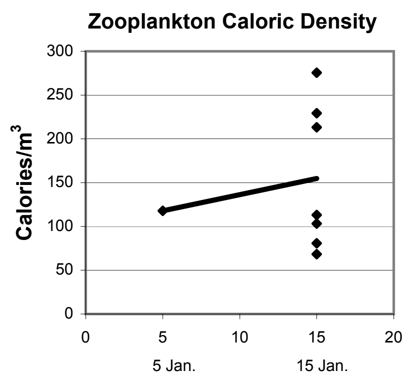


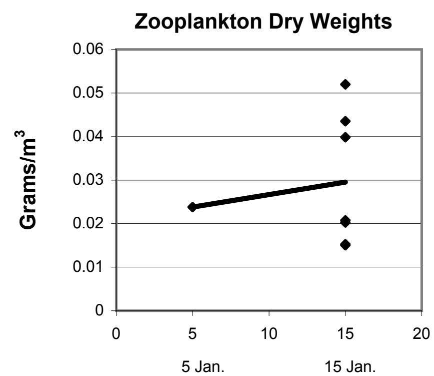
2005 SEASONAL TRENDS: x-axis values are expressed as Julian days in all graphs

Entire Cape Cod Bay:









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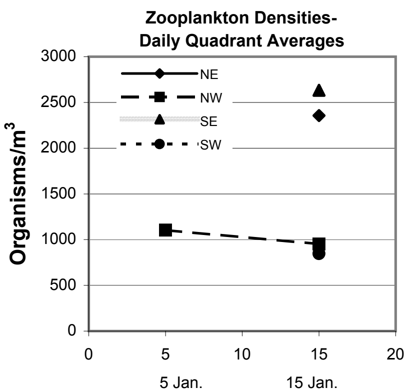

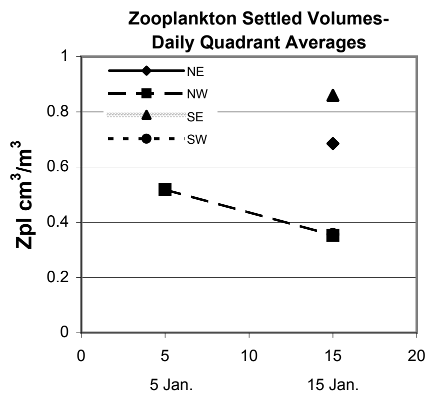

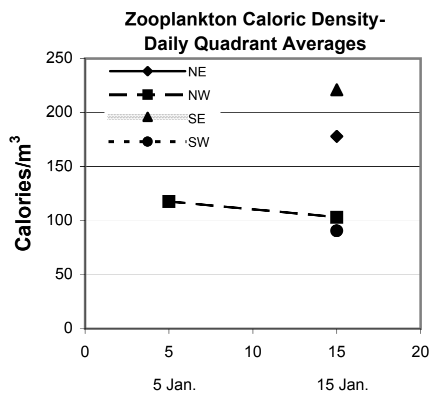

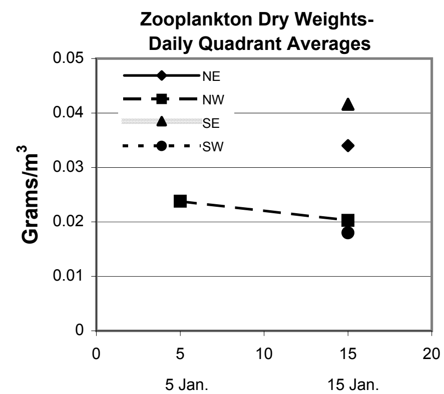

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Cruise Assessment

Results from zooplankton sampling in the four geographic quadrants of Cape Cod Bay (CCB) on March 7, cruise SW525, highlighted continued variation in organism and caloric densities and plankton species composition throughout the bay. The presence of increased numbers of right whales since previous surveys (see Aerial Surveillance) is not explained by the data obtained from traditional methods of net tow and water column profiling. On this cruise, additional samples were collected at a location (Station A) with one right whale swimming with its mouth open underwater (this whale has a mouth entanglement, which possibly explains this behavior), as observed by the aerial survey team. Other whales were present within several nautical miles of this special station as well.

Surface Layer Assessment

The mean bay-wide zooplankton density in the surface layer declined slightly from an already low value since the previous cruise eleven days ago, and individual samples fell within a broad range of 5 to 678 organisms/m^3. Extreme variation in the relative percentages of taxa among stations was apparent. Some of these unusual examples include: 58% of total zooplankton composed of adult female *Calanus finmarchicus* at station 7S, 87% of total zooplankton composed of *Centropages hamatus* at Station 9S, and 41% of total zooplankton composed of *Centropages typicus* at Station 8M. Once the two stations sampled in each quadrant were averaged together, the northeastern quadrant continued to sustain the highest values of total zooplankton and caloric densities in the surface layer. However, all measurements of the zooplankton resource in the surface layer remain extremely low, lying well below the estimated feeding threshold for right whales.

Oblique (surface to 19m) Assessment

Compared to the previous cruise, SW524, the mean bay-wide total zooplankton particle density value doubled, and the mean caloric density tripled. The discrepancy in the change of these two measures is likely explained by an increase in the average relative percentage of lipid-rich *Calanus finmarchicus* from 9% on SW524 to 36% on SW525. As an example of the influence of *C. finmarchicus* on the measures we use for assessment, it is interesting to note that the station with the highest oblique caloric density (9N), had a zooplankton particle density that measured less than half that at station 6S. Species composition clearly plays an important role in the calculation of caloric density. As stated previously, the caloric density values are calculated using only the common copepod taxa, therefore if other zooplankton taxa, including euphausiids, are present, these values do not adequately reflect calories consumed by feeding right whales.

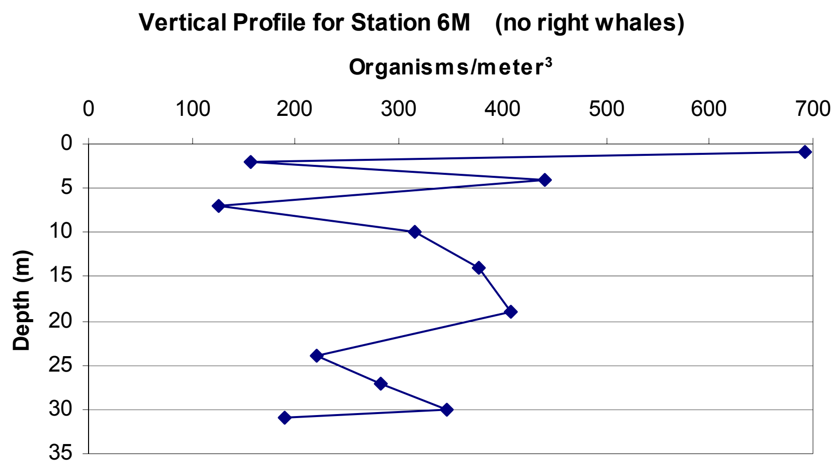
The oblique tow at station A, within ¼ nm of at least one right whale, had density values that fell within the range of neighboring stations, yet the species composition had a much higher percentage of *Calanus finmarchicus* (53%) than all other stations. Given the inherent patchiness of the zooplankton community, it is possible that this whale was targeting high-density, lipid-rich patches, which were not captured in the oblique tow.

AUTHORSHIP:
CRUISE ASSESSMENT: BESSINGER, MAYO (DMF-FUNDED CCS HABITAT STUDIES PROGRAM)
AERIAL SURVEILLANCE AND GIS PLOT: NICHOLS (DMF-FUNDED CCS AERIAL SURVEILLANCE PROGRAM)

Targeted sampling for euphausiids, through the use of rapidly hauled oblique tows, did not capture any individuals on SW525. However, we continue to believe that the presence of whales near stations 6S and 7S results to some degree from disjunct patches of *Meganyctiphanes norvegica* (see earlier assessments).

Water Column Assessment

The vertical profile of zooplankton density at station 6M displayed below shows the highest density 1m below the surface. This value was 691 organisms/m^3, only thirteen organisms greater than the density measured with the surface tow net at this location. Most densities ranged from 200- 400 organisms/m^3, well below the right whale feeding threshold.



General

Indications of normal seasonal changes in the Cape Cod Bay midwater system that are likely reflected in changes in the physical oceanography were noted during plankton enumeration. These included higher numbers of both copepod and barnacle nauplii (zooplankton at station 9S was composed of 64% nauplii) when compared to previous cruises, and indications of high densities of diatoms, both as chains of smaller diatoms in addition to the larger centrics. The effect on the copepod community of what appears to be the beginning of a spring bloom will probably be seen in future cruises.

The disparity between samples on SW525 and those from approximately a year ago (see table below), has increased since the last assessment. Surface layer values in 2005 are currently less than one order of magnitude what they were at this time in 2004, and oblique average values are also over one order of magnitude lower. However, data from 2005 continues to show more copepod species diversity, higher relative percentages of *Calanus finmarchicus* and lower relative percentage of *Pseudocalanus spp.*

The conclusion in the assessment from SW524, eleven days ago, remains applicable: the estimated copepod densities throughout the bay do not explain the continued presence of right whales. The present conditions in Cape Cod Bay are unlike any seen before, with whales apparently feeding in areas that our assessment methods suggest are not suitable. The presence of the euphausiid, *Meganyctiphanes norvegica*, on earlier cruises may well be a factor that is controlling the small but stable aggregation of whales in the southern quadrants of the bay. In an effort to determine the food source that is influencing the whales, we will undertake a directed sampling effort on the next cruise, sampling the water column in locations where whales are seen repeatedly diving. If mobile swarms of euphausiids are present we anticipate our techniques will again indicate them. With weather and time constraints on SW525 it was not possible to explore the conditions within the engybenthic layer. Thus we also anticipate intensive sampling of the engybenthos (near bottom layer) where in past years we believe whales have foraged on very thin but extremely dense layers of calanoid copepods.

Interannual Comparisons:

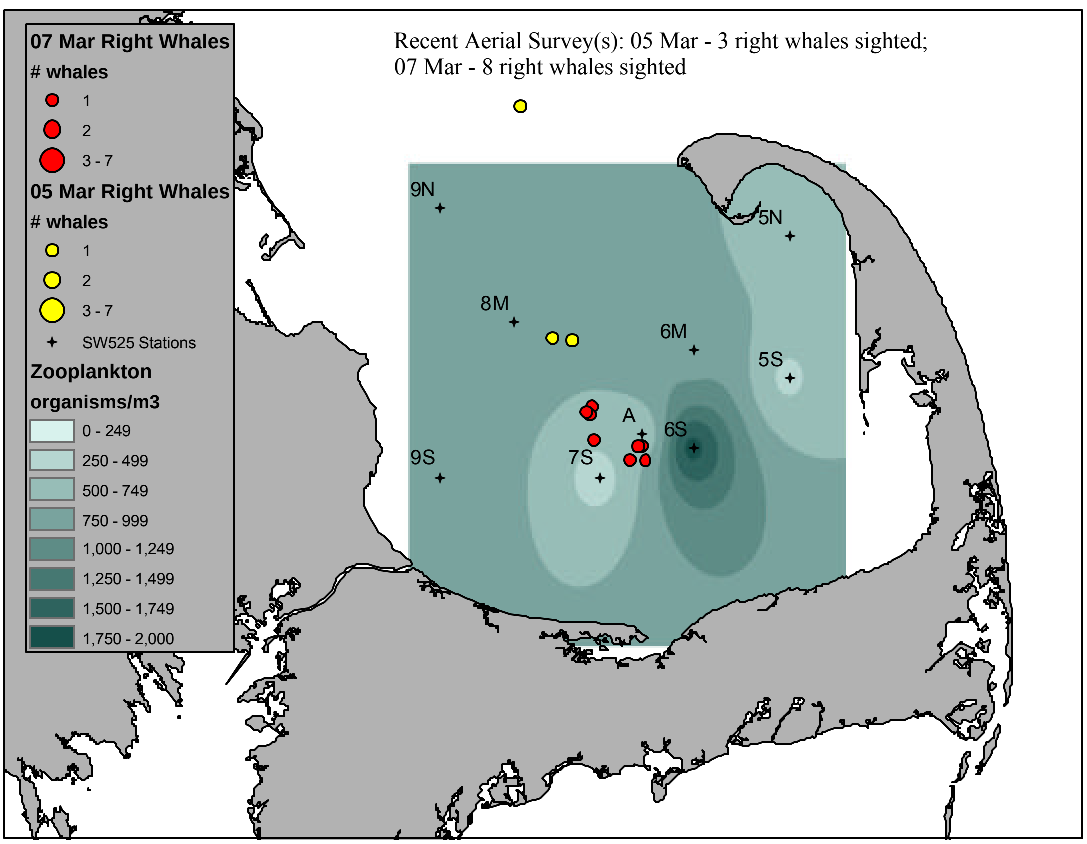
Year	Date	Cruise	Organisms/m^3 (cruise means)	Tow Type
2005	Mar. 07	SW525	211	Surface
2005	Mar. 07	SW525	874	Oblique
2004	Mar. 10	SW401	3530	Surface
2004	Mar. 10	SW401	9141	Oblique

<u>Interpreted Likelihood (1-10) of:</u>
Aggregation: Very Low (2)
Residency: Very Low (2)
Near-surface Feeding: Very Low (1)
Feeding in the Water Column (0-19m): Very Low (2)
Trends in Above: increasing in certain locations
Quadrant Quality/ Attractiveness: NE (2); SE (2); SW (1); NW (2)

Aerial Surveillance

Since the last assessment, the CCS/DMF aerial survey team has completed two surveys of Cape Cod Bay, on 05 and 07 March. On 05 Mar, three right whales were sighted, including one animal near the northern boundary of the survey area (see below). On 07 Mar, eight whales were seen farther south in the bay, at least two of which were observed with mouths open in apparent feeding behavior. Based on preliminary photo-analysis, the three whales seen on 05 Mar were among the eight individuals sighted on 07 Mar. The animal seen far to the north on 05 Mar was among the whales seen farthest south on 07 Mar, having moved a straight-line distance of over 15 nautical miles. During the two surveys, five individuals were seen by the CCS/DMF team for the first time in 2005, one of which was seen on 05 and 07 Mar, and four of which were seen on 07 Mar only. Among the whales sighted on 07 Mar was adult male #1424, an entangled whale first seen carrying gear in winter of 2002 in the southeast US. It is difficult to determine if the animals seen on 07 Mar represent an influx of whales into the bay since 05 Mar, as the southern portion of the bay was surveyed in marginal conditions (sea state up to Beaufort 5) on 05 Mar. Thirteen individual right whales have been identified in Cape Cod Bay to date in 2005, all of which have been matched to the catalog. Ten are adult females, and three are adult males. To date, each of the adult males has only been photographed once, on 26 Feb (one animal) and 07 Mar (two animals, including #1424).

Plot of zooplankton densities from oblique net tows on SW525 and right whale sightings from 2 aerial surveys on 05 and 07 March.



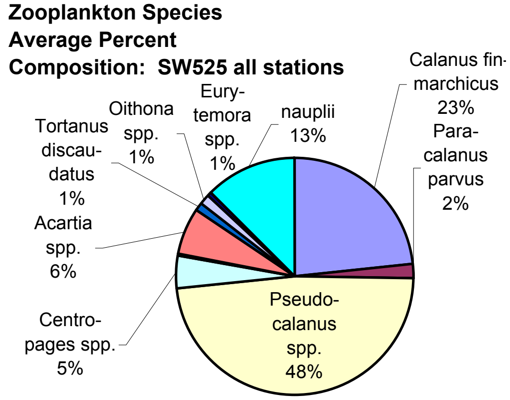
Note: The plot above was generated using an Inverse Distance Weighted (IDW; ArcGIS Spatial Analyst) interpolation method applied to data from oblique net tows at eight fixed stations and one additional station in the vicinity of a right whale (shown above, marked by +) in order to obtain a bay-wide projection of zooplankton density distribution. Coastline data: USGS.

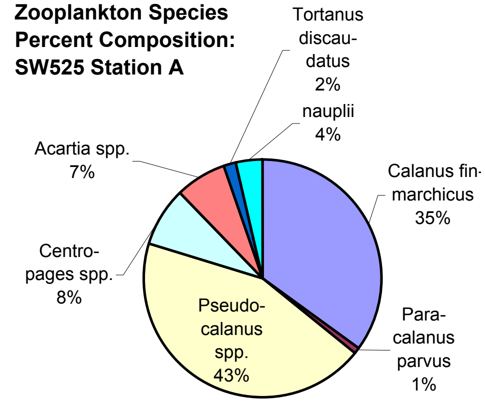
Surface Zooplankton Assessment: SW525 (3/7/2005) Julian Day 66

DMF-funded CCS aerial right whale sightings: 3 on 3/5 and 8 on 3/7   *SW525 vessel sightings: 3-4 right whales*

MEASURES:

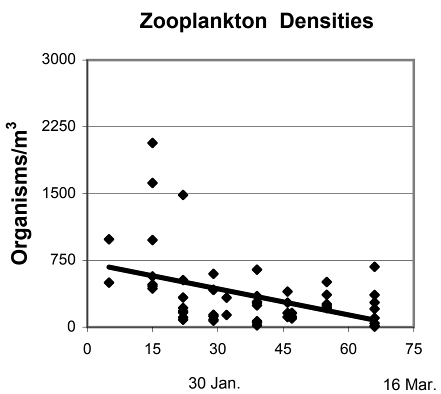
Technique	Station	Total Zpl/m³	Settled Vol/m³	Total Calories/m³	Total Dry Wt./m³
Surface Tow	5N	277.70	0.16	40.96	0.0082
Surface Tow	6M	678.07	0.26	81.22	0.0181
Surface Tow	8M	43.08	0.07	11.05	0.0020
Surface Tow	9N	102.84	0.17	36.13	0.0067
Surface Tow	5S	204.30	0.47	16.03	0.0033
Surface Tow	6S	361.73	0.22	29.94	0.0073
Surface Tow	7S	5.16	0.02	3.02	0.0005
Surface Tow	9S	11.27	0.01	1.86	0.0004
Cruise Average:		**210.52**	**0.17**	**27.53**	**0.0058**
Previous Cruise Average:		**299.60**	**0.13**	**28.98**	**0.0056**

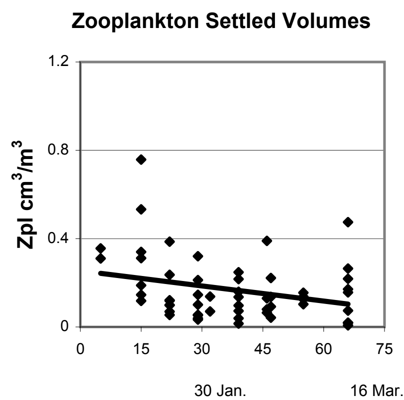


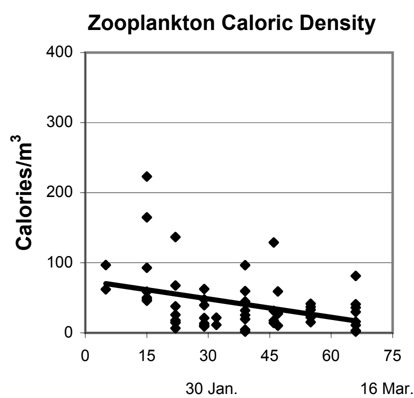


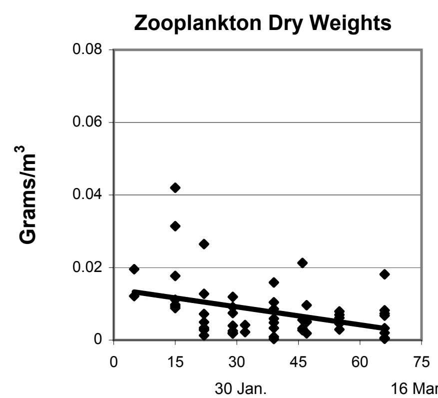
2005 SEASONAL TRENDS: x-axis values are expressed as Julian days in all graphs

Entire Cape Cod Bay:

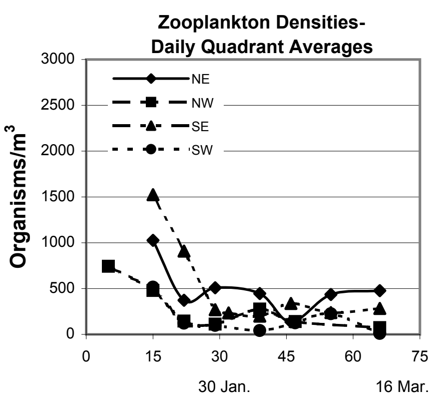


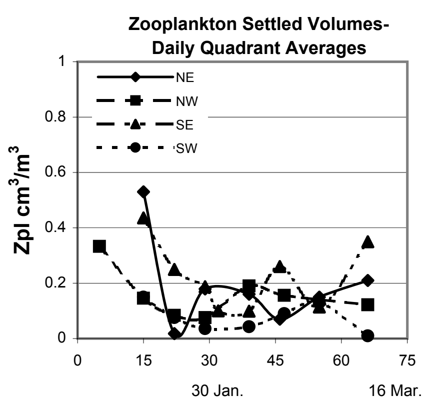


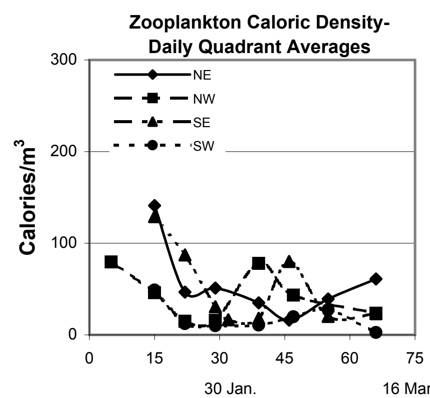


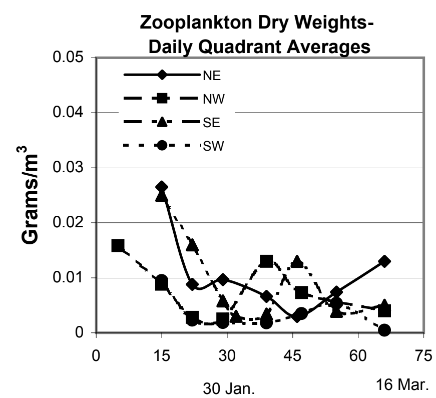


Geographic Quadrants:









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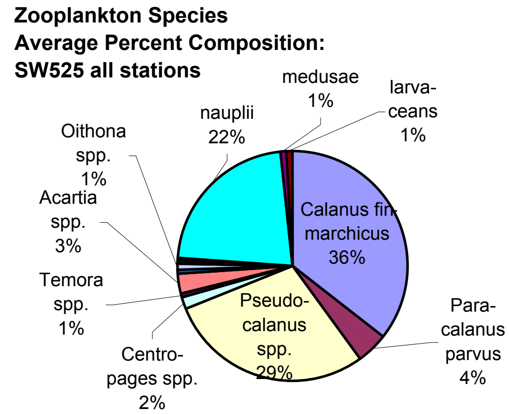
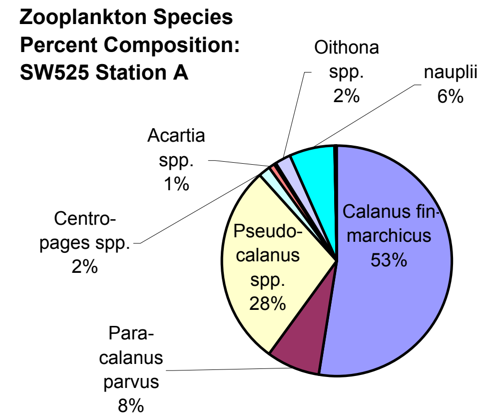
Oblique Zooplankton Assessment: SW525 (3/7/2005) Julian Day 66

DMF-funded CCS aerial right whale sightings: 3 on 3/5 and 8 on 3/7 *SW525 vessel sightings: 3-4 right whales*

MEASURES:

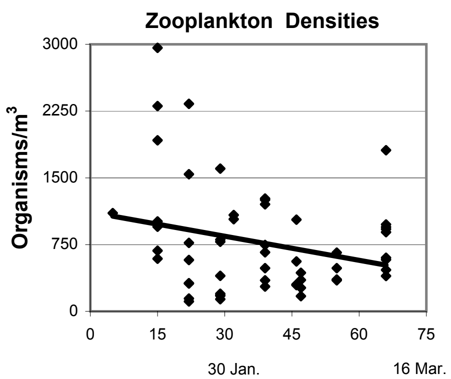
Technique	Station	Total Zpl/m^3	Settled Vol/m^3	Total Calories/m^3	Total Dry Wt./m^3
Oblique Tow	5N	581.43	0.32	49.70	0.0103
Oblique Tow	6M	947.45	0.41	160.40	0.0372
Oblique Tow	8M	923.22	1.05	239.02	0.0451
Oblique Tow	9N	889.01	0.91	317.01	0.0588
Oblique Tow	5S	466.35	0.91	33.32	0.0067
Oblique Tow	6S	1809.47	0.95	260.43	0.0622
Oblique Tow	7S	397.88	0.32	87.86	0.0212
Oblique Tow	9S	975.53	0.30	42.29	0.0106
Cruise Average:		**873.79**	**0.65**	**148.75**	**0.0315**
Previous Cruise Average:		**426.49**	**0.26**	**49.41**	**0.0092**

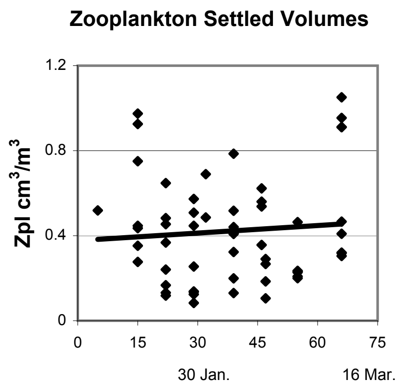


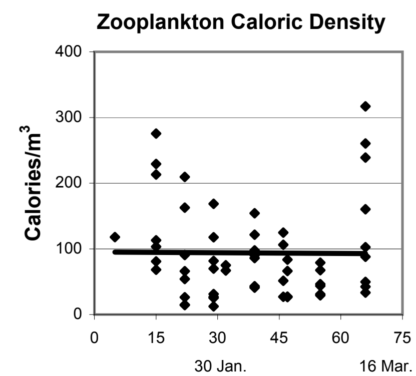


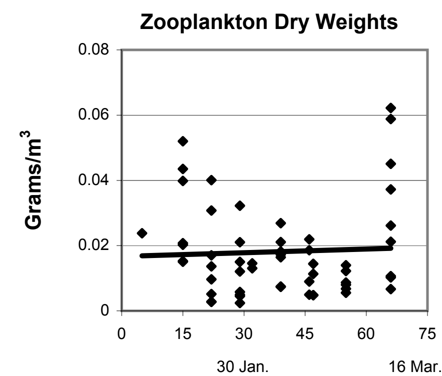
2005 SEASONAL TRENDS: x-axis values are expressed as Julian days in all graphs

Entire Cape Cod Bay:

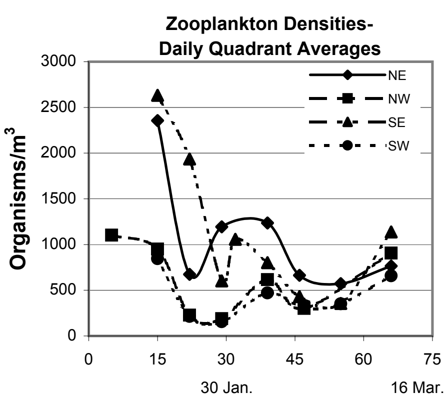


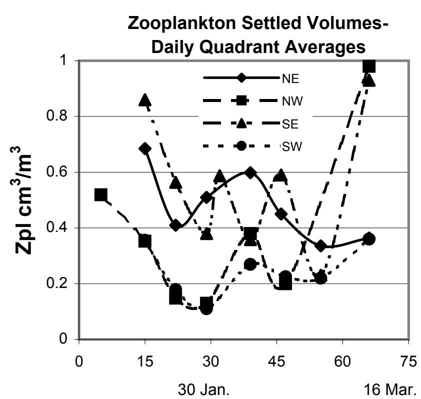


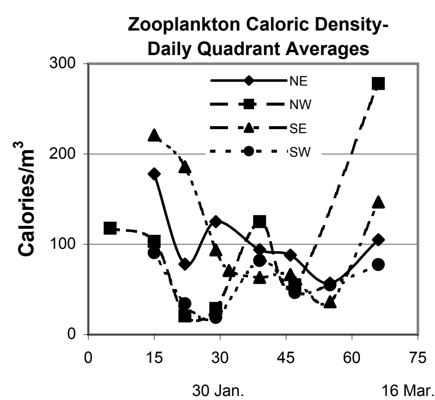


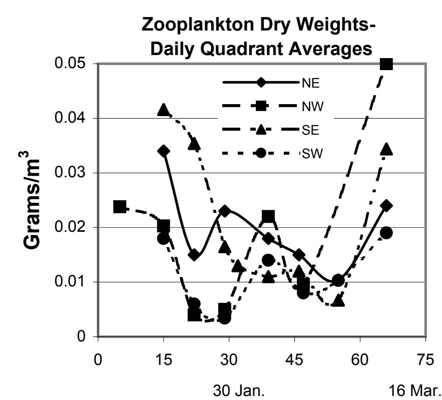


Geographic Quadrants:









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Cruise Assessment

SW545, the final cruise of 2005, produced a few exciting twists with which to end the season. Although no right whales were sighted, two oblique samples had densities near the estimated feeding threshold (7S was just above and 6M was just below it), and station 7S was composed of 96% *Calanus finmarchicus*. However, it is unlikely that this one isolated high density, calorically- rich area of Cape Cod Bay will attract aggregations of right whales due the isolated nature of the patch and competition from the Great South Channel, where aerial surveys have recently observed many right whales feeding.

Surface Layer

During the four days since SW544, the mean bay-wide surface layer density has re-gained the order of magnitude that it lost during the previous cruise interval, resulting in a value similar to that from SW541 on 4 May. However, this rise in the bay-wide mean is misleading, as it results entirely from a large increase in surface density at station 7S (from 32 to 2285 organisms/m^3), while all other stations remained at extremely low density levels. The assessment from the previous cruise discussed station 5N as a similar example of this patchy occurrence of high-density zooplankton. In addition to a much higher density, the zooplankton species composition at 7S was also different from all other stations (see pie charts). This rich patch was composed of 96% *C. finmarchicus*, with *Pseudocalanus* spp. and *Centropages hamatus* the only other taxa present. Elsewhere, the zooplankton continued to diversify, with higher relative percentages of other copepod species as well as barnacle larval stages, cladocerans, larvaceans, and fish eggs. The eastern/western CCB species composition partitioning observed on SW544 was not seen on SW545.

Oblique (surface to 19m) Assessment

In contrast to the surface layer, samples collected in oblique net tows increased more uniformly at all stations, although the peak at 7S was again seen. The mean bay-wide oblique zooplankton density more than doubled since the last cruise, and remains higher than the past two cruises. As compared to SW544, there were large increases in density at stations 7S and 6M, and moderate increases at 8M, 6S, 9S and 9N. Both 5S and 5N decreased in density, and high numbers of ctenophores were present at 5S. Yet it is important to keep in mind that only one sample was above the feeding threshold, and that most stations remain at very low densities not attractive to right whales.

As mentioned in the previous assessment, the developmental composition of *C. finmarchicus* remains almost entirely early stages (I-IV) at all stations, resulting in relatively low caloric densities. In addition, as in the surface layer, more zooplankton species diversity at all stations except 7S was seen on SW545. There was a noticeable increase in the copepods *Oithona* and *Eurytemora* spp., as well as larvaceans, crustacean zoea, euphausiids, and cladocerans. All representatives of *Centropages* taxa were the species *C. hamatus*. Finally, continued large amounts of phytoplankton, particularly *Chaetoceros* spp. diatoms, were collected at all stations, and contributed to elevated settled volume measurements.

AUTHORSHIP:
CRUISE ASSESSMENT: BESSINGER, MAYO (DMF-FUNDED PCCS HABITAT STUDIES PROGRAM)
AERIAL SURVEILLANCE AND GIS PLOT: NICHOLS (DMF-FUNDED PCCS AERIAL SURVEILLANCE PROGRAM)

Water Column Assessment

There was no vertical sampling of the water column on SW545.

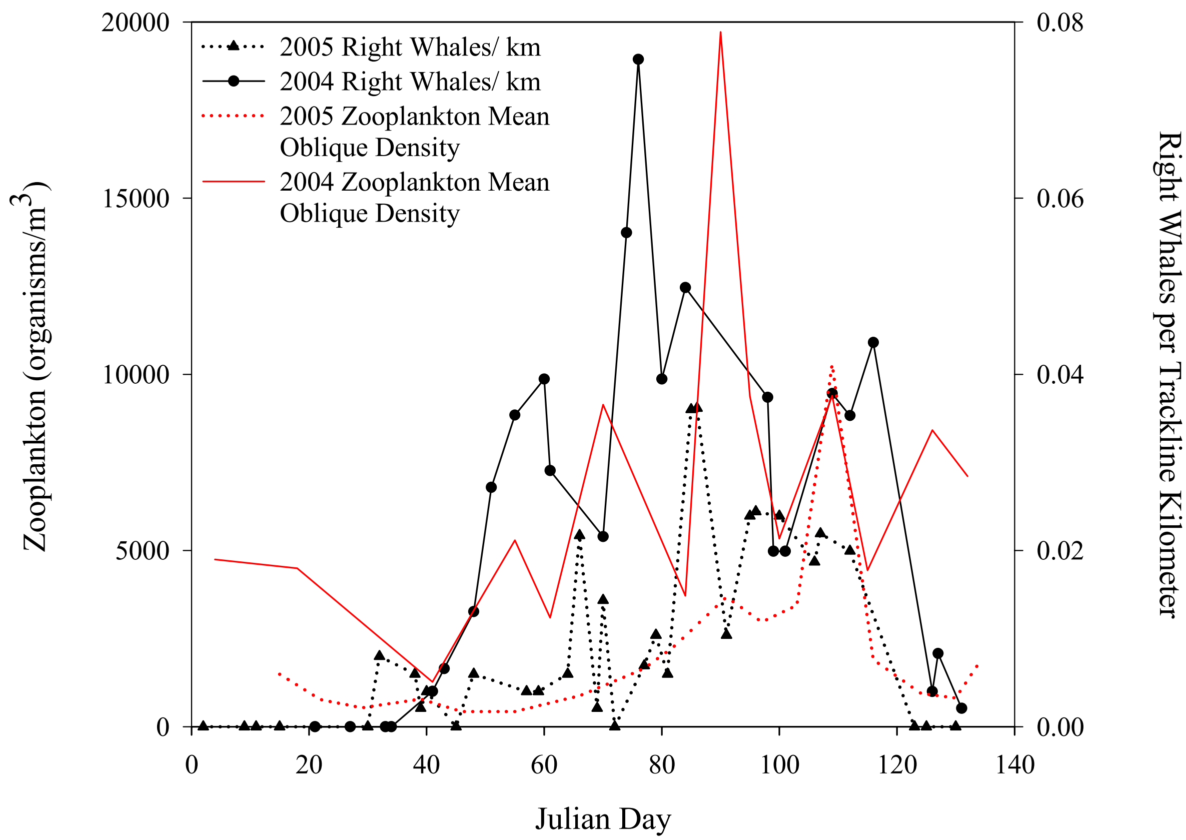
General

The graph on the following page tracks the seasonal decline of zooplankton densities in CCB through SW545. Although densities on this cruise rebounded somewhat, values are still well below those required to predict foraging by right whales, and are unlikely to improve in this habitat as summer approaches. The last aerial survey of the bay was flown on 10 May, and no right whales have been sighted from any PCCS platforms since 26 April. Given the known zooplankton productivity of the Great South Channel and perhaps other unsampled areas at this time of year, it is unlikely that right whales will return to CCB, other than for brief periods, in 2005.

Interannual Comparisons:

Year	Date	Cruise	Organisms/m^3 (cruise means)	Tow Type
2005	14 May	SW545	373	Surface
2005	14 May	SW545	1812	Oblique
2004	11 May	SW417	3288	Surface
2004	11 May	SW417	7106	Oblique

The following summary graph comparing zooplankton concentrations and right whale sightings is updated to include SW545.



Right whales sighted per kilometer of aerial survey track completed in Cape Cod Bay.

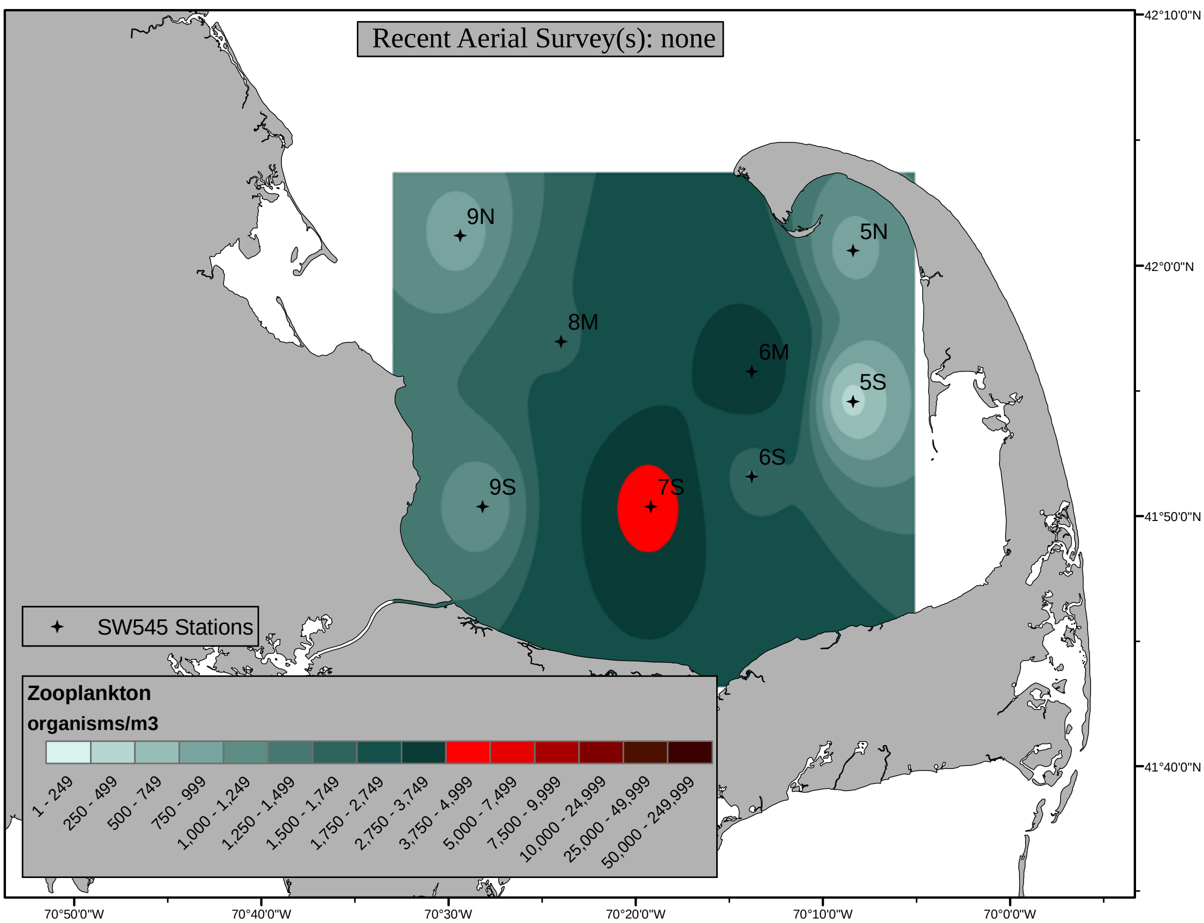
The estimate of track distance completed consists only of survey effort conducted on linear survey tracks (not including circling or turning between track lines). Sightings and survey effort north of the standard survey area or east of the Cape were excluded.

<u>Interpreted Likelihood (1-10) of:</u>
Aggregation: Very Low (2)
Residency: Very Low (1)
Near-surface Feeding: Very Low (1)
Feeding in the Water Column (0-19m): Low (3)
Trends in Above: stable, with occasional spikes in isolated areas
Quadrant Quality/ Attractiveness: NE (2); SE (1); SW (2); NW (1)

Aerial Surveillance

The PCCS/DMF aerial survey team has completed no surveys since 10 May (no right whales sighted during the last 3 surveys of Cape Cod Bay). At least forty-two individual right whales have been identified in Cape Cod Bay and matched to the catalog this year to date. Twenty-one are adult females (including six mothers accompanied by calves), one is a juvenile female, twelve are adult males, and two are adults of unknown sex. At least twenty-eight additional individuals, including four mother-calf pairs, have been only seen outside the bay.

Plot of zooplankton densities from oblique net tows on SW545 (14 May).



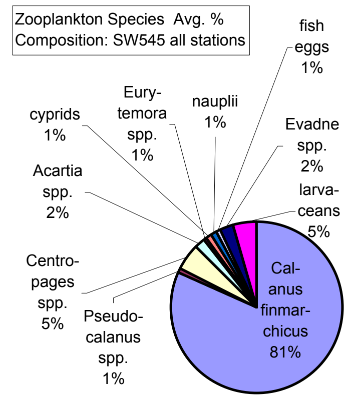
Note: The plot above was generated using an Inverse Distance Weighted (IDW; ArcGIS Spatial Analyst) interpolation method applied to data from oblique net tows at eight fixed stations (shown above, marked by +) in order to obtain a bay-wide projection of zooplankton density distribution. Zooplankton densities above the estimated right whale feeding threshold are indicated in shades of red. Coastline data: USGS.

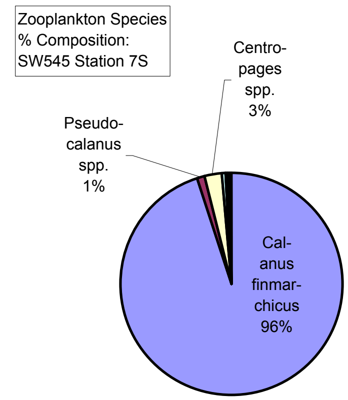
Surface Zooplankton Assessment: SW545 (5/14/2005) Julian Day 134

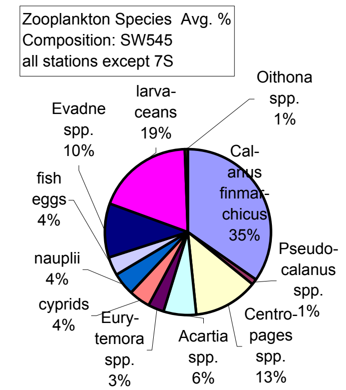
DMF-funded PCCS aerial right whale sightings (CCB): 0 on 5/10 *SW545 vessel sightings: 0 right whales*

MEASURES:

Technique	Station	Total Zpl/m^3	Settled Vol/m^3	Total Calories/m^3	Total Dry Wt./m^3
Surface Tow	5N	67.62	0.35	10.52	0.0030
Surface Tow	6M	133.05	0.13	18.78	0.0049
Surface Tow	8M	177.89	0.87	8.59	0.0020
Surface Tow	9N	138.84	0.07	8.93	0.0022
Surface Tow	5S	6.93	0.02	0.13	0.0000
Surface Tow	6S	124.72	0.09	23.78	0.0068
Surface Tow	**7S**	**2284.68**	**1.77**	**580.49**	**0.1609**
Surface Tow	9S	52.82	0.11	4.89	0.0013
Cruise Average:		**373.32**	**0.43**	**82.01**	**0.0226**
Previous Cruise Average:		**36.76**	**0.06**	**6.96**	**0.0015**



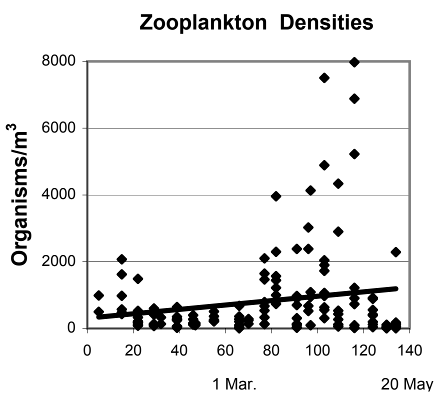


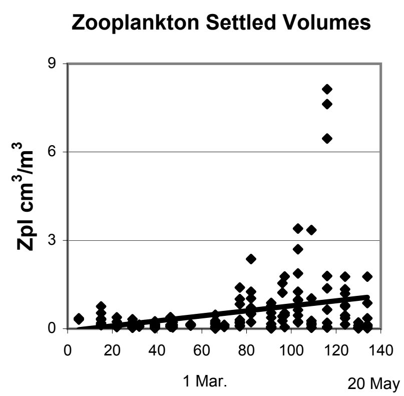


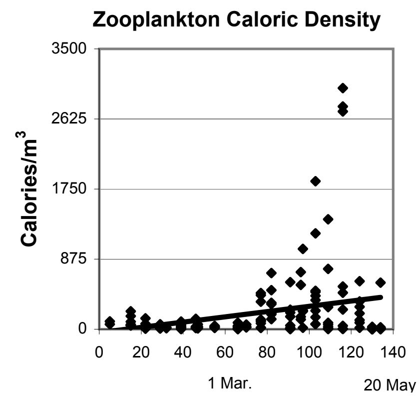
2005 SEASONAL TRENDS: x-axis values are expressed as Julian days in all graphs

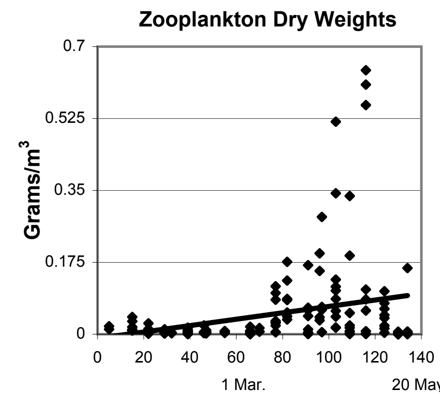
Entire Cape Cod Bay:

Note scale differences between surface and oblique graphs

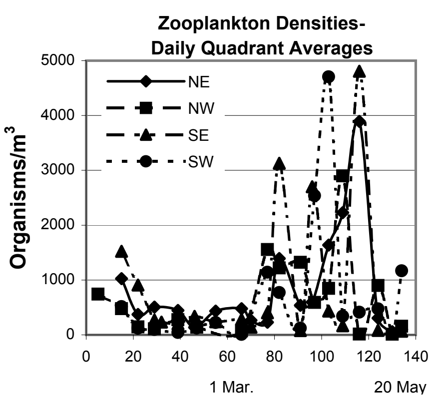


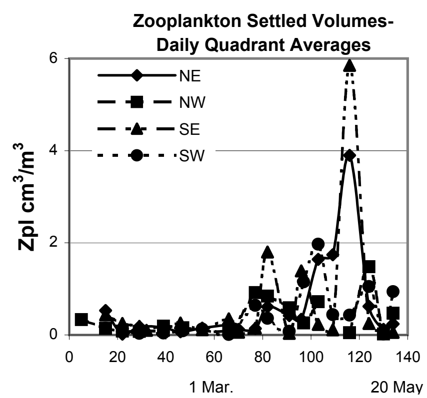


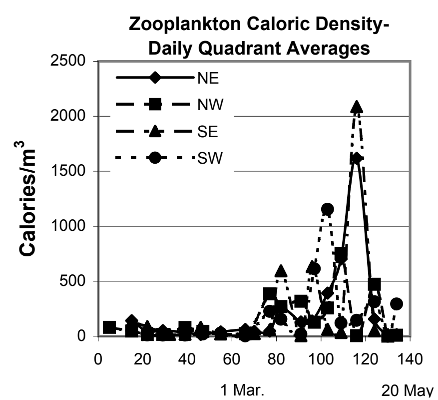


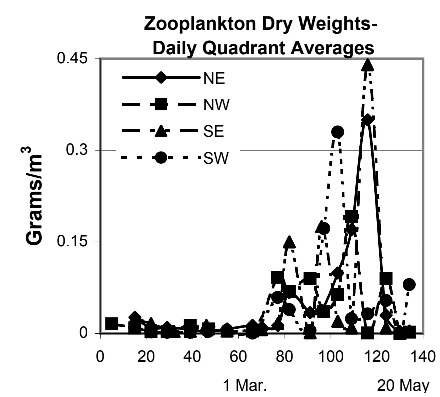


Geographic Quadrants:









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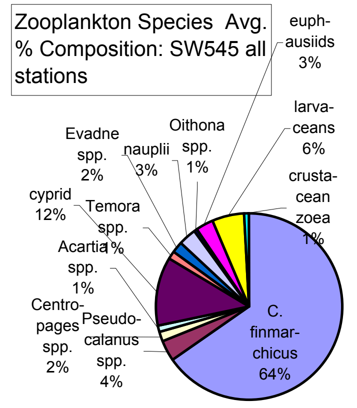
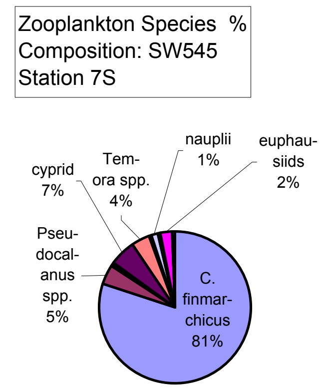
Oblique Zooplankton Assessment: SW545 (5/14/2005) Julian Day 134

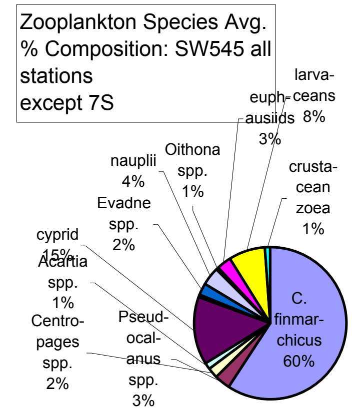
DMF-funded PCCS aerial right whale sightings (CCB): 0 on 5/10 ***SW545 vessel sightings: 0 right whales***

MEASURES:

Technique	Station	Total Zpl/m³	Settled Vol/m³	Total Calories/m³	Total Dry Wt./m³
Oblique Tow	5N	912.20	0.67	127.43	0.04
Oblique Tow	6M	3668.43	2.06	807.05	0.22
Oblique Tow	8M	1710.54	1.02	116.78	0.03
Oblique Tow	9N	899.94	1.06	104.22	0.03
Oblique Tow	5S	433.56	0.39	15.85	0.00
Oblique Tow	6S	1489.48	0.73	297.31	0.08
Oblique Tow	**7S**	**4291.42**	**2.22**	**857.08**	**0.24**
Oblique Tow	9S	1092.34	1.11	128.92	0.04
Cruise Average:		**1812.24**	**1.16**	**306.83**	**0.09**
Previous Cruise Average:		**808.78**	**0.83**	**145.24**	**0.04**



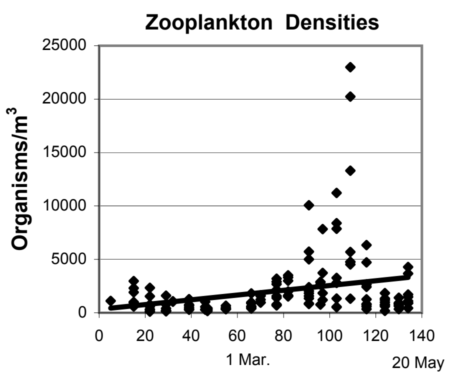


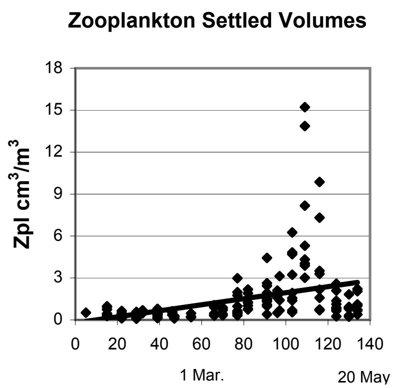


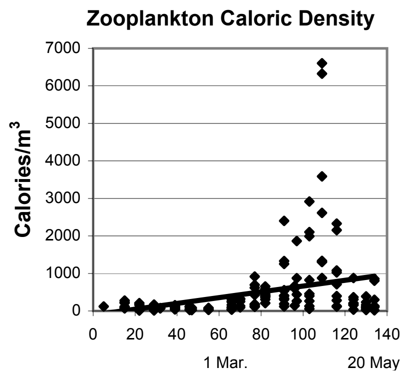
2005 SEASONAL TRENDS: x-axis values are expressed as Julian days in all graphs

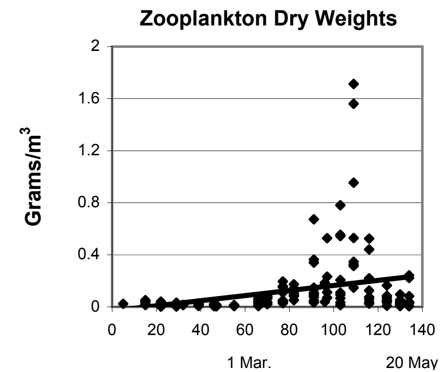
Entire Cape Cod Bay:

Note scale differences between surface and oblique graphs

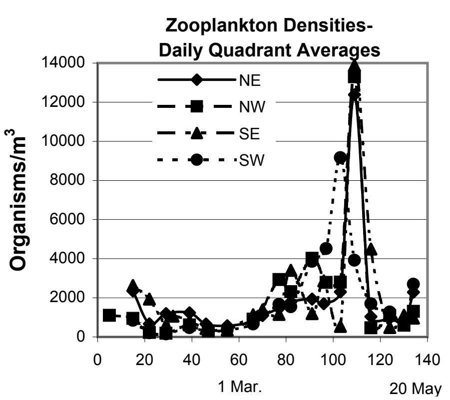


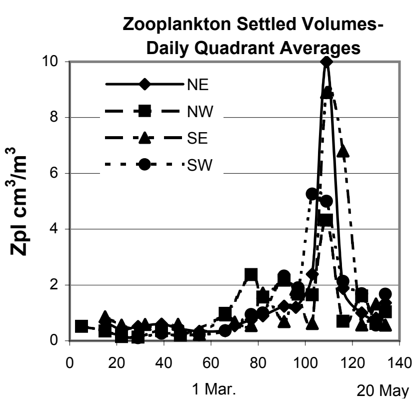


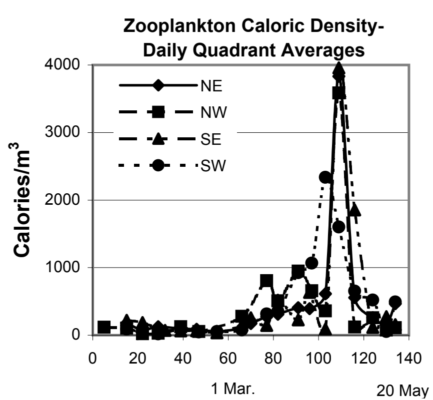


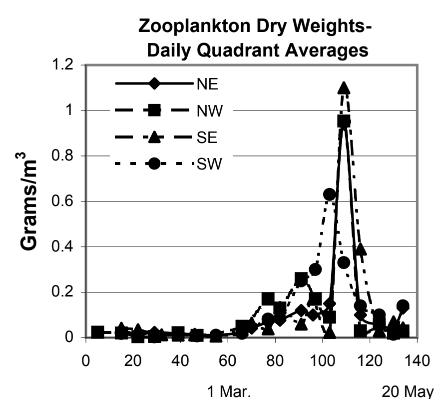


Geographic Quadrants:









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SECTION 3: A COMPARISON OF NORTH ATLANTIC RIGHT WHALES AND ZOOPLANKTON DISTRIBUTION IN CAPE COD BAY – 2005

3.1. Introduction

The principal causes of right whale mortality along the east coast of North America are entanglement and ship strike, both also potential causes of mortality in Cape Cod Bay. The Division of Marine Fisheries of the Commonwealth of Massachusetts (DMF) has for more than a decade sought to reduce the possibility of entanglement in fishing gear by instituting a variety of regulations controlling fishing activities during the right whale winter residency period in the bay and adjacent waters. The underpinning of the DMF management strategy is the concept that by reducing the co-occurrence of whales and the risky aspects of fishing activities, primarily lines in the water column associated with lobster traps, the risk of entanglement will be reduced. This strategy heavily depends upon knowledge of where whales are located and therefore benefits from both near-real time observations (from vessel and aircraft) and from the use of predictions that would allow timely and informed management actions. The surveillance program in Cape Cod Bay has evolved to accomplish DMF's goals of making their management decisions based on observational and predictive information.

The key product of the habitat study of Cape Cod Bay is the assessment instrument that reports the observations of each cruise of R/V *Shearwater*, giving a near-real time foundation for a prediction of the locations and behavior of whales within the bay. The assessment instrument, developed by the Provincetown Center for Coastal Studies (PCCS) in collaboration with DMF is comprised of a detailed report on the food resource, an overlay of whale sightings and zooplankton densities, and a prediction section. The assessment instrument is presented as a report to a wide variety of managers to whom it is sent by email usually within two days of a cruise. The reports using this assessment instrument are the most timely and direct product of the habitat program. Examples of the 22 reports of 2005 are found in Appendix II of section 2 of this report. Taken together, the aerial surveillance and habitat characterization components of the Cape Cod Bay study are intended to alert the DMF to the presence of right whales within the Cape Cod Bay Critical Habitat.

The underpinning of the assessment process used in the study is the concept that the quality of the zooplanktonic food resource controls the distribution and occurrence of the right whales in the bay, identifying many of the conditions that place the whales at risk of entanglement and of ship strike. Among the risk conditions that can be reliably predicted from a review of the resource conditions are:

- the likelihood of feeding activities that may occur and result in mouth entanglements
- the depth of feeding activities that influences the potential for ship strike and for entanglement
- the location within the bay where whales may aggregate

- the potential for the bay to attract whales and elicit feeding and residency

All of these considerations are part of the process by which the assessment instrument addresses the principal management issues before DMF. Therefore the habitat analysis that supports the assessment instrument specifically identifies whale behavior that is associated with the identified zooplankton characteristics and based on those predicts the behavior, location and occurrence of whales within the jurisdiction of DMF.

3.2. Methods

The collections of zooplankton used in the comparative studies were obtained using methods referred to in Section 2. For the summaries comparing zooplankton distribution and whale distribution, the mean raw zooplankton abundance was calculated at each of the eight fixed stations from oblique collections. 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 oblique zooplankton collection 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:

1. Oblique zooplankton samples were used in the development of the zooplankton abundance 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 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 not precisely representative of the resource abundance in the waters over the entire bay. The comparisons thus suffer 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.

3.3. Results

A comparison of the gross occurrence of whales identified during aircraft survey efforts with mean surface and oblique zooplankton densities from the 8 fixed stations are shown in Figures 1 through 6. These season-long profiles present a temporal perspective on the occurrence of whales and the associated zooplankton densities.

For the comparison of the spatial and temporal distribution of zooplankton and whales in Cape Cod Bay, the observations were grouped into three presentations: whole season (Figure 7), three 45-day comparisons (Figures 8-10), and bi-weekly plots (Figures 11-19). 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.

3.4. Discussion

The management responsibility of the right whale surveillance program, 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 habitat conditions, particularly zooplankton density and distribution, influence the occurrence and distribution of the whales, and that the co-occurrence of whales with vessels and fixed fishing gear increases the threat to whales of entanglement, serious injury, and mortality, the identification and prediction of locations where whales may aggregate is crucial to management of the habitat. Thus the principal product of the habitat program is the weekly assessment instrument (see examples in Appendix II of section 2 of this report) and predicts both the 'attractiveness' of the bay for right whale aggregation, and the behaviors that are likely associated. Further, the assessments give an indication of trends in vital measures of resource quality in each of four quadrants of the bay and offer a predictive section that uses the information and trends to forecast near-term future changes in whale behavior and distribution. Here we retrospectively summarize the general trends in the relationship between the habitat descriptions and the distribution and occurrence of whales in time periods larger than encompassed by the assessment instruments that are distributed to management agencies during the season.

3.4.1. Gross Whale Occurrence and Zooplankton Abundance Patterns

In the most general view of the habitat assessment work, the data permit a crude forecast of the general aggregation and dispersion of whales in Cape Cod Bay by using the bay-wide zooplankton densities as a measure of the attractiveness of the bay to whales (see Figures 1-6). This summary approach is intended to present managers and industry with a general understanding of the entry and departure of whales and of the influence of zooplankton on their occurrence. The season-long comparisons for 2003-2005 demonstrate both the value and the limitations of such an approach. In these figures we compare both average surface (Figures 1-3) and oblique (Figures 4-6) bay-wide zooplankton densities with aerial survey right whale sightings normalized by track line kilometer. These figures show that, in general terms, the trends in the numbers of whales in the bay reflect the observed zooplankton densities thus offering the potential that zooplankton surveys of Cape Cod Bay and of other locations where whales may occur will yield a general prediction of the presence of whales within the area.

The comparison of the two sampling methods used to characterize the zooplankton resource suggests that a combination of both surface and oblique net collections offers the best visualization and the most reliable predictive basis for the assessment of the attractiveness of Cape Cod Bay. It is likely that the dual sampling approach provides the clearest relationship to whale density because it yields two different perspectives of the resource. The comparison shows that in some years tracking the trend in the surface density of zooplankton is as useful as is that available from oblique samples (i.e. in 2003 and 2005) while in 2004 the relationship was less clear and the oblique samples appeared to be somewhat more expository.

3.4.2. Seasonal Plots

Figure 7 presents an overlay of the spatial comparison of the season-long zooplankton and whale distribution and densities, a counterpart to the temporal relationship between whale and food density referred to above. The average zooplankton density shown in Figure 7 is rather uniform throughout the bay system and yet the distribution of whales during the 2005 season was discreetly clumped in the eastern and southern portion of the bay. The lack of equivalent distribution patterns in Figure 7 is likely due to the season-long averaging method used to smooth the zooplankton data in which the short-term enrichment in localized areas that is important to feeding and aggregating whales is not visible against the background regional variability of the entire season.

More illustrative of the spatial relationship between the density of the zooplankton resources and of the whales than the year-long spatial comparisons are the 45-day plots shown in Figures 8-10. In Figure 8 a general richness in the food resource during the early part of the season in the eastern bay corresponds with general whale aggregation in the east and south. The subsequent 45-day plot (Figure 9) does not demonstrate as clear a relationship. Although we can't validate the reason for the weakness of the relationship, it is likely as was reported in the weekly assessments that whales were feeding on juvenile midwater euphausiids of the genus *Meganyctiphanes*, a "krill" organism, that are poorly sampled using zooplankton nets. Concentrations of what appeared to be these organisms were located by the 200 kHz. echo sounder in February, appearing as small, dense, disjunct patches 3-10 meters below the surface. Individual euphausiids were occasionally collected in zooplankton nets in the southern and central part of the bay from mid-February to late March, a period covered by Figure 9; however the influence of the krill on the observed distribution of whales remains conjectural. Feeding by right whales on euphausiids was directly observed only once in 2005 and the remainder of the hypothesized resource was apparently confined to subsurface patches. In contrast to the loose association between whales and zooplankton seen during the early part of the season, during the peak feeding period in April (Figure 10) dominated by a calanoid copepod (*Calanus finmarchicus*) resource, the distribution of whales was as expected reflective of zooplankton distribution.

3.4.3 Bi-Weekly Plots

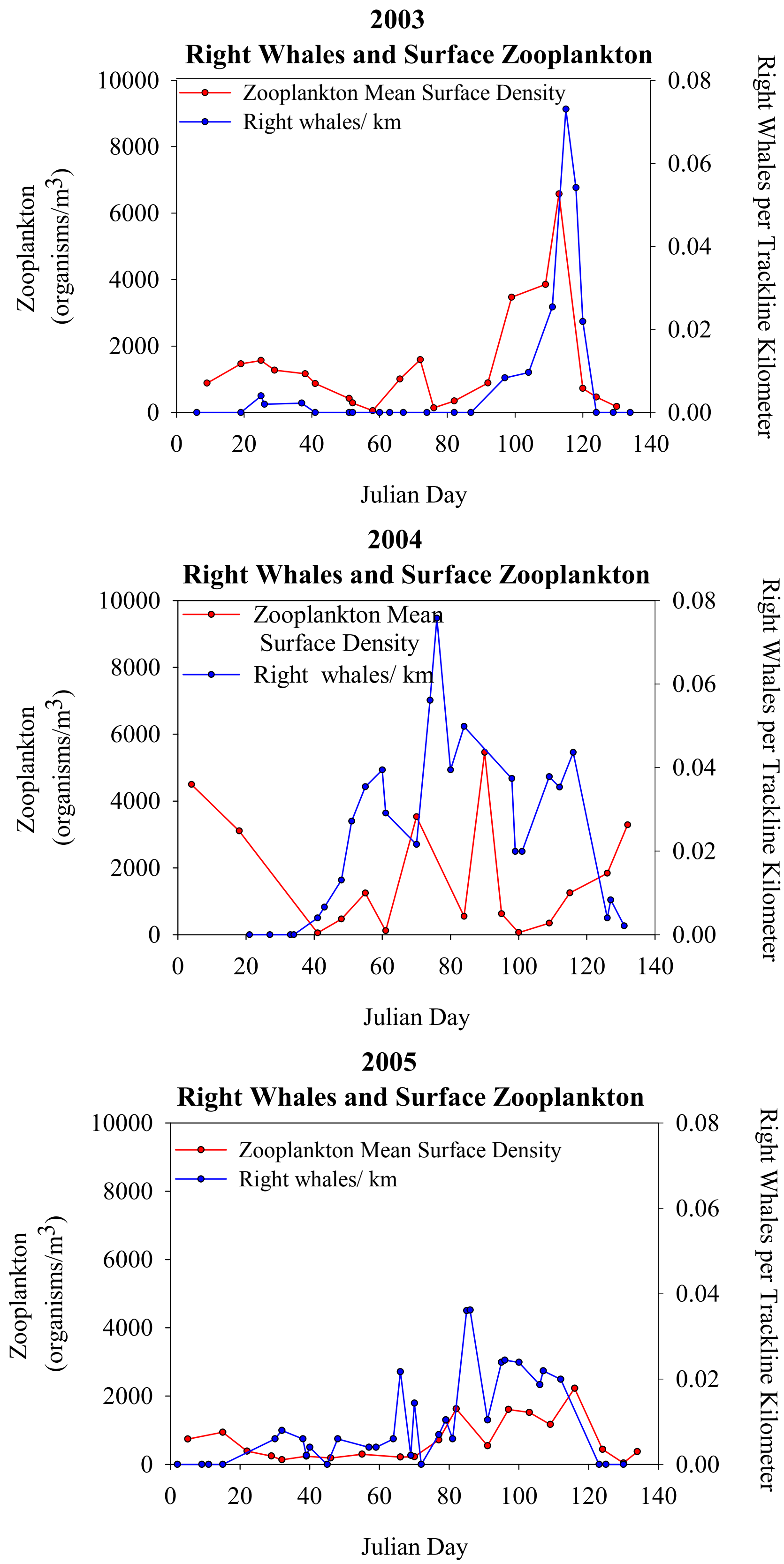
Because the distribution of the zooplanktonic foods is "fluid", literally and figuratively, the most accurate comparisons of the spatial relationship between the density of whales and of zooplankton are of short duration. Among the products that the surveillance program presents, the weekly assessments combined and presented here as bi-weekly comparisons (Figures 11-19) are the most diagnostic and useful for management purposes. The bi-weekly overlays show the seasonal enrichment of the zooplankton resource typical of the eastern and southern Cape Cod Bay system. The January plot (Figure 11) shows a food resource below the estimated feeding threshold of 3,750 organisms/m^3 and with the greatest richness in the eastern bay. As referred to earlier, the influx of whales during early February was not explained by an increase in copepod density but was more likely influenced by the presence of patches of juvenile euphausiids that cannot be accurately represented using traditional zooplankton collection techniques. Early-season zooplankton densities as reported in the assessment instruments and combined into the bi-weekly comparisons suggest a low bay-wide resource that would not cause aggregation of whales.

The passage of the season brought both an increase in the zooplankton density throughout the bay and an influx of whales. Though we have hypothesized that a substantial *Meganyctiphanes* resource may have had an impact on the distribution of whales during the middle part of the season, the calanoid copepod patches that are regularly found in Cape Cod Bay in 2005 appeared to exert their influence on the occurrence and distribution of whales starting in mid March (Figure 15) and reached a peak in the subsequent month (Figures 16-17). The dramatic decline in water-column zooplankton resources in late April and early May (Figure 18) was coupled with the obvious dispersion of whales seen in the plots of that time period. This change in the quality of the zooplankton and associated whale density is also demonstrated in Figure 6 during the period between 10 April through 30 April (JD100 and JD120), and appears as a regular feature of the late spring departure of the whales as seen in 2003 (Figure 4).

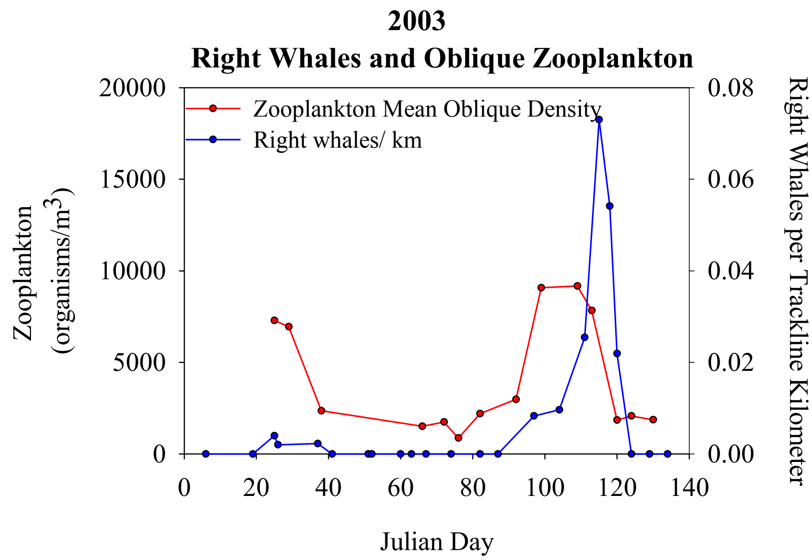
3.5. Summary

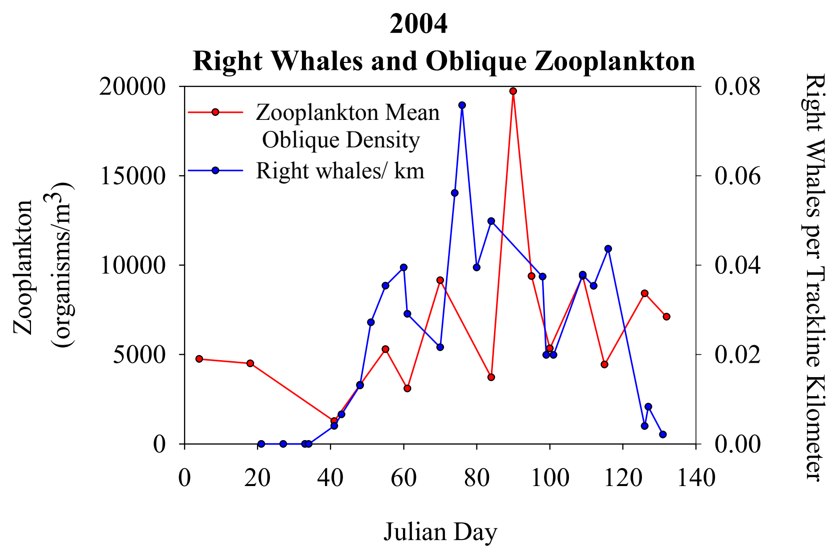
The Cape Cod Bay system is dominated by a counterclockwise current onto which is superimposed a semi-diurnal tidal flux and occasional wind-driven bulk water movement. The complicated physical processes influencing the drifting, dispersal, and aggregation of zooplankton resulting in the formation of the dense patches of copepods favored by right whales, dictate an exceedingly complex and dynamic relationship between the whales and their food. The surveillance program and, particularly the predictive part of the assessment reports, seeks to resolve and simplify the complex conditions and to forecast the reactions of highly mobile whales. Therefore any significant lag between zooplankton collections and data from aerial surveillance reduce the apparent precision of the small-scale predictive capacity of the technique. Thus the distribution of whales and high zooplankton concentrations on a short time-scale appear a much more accurate depiction of the relationship than those of longer time periods. By considerably increasing the density of the zooplankton sampling in order to approach the timing and coverage of the aerial survey, the fit between the two variables will likely be improved. Nevertheless, it is clear that directed sampling of zooplankton resources offers a sensitive method for predicting of the aggregation and dispersion of whales as well as presenting a method for identifying the general locations where whales may perform risky behaviors.

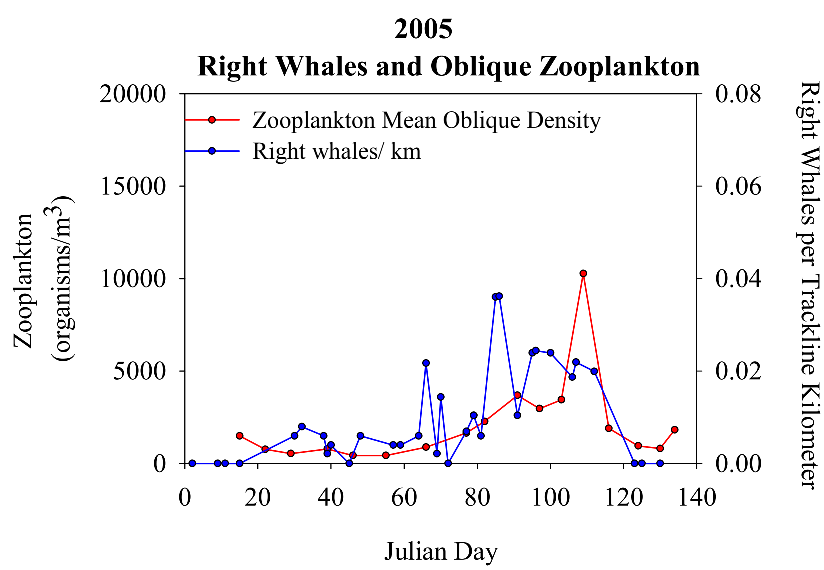
The hypotheses presented in the 2004 report, that whales in 2004 did not follow advected zooplankton into the bay and, at the end of the season, were probably attracted to areas of high zooplankton resources outside of the bay, are not factors that appear as important in interpreting the 2005 observations. The general season-long pattern of the entry of whales in 2005 closely followed the hypothesized process of whales being lured by a rich resource, while in the late season the efflux may be explained by a decline by an order of magnitude in total zooplankton density (Figures 3 and 6). It is likely that many aspects of the zooplankton resource conspire to result in the patterns of aggregation and dispersal that we observe, and that in 2005 the relatively simple relationship between the local Cape Cod Bay food density and richness and the movement of whales was the primary influential factor.



Figures 1 (top), 2 (middle) and 3 (bottom). 2003, 2004, and 2005 comparisons of right whales and surface zooplankton densities.







Figures 4 (top), 5 (middle) and 6 (bottom). 2003, 2004 and 2005 comparisons of right whales and oblique layer zooplankton densities.

Figure 7. Interpolated zooplankton density averaged from oblique net tows at eight fixed sampling stations (marked by +) and right whale sightings from aerial surveys during the 135-day period 1 January - 15 May 2005.

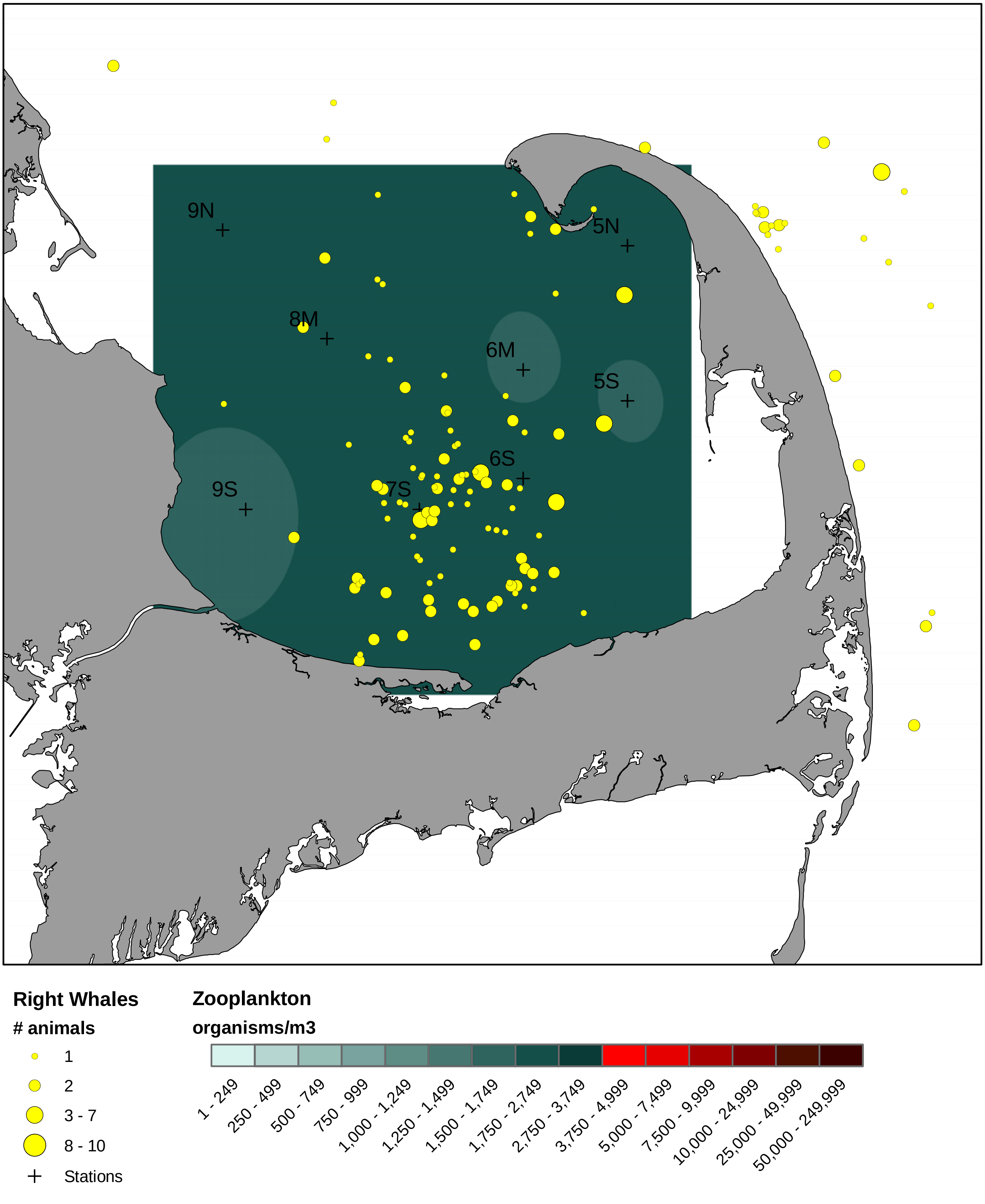


Figure 8. Interpolated zooplankton density averaged from oblique net tows at eight fixed sampling stations (marked by +) and right whale sightings from aerial surveys during the 45-day period 1 January - 14 February 2005.

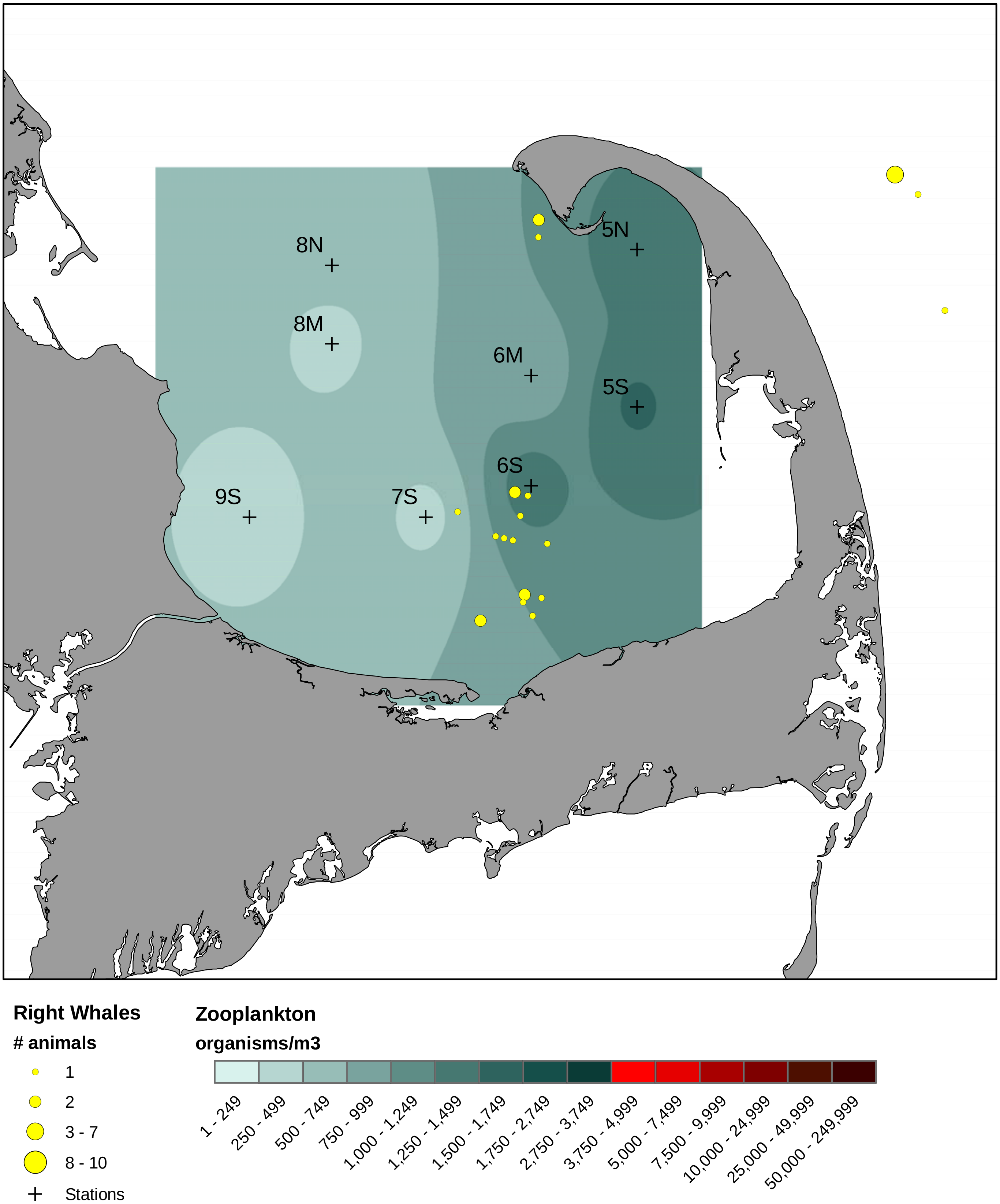


Figure 9. Interpolated zooplankton density averaged from oblique net tows at eight fixed sampling stations (marked by +) and right whale sightings from aerial surveys during the 45-day period 15 February - 31 March 2005.

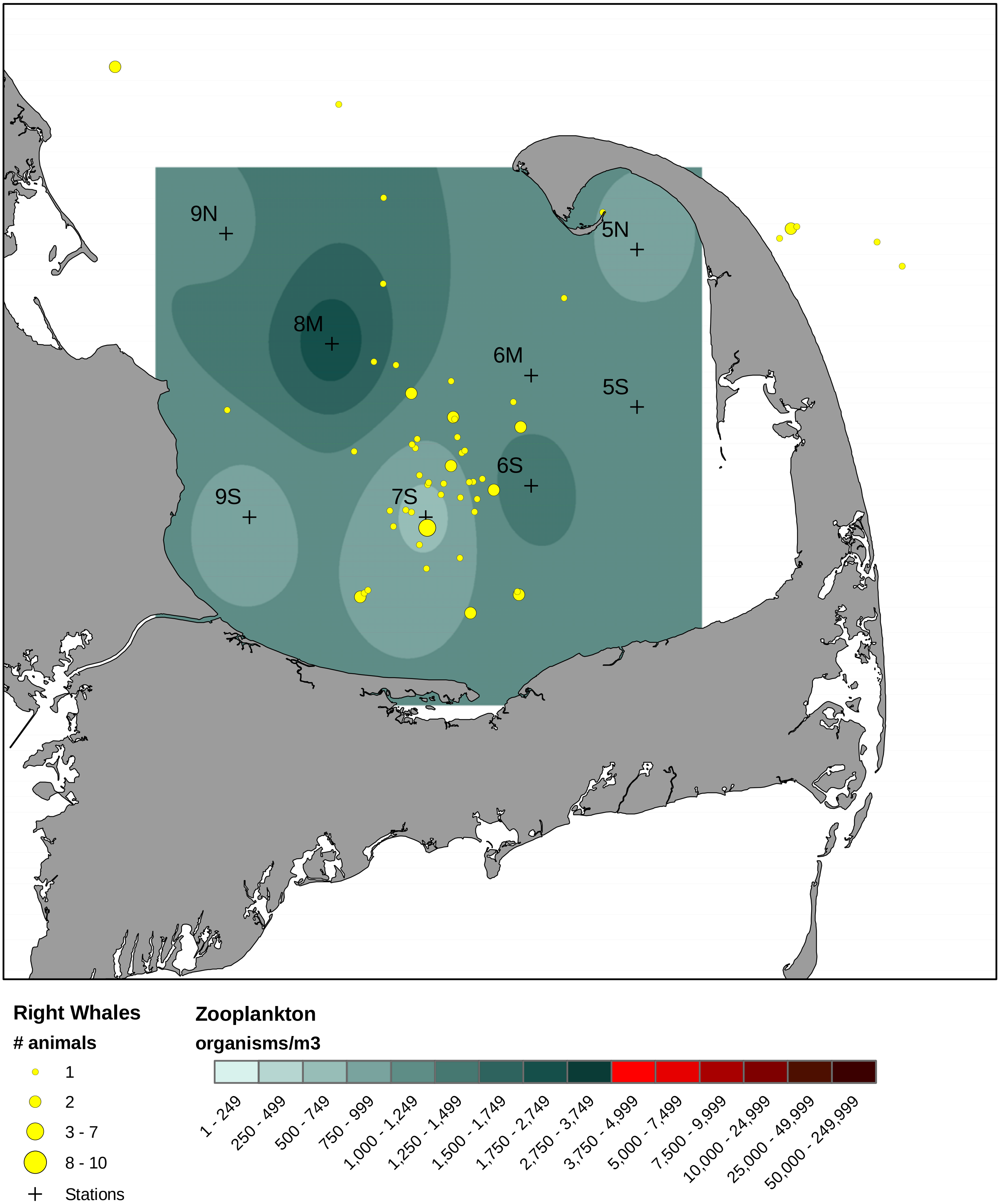


Figure 10. Interpolated zooplankton density averaged from oblique net tows at eight fixed sampling stations (marked by +) and right whale sightings from aerial surveys during the 45-day period 1 April - 15 May 2005.

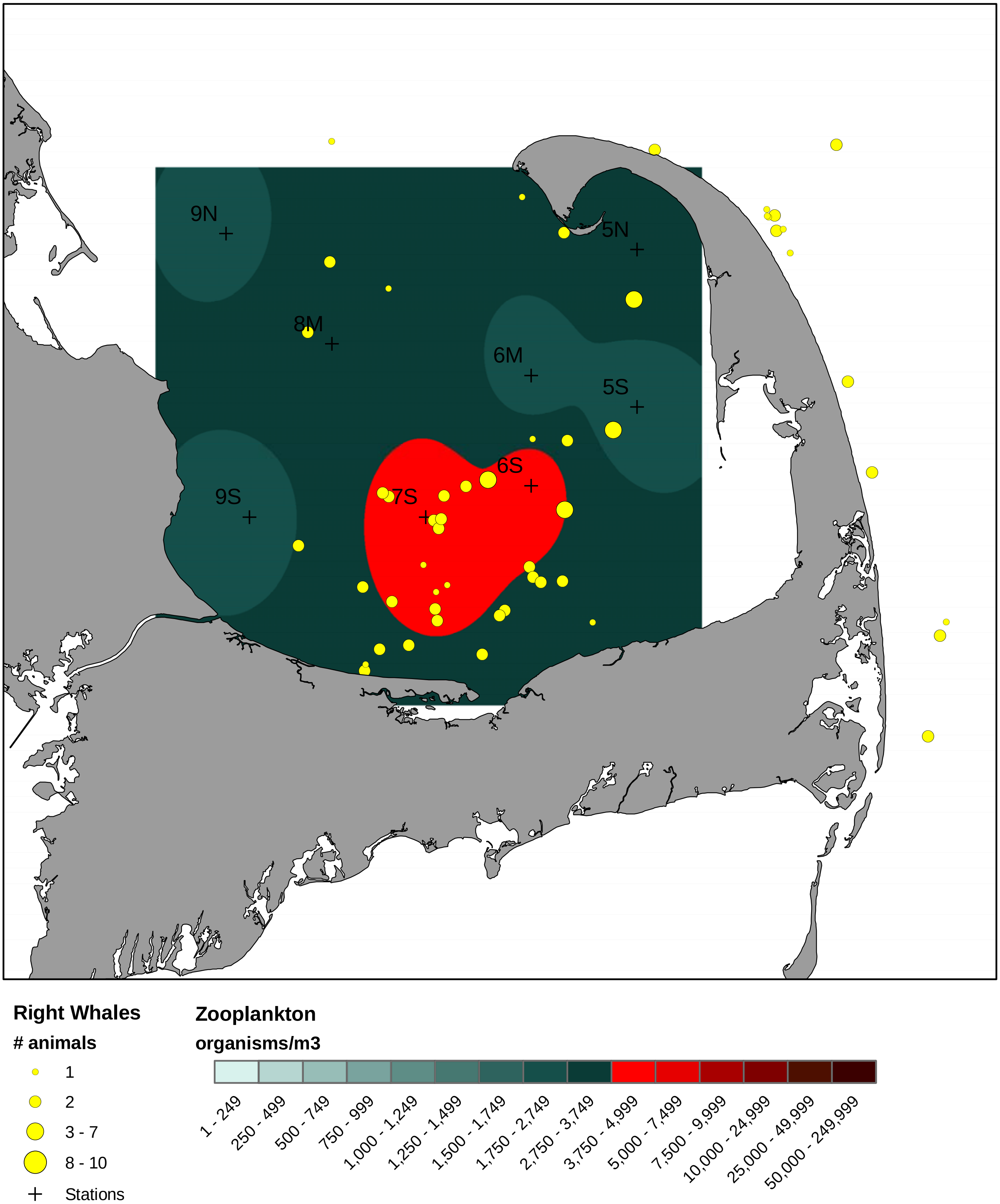


Figure 11. Interpolated zooplankton density averaged from oblique net tows at eight fixed sampling stations (marked by +) and right whale sightings from aerial surveys during the 14-day period 15 - 28 January 2005.

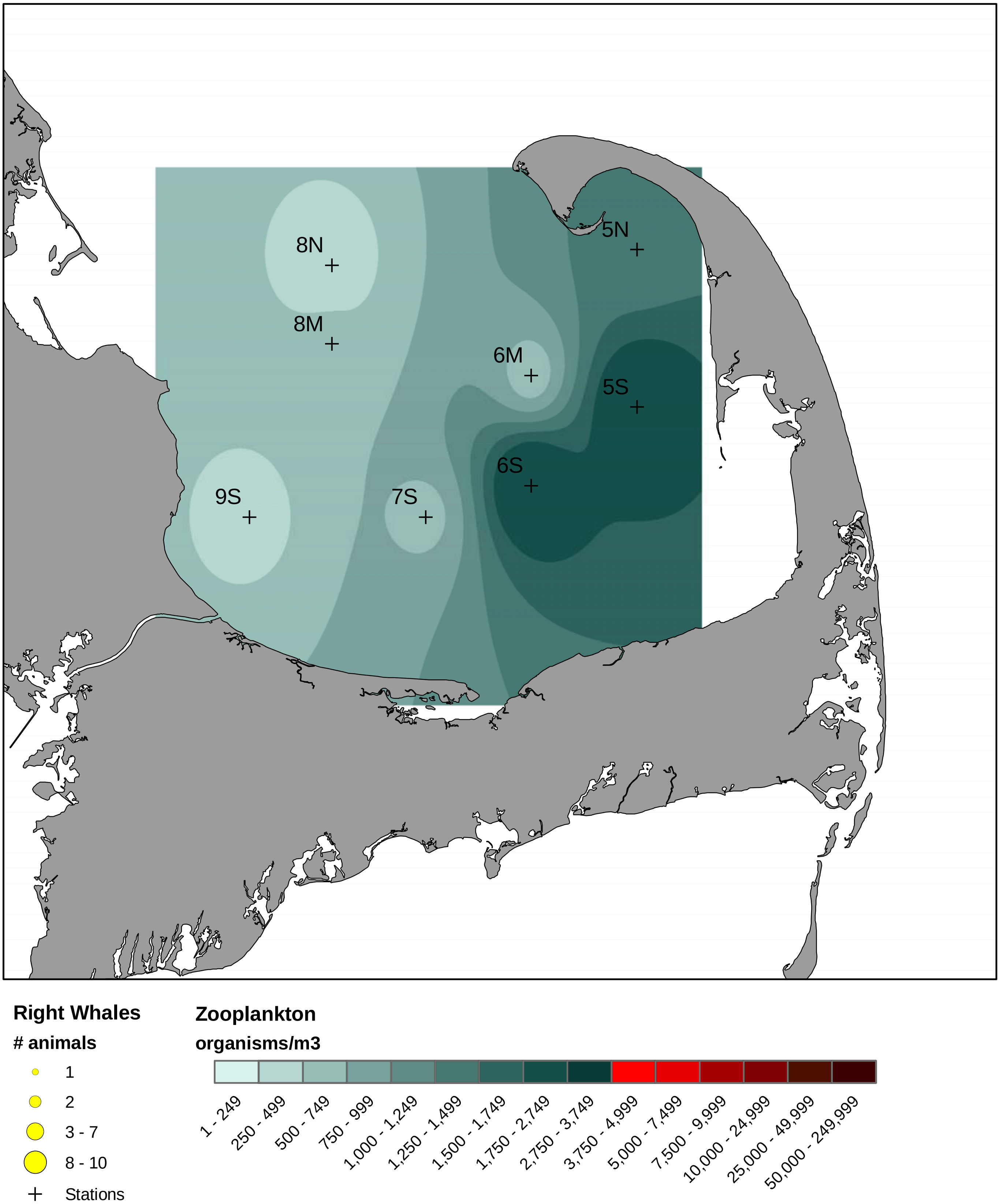


Figure 12. Interpolated zooplankton density averaged from oblique net tows at nine fixed sampling stations (marked by +) and right whale sightings from aerial surveys during the 14-day period 29 January - 11 February 2005.

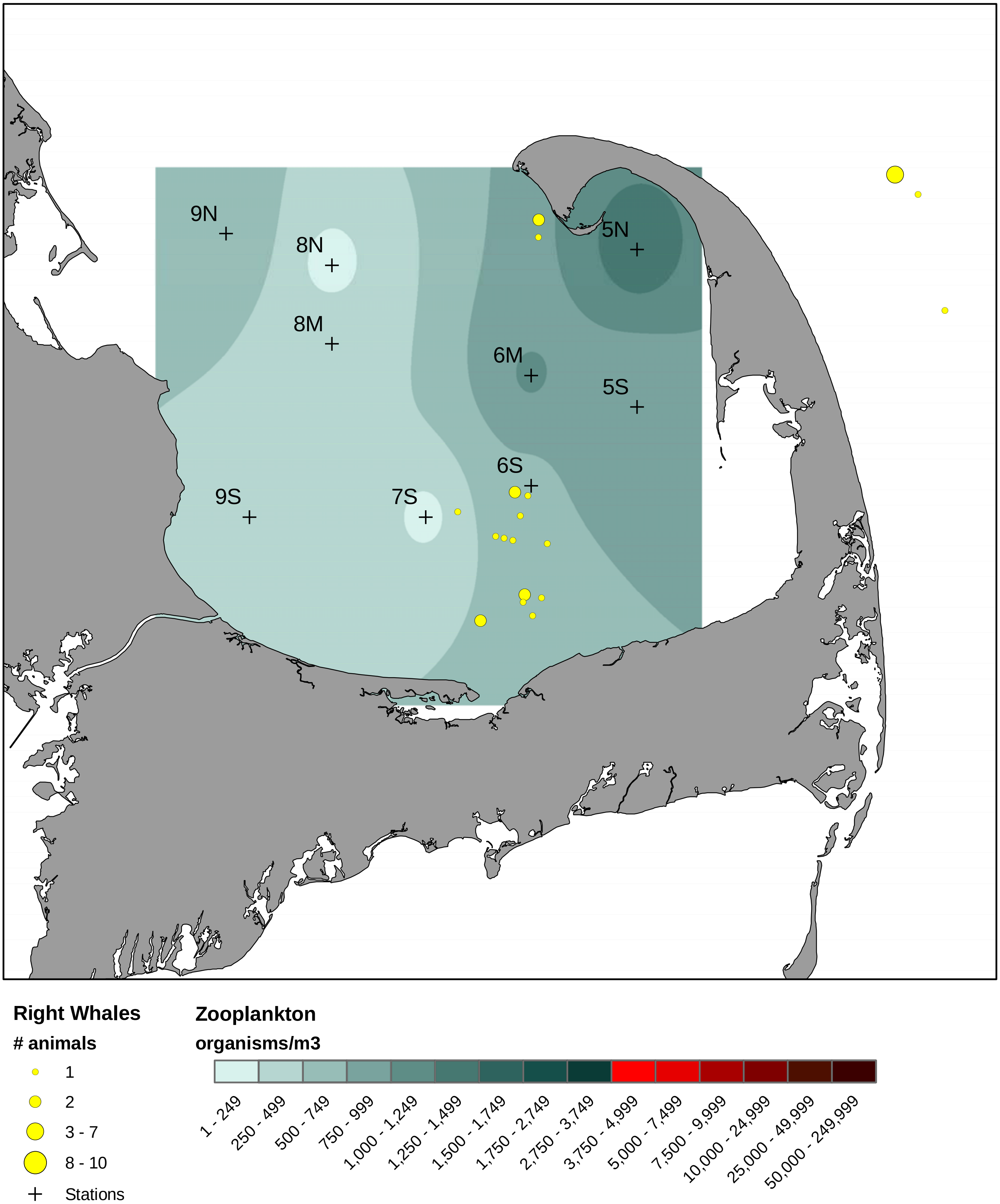


Figure 13. Interpolated zooplankton density averaged from oblique net tows at eight fixed sampling stations (marked by +) and right whale sightings from aerial surveys during the 14-day period 12 - 25 February 2005.

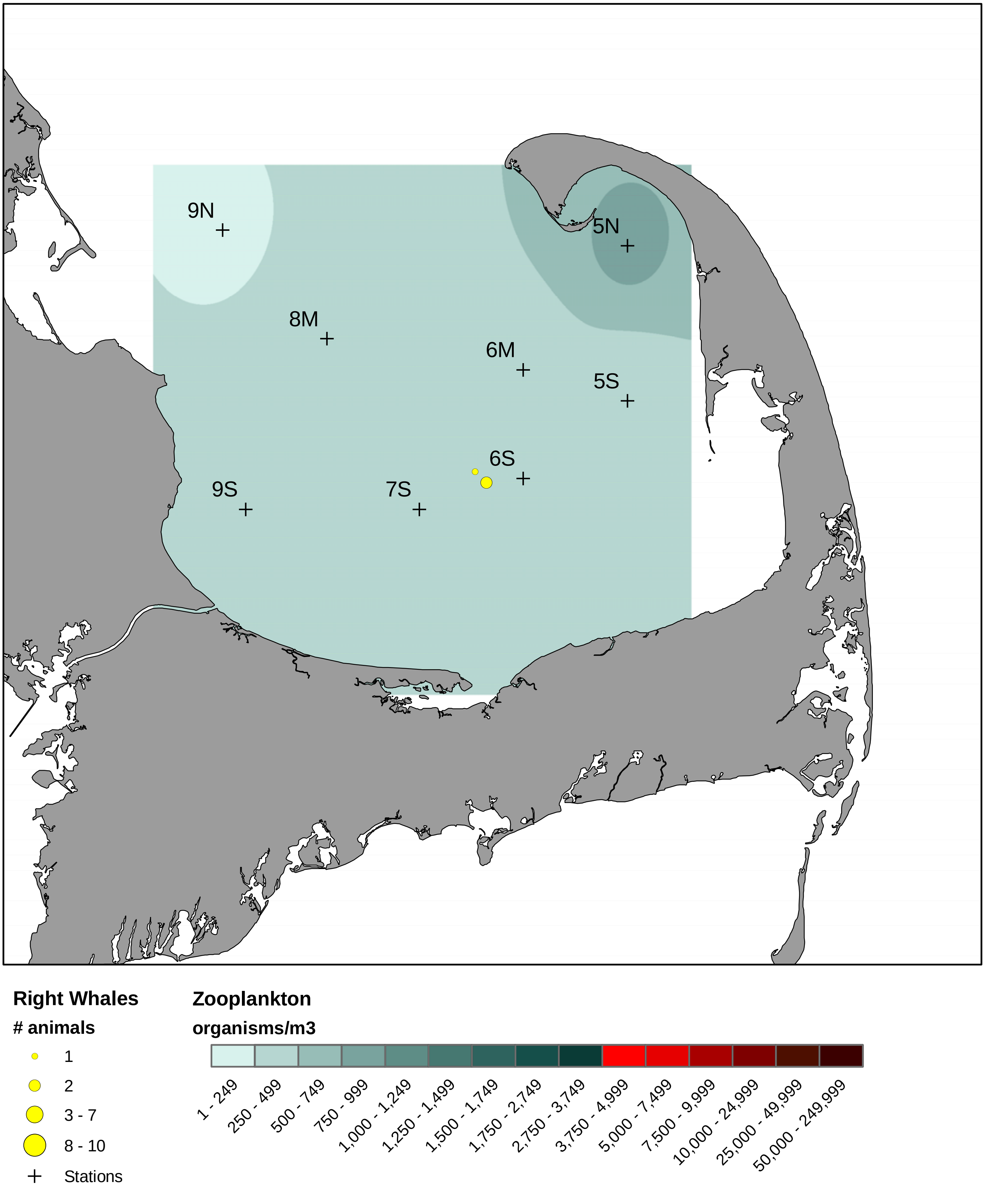


Figure 14. Interpolated zooplankton density averaged from oblique net tows at eight fixed sampling stations (marked by +) and right whale sightings from aerial surveys during the 14-day period 26 February - 11 March 2005.

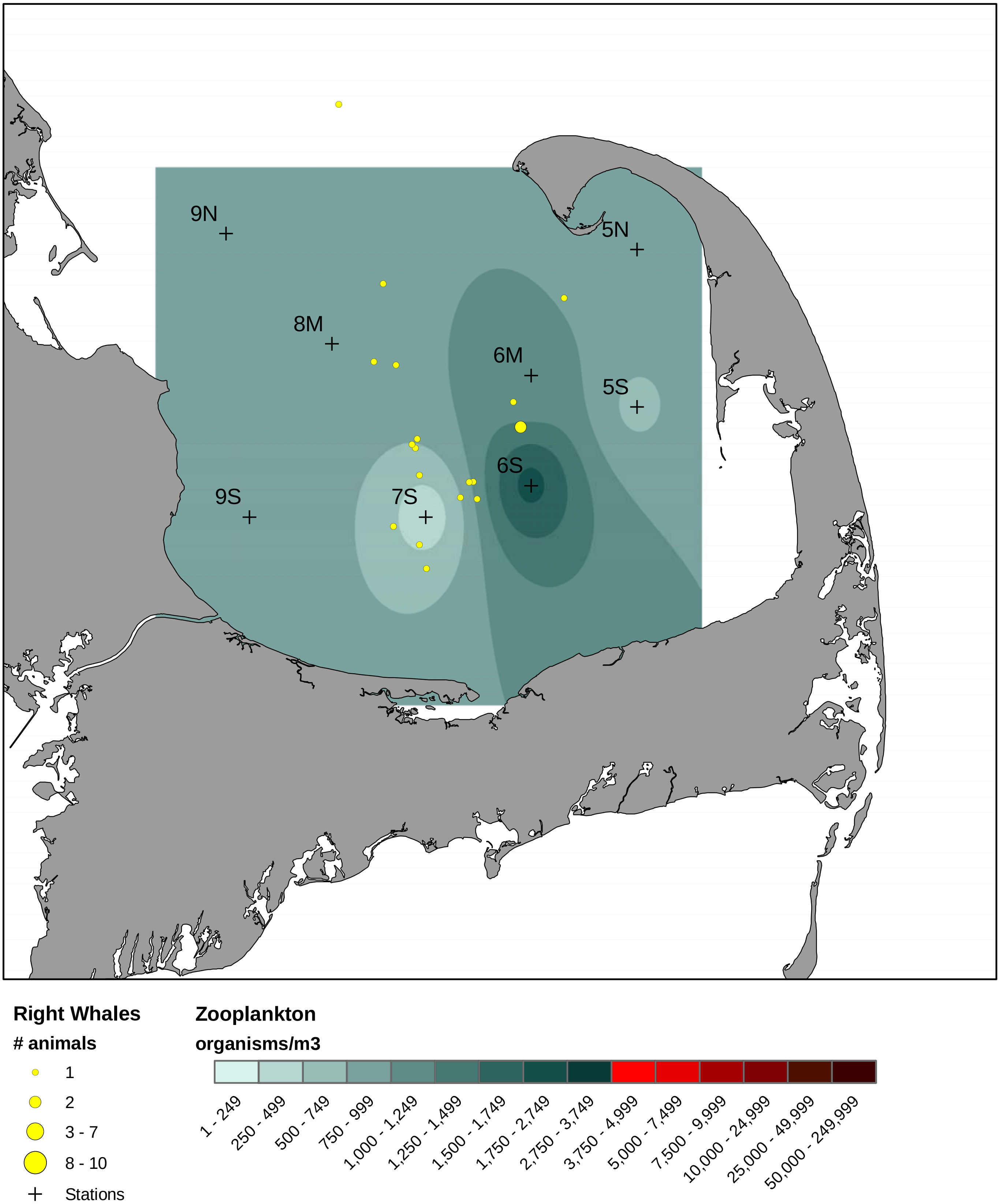


Figure 15. Interpolated zooplankton density averaged from oblique net tows at eight fixed sampling stations (marked by +) and right whale sightings from aerial surveys during the 14-day period 12 - 25 March 2005.

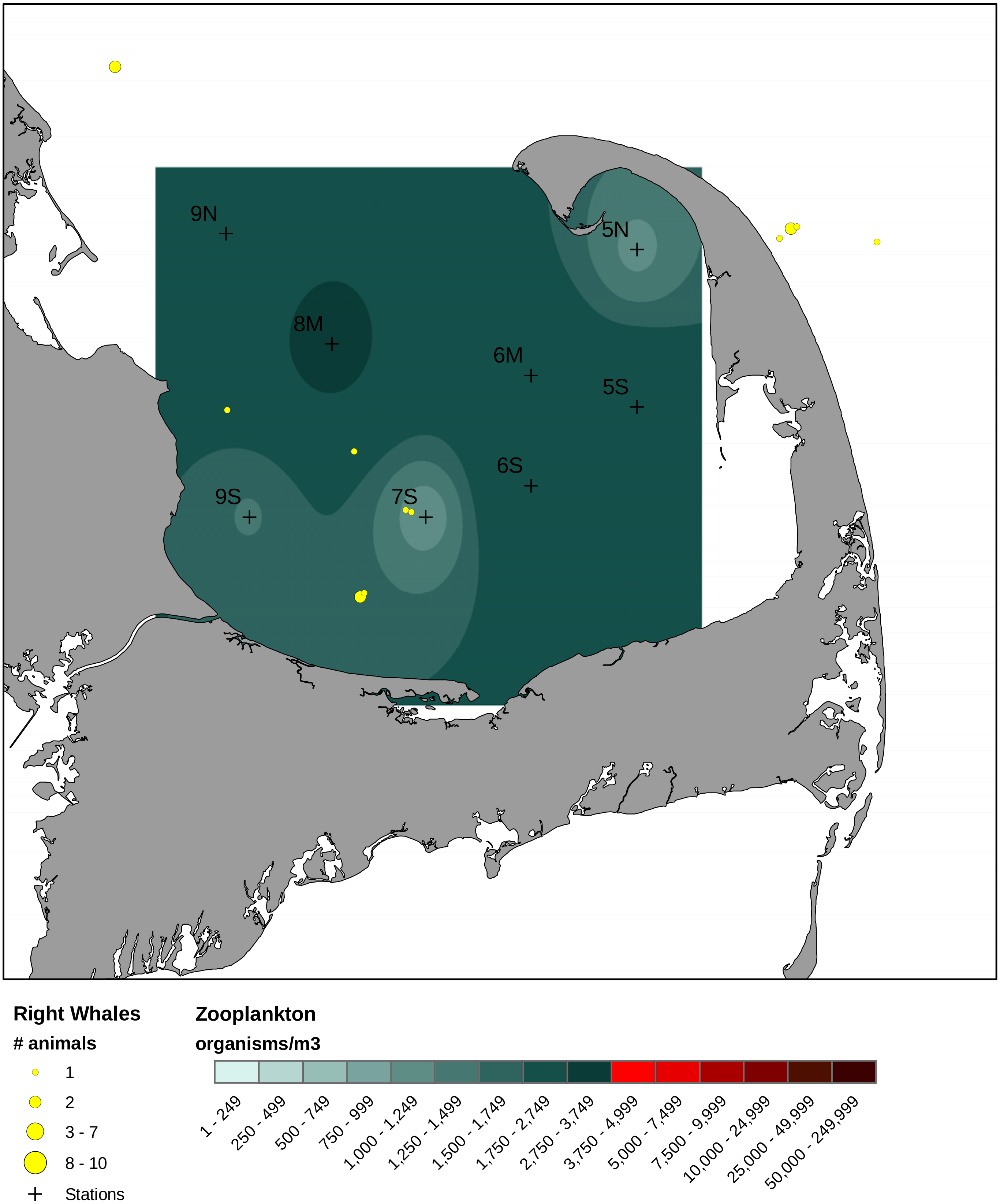


Figure 16. Interpolated zooplankton density averaged from oblique net tows at eight fixed sampling stations (marked by +) and right whale sightings from aerial surveys during the 14-day period 26 March - 8 April 2005.

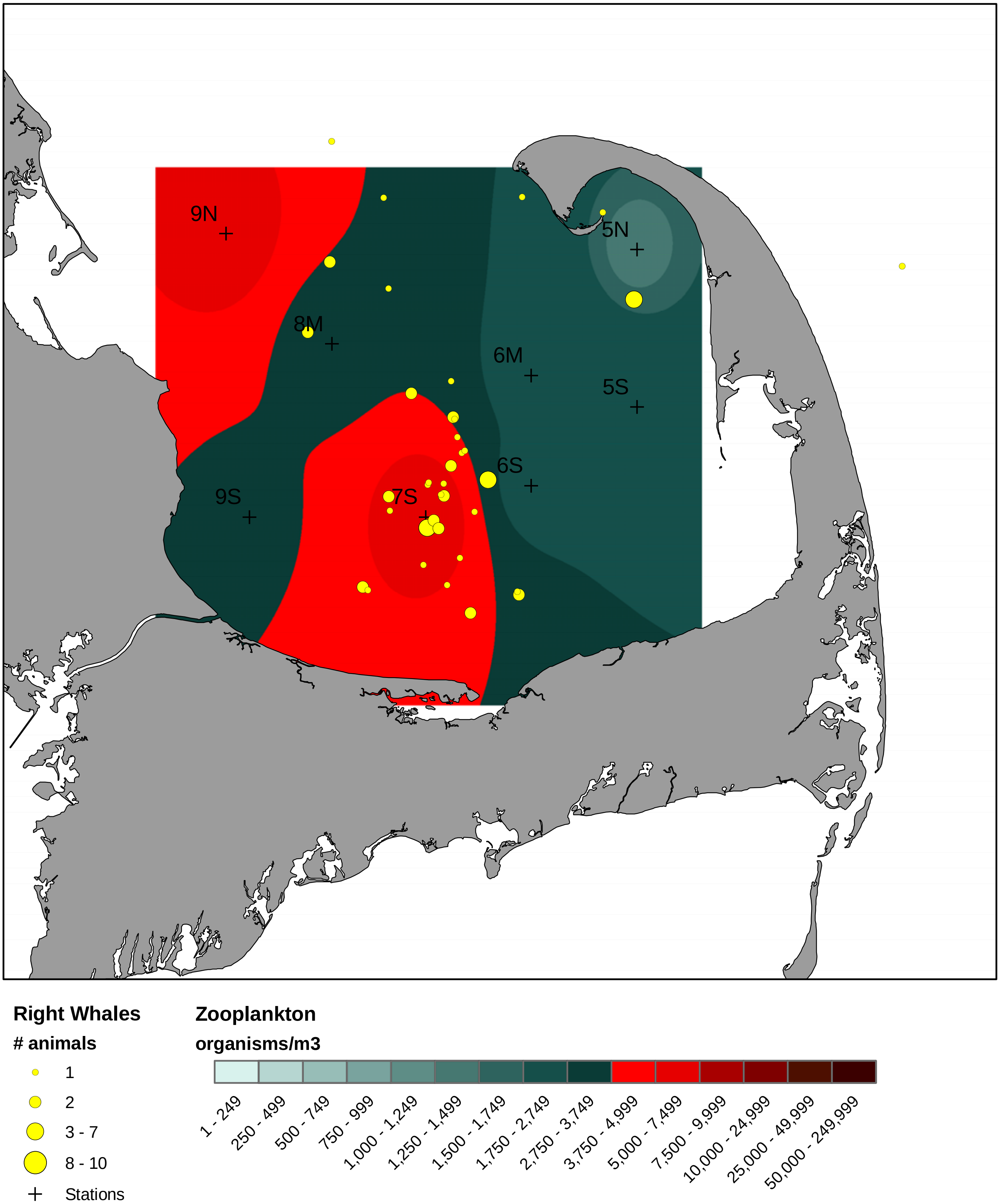


Figure 17. Interpolated zooplankton density averaged from oblique net tows at eight fixed sampling stations (marked by +) and right whale sightings from aerial surveys during the 14-day period 9 - 22 April 2005.

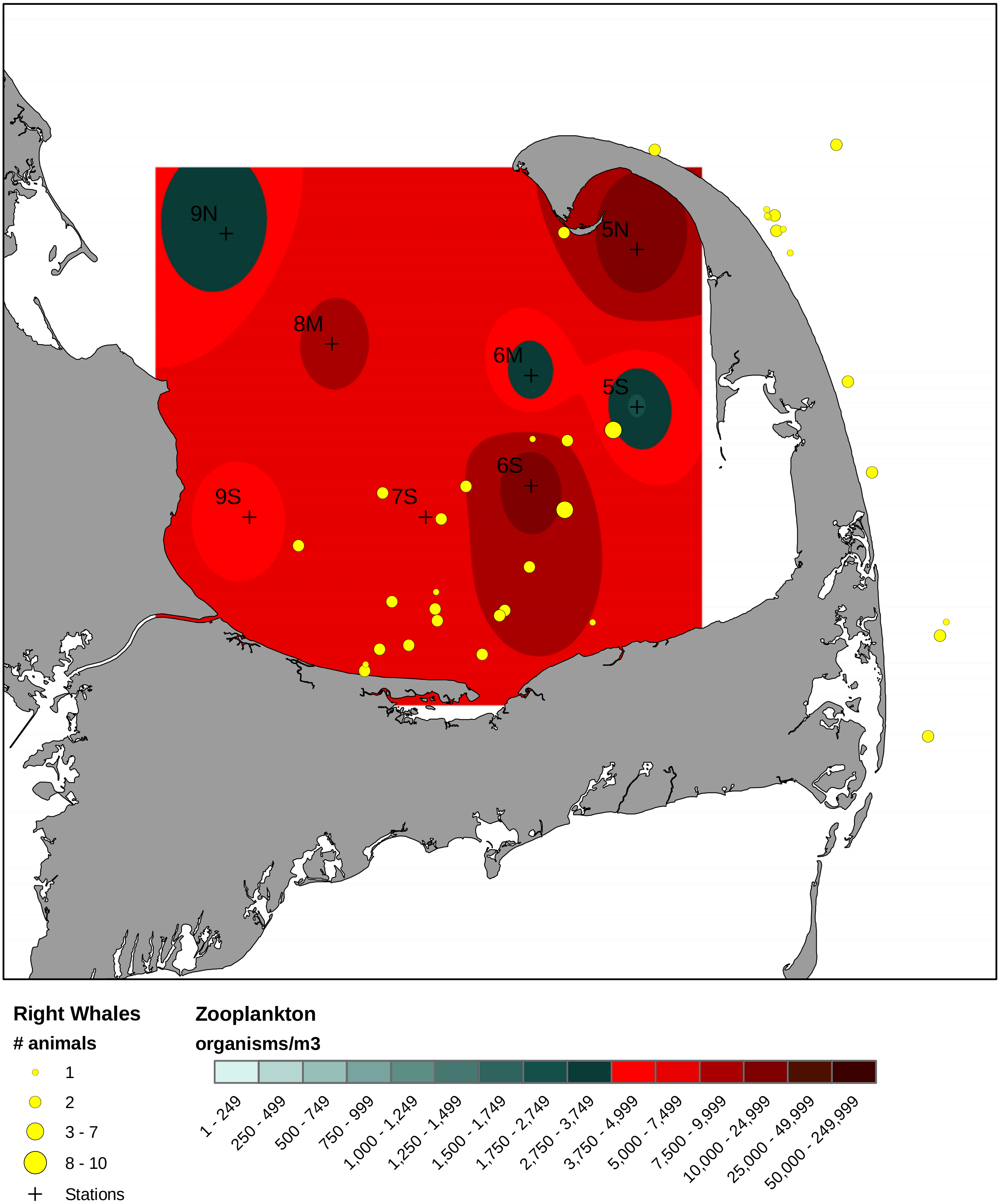


Figure 18. Interpolated zooplankton density averaged from oblique net tows at eight fixed sampling stations (marked by +) and right whale sightings from aerial surveys during the 14-day period 23 April - 6 May 2005.

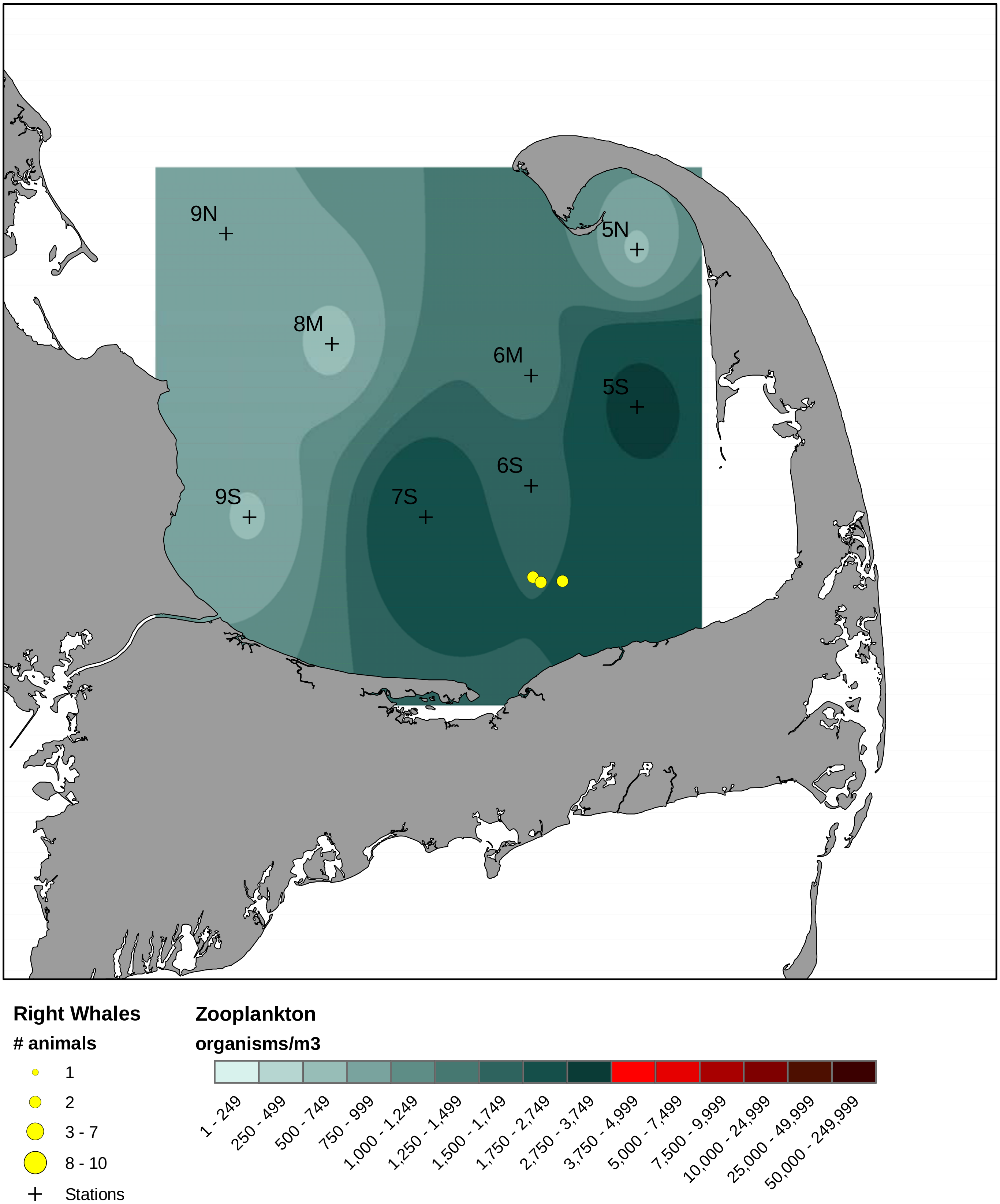
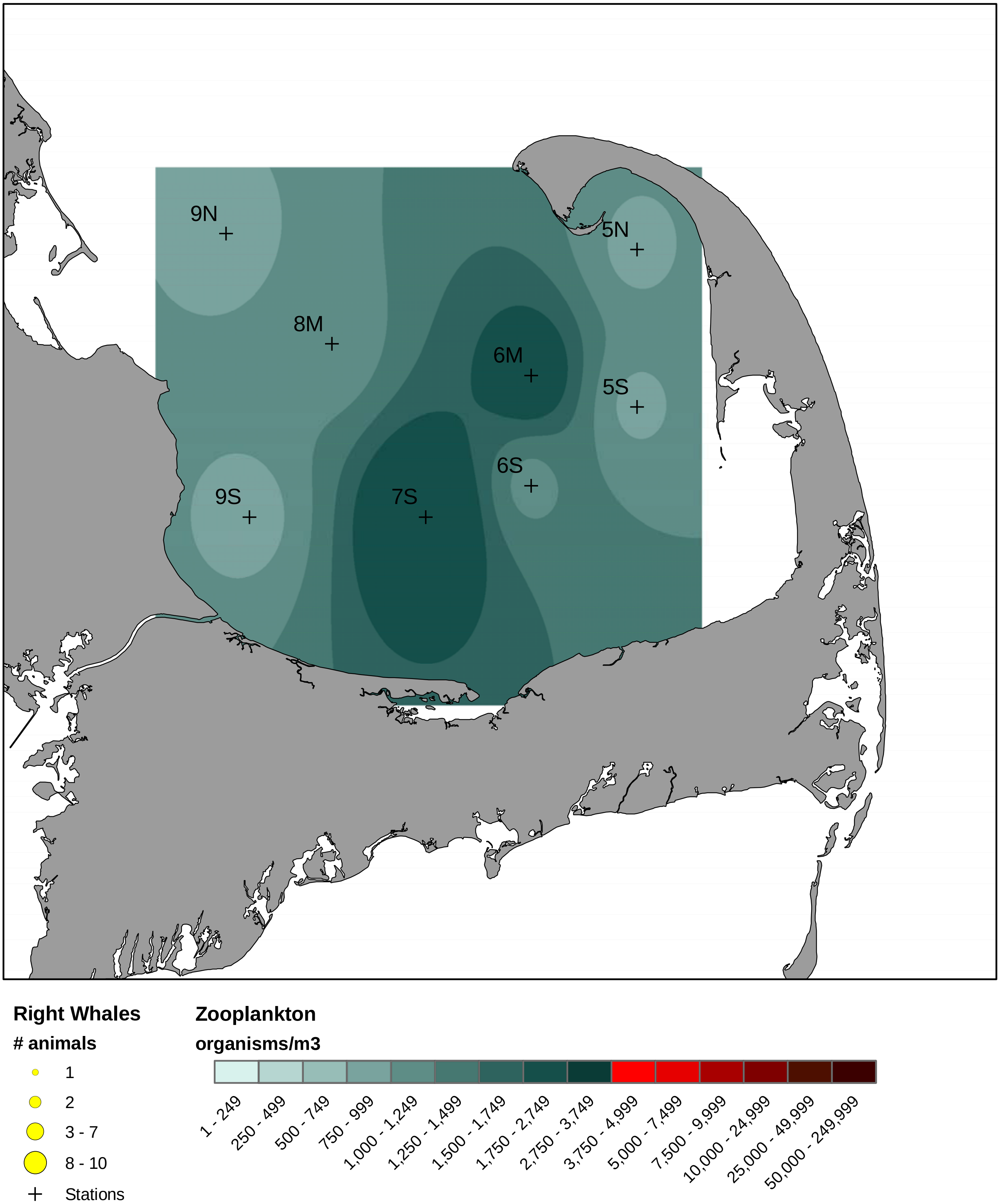


Figure 19. Interpolated zooplankton density averaged from oblique net tows at eight fixed sampling stations (marked by +) and right whale sightings from aerial surveys during the 9-day period 7 - 15 May 2005.



SECTION 4: EVALUATION OF REMOTE SAMPLING INSTRUMENTS FOR RIGHT WHALE HABITAT MONITORING

4.1. Introduction

The association between occurrence patterns of North Atlantic right whales and the distribution of their food has long been used to assist in the management of this critically endangered species in the Cape Cod Bay region. Determining the spatial distribution and abundance of zooplankton relative to whales, resources, and physical and chemical parameters has been part of the mission of the PCCS Habitat Studies team since 1984, and managers have used the weekly habitat assessment reports provided by PCCS to guide management decisions during times of right whale residence in the Bay. Such reporting, however, has hitherto been a challenging activity due to the extreme spatial heterogeneity of the zooplankton. Indeed, assessment of the distribution of zooplankton using traditional net techniques is a labor-intensive and time-consuming endeavor, involving field collection of samples followed by painstaking microscope analyses for the enumeration and characterization of zooplankton taxa. In addition, such methods yield integrated samples, with nets having been hauled vertically or towed horizontally, thereby offering limited spatial resolution on both fine and large scales.

Recent advances in zooplankton sampling technologies have significantly improved our ability to rapidly detect, quantify, and visualize spatial distributions of organisms on scales from millimeters to kilometers. One such sampling device is the Optical Plankton Counter (OPC; Focal Technologies, Dartmouth, Nova Scotia). The OPC collects high-frequency data on the abundance and size of zooplankton that pass through its sampling channel as the instrument is towed behind a vessel or deployed as a vertical profiler. Use of an OPC in concert with other sensors (e.g., a Conductivity-Temperature-Depth Probe, or CTD) can provide biological, physical, and chemical measurements at comparable spatial and temporal scales, yielding information about the relative importance of various environmental forcing factors in controlling patterns of zooplankton distribution. Effective conservation and management strategies depend on the understanding of the relationships between right whales and the spatial and temporal dynamics of the prevailing biotic and abiotic factors in their environment. With further development, the high-resolution oceanographic and zooplankton data collected by these instruments can be made available to managers in a timely manner, and can aid in predicting when conditions are conducive to right whale presence and foraging.

4.2. Objectives

The 2005 right whale habitat monitoring season was designed as a testing period for the incorporation of an optical plankton counter into PCCS's existing zooplankton sampling and assessment program in Cape Cod Bay. The first goal was to develop and implement sampling protocols for the OPC/CTD package and assess its utility as a water column profiler. Upon evaluation of the sensors' capabilities and weaknesses, with subsequent gear or methods modifications if necessary, the instruments were to be used in a towed configuration in which they would undulate through the water column along predetermined transects. Another hurdle we hoped to clear during the 2005 season was the development and automation of appropriate processing, analysis, and visualization techniques for OPC data using graphical tools such as MATLAB and GIS (Geographic Information Systems). Eventually, we aimed to integrate OPC/CTD oceanographic data with the net tow zooplankton assessment in the weekly analyses of habitat suitability (for both whales and zooplankton) reported to the Division of Marine Fisheries.

4.3. Challenges and Difficulties

This being the inaugural season for the optical plankton counter, it was expected that more than a few start-up obstacles would be encountered and that working with this new technology might involve persistent troubleshooting during much of the field season. Many of the difficulties that arose, however, were entirely unforeseeable, and posed a greater challenge and inconvenience than was initially anticipated. Among the problems that occupied our efforts and attention were the following:

- ♣ *Antiquated and simplistic OPC software* – The data acquisition software provided by the OPC manufacturer offered poor system flexibility with minimal customization options (e.g., with regard to compatibility with computer components, operating systems, etc.), very few options for user troubleshooting, and extremely limited (read: little to no) technical support.
- ♣ *A trio of platforms* – The OPC/CTD instrument package consists of three principal components: an optical plankton counter, a CTD, and the tow body on which these and several auxiliary sensors were mounted. Each of the main components has its own unique requirements for communicating with on-deck computers and also with the other sensors. Additionally, since each of the main components is produced by a unique manufacturer and there is no industry-wide standard configuration, integration is rarely seamless and typically requires innovation by the user. Because of this, instrument communication issues were a source of many frustrations during the field season.
- ♣ *An inherently flawed configuration* – With the initial instrument set-up as delivered by the manufacturer of the tow body, communication between sensors and with deck computers was impossible. Specifically, that configuration did not take into account the fact that the CTD outputs hexadecimal data to an OPC that requires as input ASCII characters (i.e., comma-delimited values in engineering units). PCCS scientists designed a custom underwater cable to circumvent this problem, avoiding the problem of multiplexing the CTD and OPC data altogether, and instead opting to transmit data as two independent streams through the towing cable. Receiving two data streams on deck would allow us to run each instrument's data acquisition software simultaneously, providing real-time data from all sensors and allowing us to better improvise and make informed sampling decisions in the field.

By late March, these problems had been sufficiently resolved to proceed with field testing and implementation. Through April and into May, the OPC/CTD package was used in a profiling mode, collecting detailed biological and physical oceanographic data about the vertical water column at the predetermined zooplankton sampling stations. After the close of the monitoring season, two cruises were made during which we conducted preliminary attempts to tow the instruments and “fly” them up and down through the water column. These attempts met with limited success, as they were plagued by malfunctioning depth sensors and deck-to-instrument communication problems.

4.4. Methods

4.4.1 Field Sampling Techniques

The spatial distribution of zooplankton was investigated using an optical plankton counter mounted on a tow-body that carried an array of sensors. In an attempt to integrate the oceanographic instrument sampling into the existing ongoing net sampling regime (so as not to deviate from or interfere with established protocols), a programme was devised in which the eight regular habitat monitoring stations in Cape Cod Bay would be visited and instrument profiles conducted at as many stations as time and weather would allow (Table 1). Routine on-station sampling thus involved vertical profiles, or “casts,” of an instrument package consisting of an OPC, a CTD (SBE19; Sea-Bird Electronics, Inc., Bellevue, WA), a 685 nm Seapoint Chlorophyll Fluorometer (Seapoint Sensors, Inc., Kingston, NH), and a Photosynthetically-Active Radiation, or PAR, sensor (LI-192SA; LI-COR, Inc., Lincoln, NE). The instruments were lowered through the water column at a constant velocity of 0.5 to 1.5 m/s and data were recorded every 0.5 seconds. Immediately after completion of a cast, the instruments were deployed for a second, or “replicate” cast, the purpose of which was to aid in assessing the performance of each individual sensor, as well as to reinforce the statistical rigor of the data set. All station sampling was conducted during daylight hours to avoid potential bias associated with vertically migrating organisms at night.

Table 1. Summary of OPC/CTD vertical profile sampling in Cape Cod Bay, 2005. An "X" indicates that casts of the OPC/CTD tow package were conducted at the specified station. At stations marked with brackets [ ], the OPC data was found to be corrupted and so was unusable in subsequent analyses.

Cruise	Date	Regular Stations							
		5N	5S	6M	6S	7S	8M	9N	9S
SW527	18-Mar	.	.	X	.	.	.	.	.
SW530	1-Apr	.	.	X	.	X	.	.	.
SW532	6-Apr	.	.	X	X	.	.	.	.
SW533	7-Apr	.	.	.	.	X	X	X	.
SW535	13-Apr	.	.	X	.	X	X	X	.
SW537	19-Apr	.	.	X	[X]	X	X	.	X
SW541	4-May	.	.	X	X	X	X	.	X
SW544	10-May	.	.	X	X	X	[X]	[X]	[X]

4.4.2 Instrument Validation

As with all new sampling technologies, it was important that steps be taken to verify the data returned by the OPC. Generally, the major validation issues that needed to be addressed were either quantitative or qualitative in nature:

- ♣ *Quantitative validation* of abundance measurements to ensure that the OPC was accurately counting the number of organisms present in a parcel of water. The intrusive nature of the instrument, moving through and disturbing an area of water as it samples, may introduce biases due to organism avoidance responses, resulting in false-low counts of the more mobile species of zooplankton. Additionally, if more than one organism passes through the OPC's sampling beam at any given time they will register as a single large organism, leading to an under-counting bias as well as flawed size class information.
- ♣ *Qualitative validation* of particle types to overcome instrument "blindness." The OPC is essentially a counter of objects within the limits of its detectable size range: it has no ability to discriminate between biotic and abiotic particles. Aggregates of diatoms, crustacean molts, fecal material, and miscellaneous debris can cause interference and confuse the measurements of living zooplankton in the water column. Another consequence of this "blindness" is that characteristics of the taxonomic composition of the zooplankton community can only be resolved by comparative net tows and subsequent microscope analysis.

Several strategies were undertaken for instrument validation purposes. Since zooplankton sampling on-station was already being conducted, these samples, especially the oblique collections, could be used to provide information about taxonomic composition and species size class data. Furthermore, these samples could potentially be used to compare water column average concentrations (to the depth of the oblique tow, 19 m). Another strategy for groundtruthing the OPC data was on-station pump sampling at specific depths of the water column (as detailed in Chapter 2). These samples, in addition to providing taxonomic and size class information, could be compared to at-depth OPC enumerations of zooplankton. Finally, in taking replicate casts at each OPC/CTD station we could demonstrate whether the vertical patterns of distribution returned by the instruments were reproducible over very brief time intervals, thereby adding to or detracting from the believability of the measurements.

4.4.3 Data Processing

After each cruise, OPC and CTD data was downloaded to a single computer for quality control, processing, and presentation. The high-frequency vertical profile data from both instruments were consolidated into 0.5-second bins. OPC data was then converted from per-time-interval measurements to zooplankton per-unit-volume (organisms per liter or per cubic meter). Additionally, OPC data were analyzed to verify that the instrument's instantaneous velocity during each cast was at all times within the manufacturer-specified effective range of 0.5 to 4.0 m/s.

The sheer quantity of data collected by the array of sensors can be somewhat overwhelming, and so required strict and thoughtful organization and documentation at all stages of data processing. For this reason, original MATLAB programs were developed by PCCS researchers in an attempt to automate data processing and for graphical presentation routines. The graphical output created by several of these programs is discussed more thoroughly in the following Results and Discussion section.

4.5. Results and Discussion

The effort to incorporate high-frequency oceanographic instrument sampling into the existing Cape Cod Bay habitat monitoring program resulted in limited success. After a string of disconcerting initial setbacks, the OPC/CTD package was finally introduced into the waters of Cape Cod Bay in late March, and for the remainder of the field season (8 consecutive monitoring cruises) collected on-station vertical profile data. Although this data was not reported in PCCS habitat assessments, our efforts during the 2005 season represent the first step in developing a more automated method for assessing right whale habitat suitability. With further development of these remote sampling techniques, the wealth of information that they collect will be a significant addition to baseline data on the biological, chemical, and physical qualities of the system, contributing to our understanding of what conditions support right whale aggregation.

Numerous preliminary graphs were prepared as we investigated meaningful ways to analyze the plethora of data collected by the sensors. Examples of potential future uses for OPC and CTD data include (but are certainly not limited to) the following:

- ♣ *Geographical comparisons* – Inter-station comparisons may reveal characteristics about specific locations (e.g., their physical oceanography and resource environment) that either promote or discourage right whale presence. Figure 1 presents example plots for this type of analysis.
- ♣ *Temporal trends* – Understanding the development of oceanographic and resource conditions can be facilitated by the creation of graphics which show the temporal progression of a specific parameter at a location. Such visualizations may simply show changes by plotting the profile data collected at different times superimposed on the same set of axes, as in Figure 2. Another effective means of showing temporal trends involves plotting a parameter's changing values through time and using a colorbar scale to represent the spectrum of low to high values, as in Figure 3.
- ♣ *Replicate analyses* – The measurement consistency of each sensor can be evaluated by plotting replicate cast data together on a single set of axes. This type of analysis can also be very revealing when troubleshooting instruments. Figure 4 displays sample replicate plots that were taken during the 2005 field season.

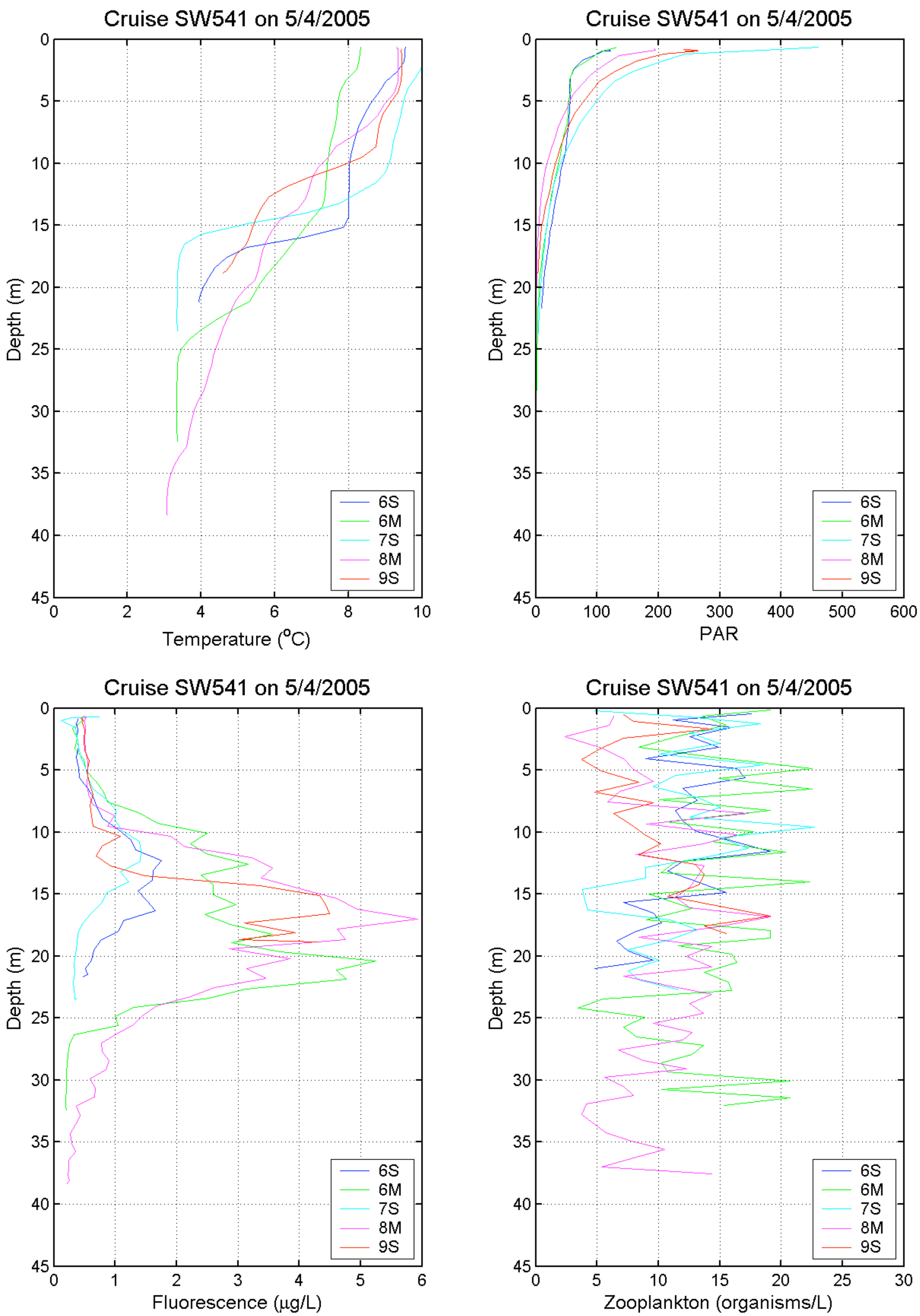


Figure 1. Sample plots to demonstrate potential geographical analyses. For a specific cruise (SW541 on 4 May 2005), plots were created to show inter-station variations in the vertical profiles of each individual parameter (i.e., temperature, PAR, fluorescence, and zooplankton concentrations). Note that near-surface PAR values at stations 6S and 6M were influenced by the sensor passing through the research vessel's shadow.

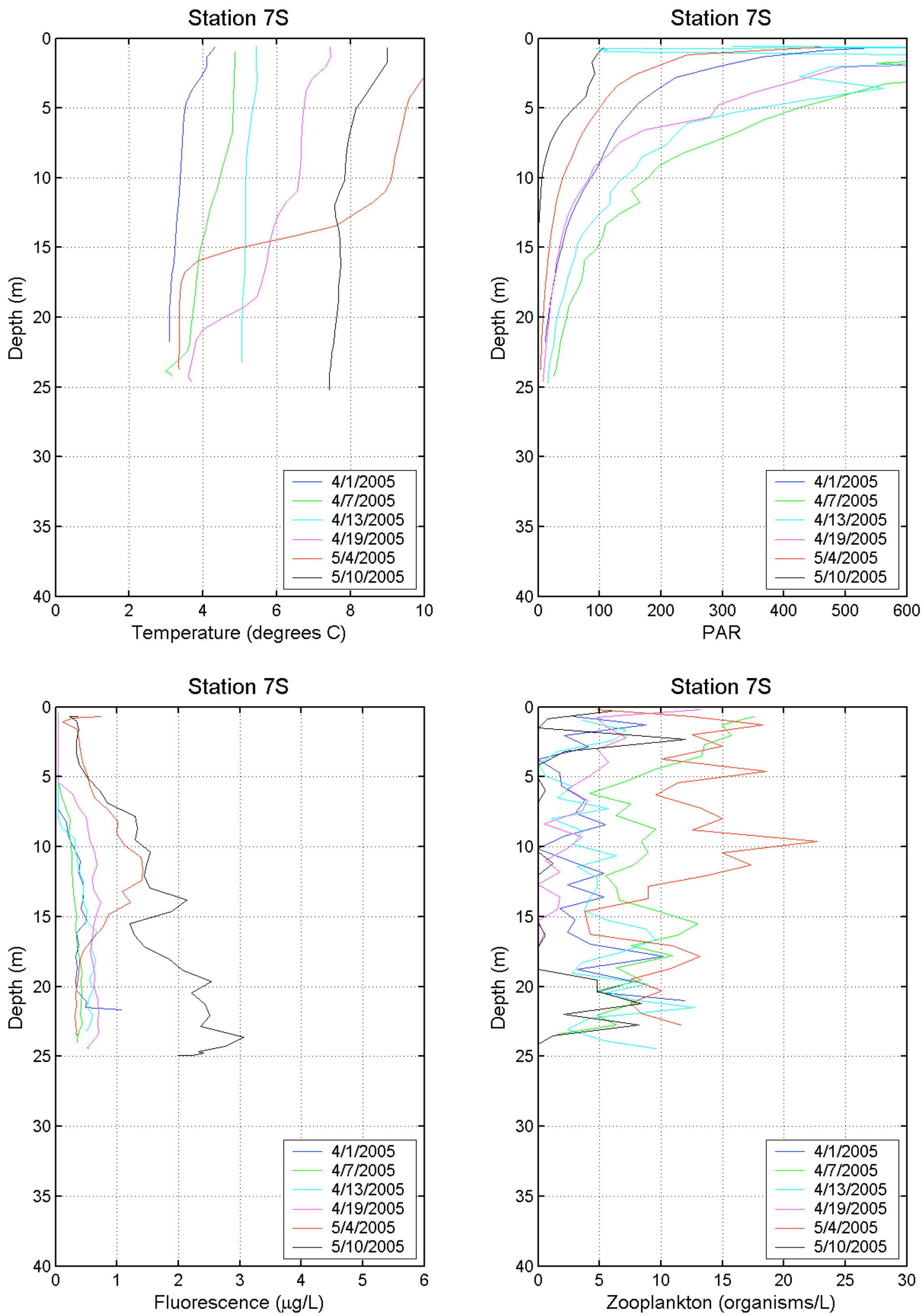


Figure 2. **Sample plots of potential temporal analyses. At a specific location (station 7S in this example), all of the casts collected throughout the sampling season were plotted on a single set of axes to display the time-sequence of a parameter's vertical profiles.**

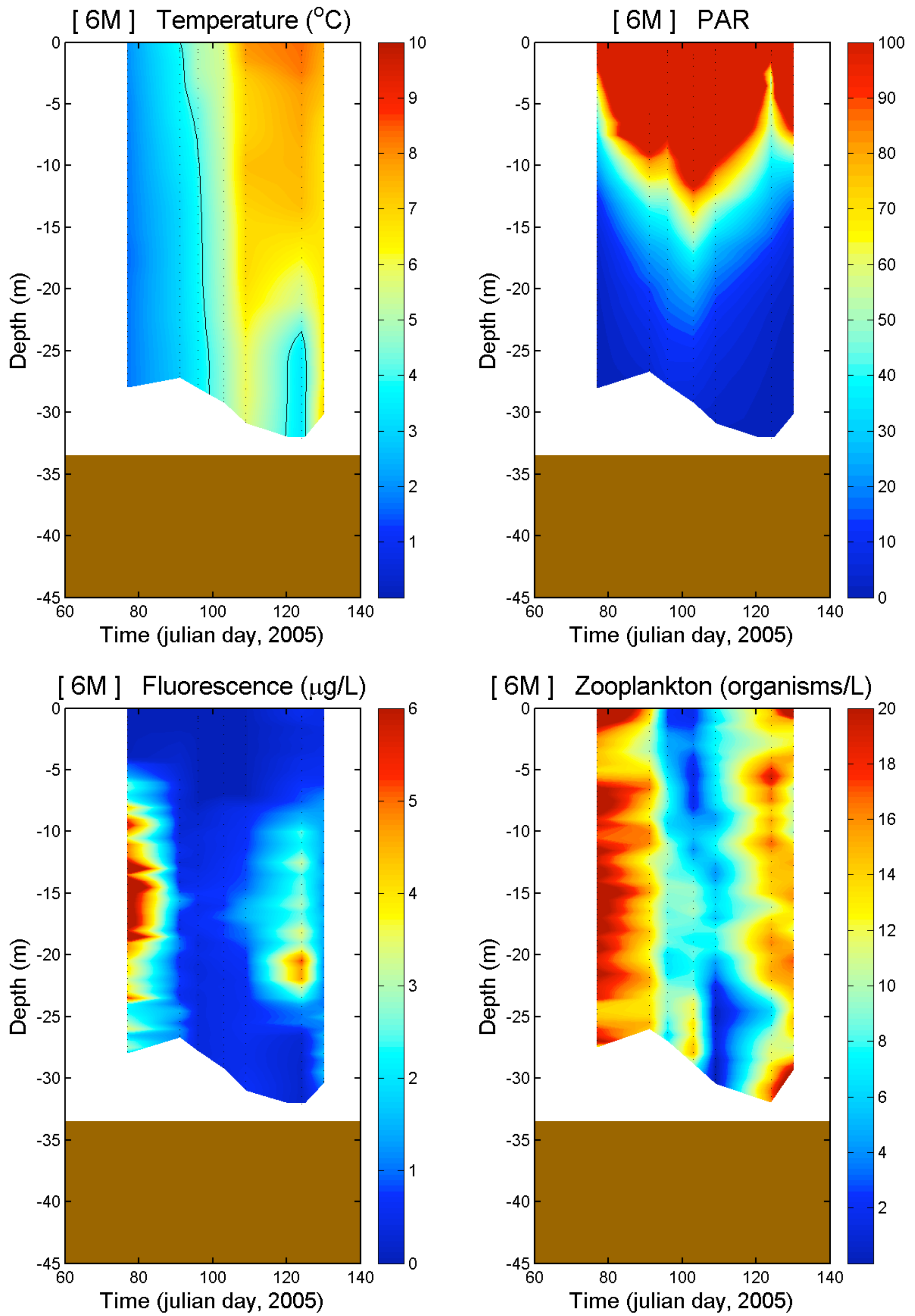


Figure 3. Additional analyses to display temporal trends. The brown area at the bottom of each plot represents the depth of the ocean floor at this station (6M). A black contour line on the temperature plot represents the 4°C isotherm.

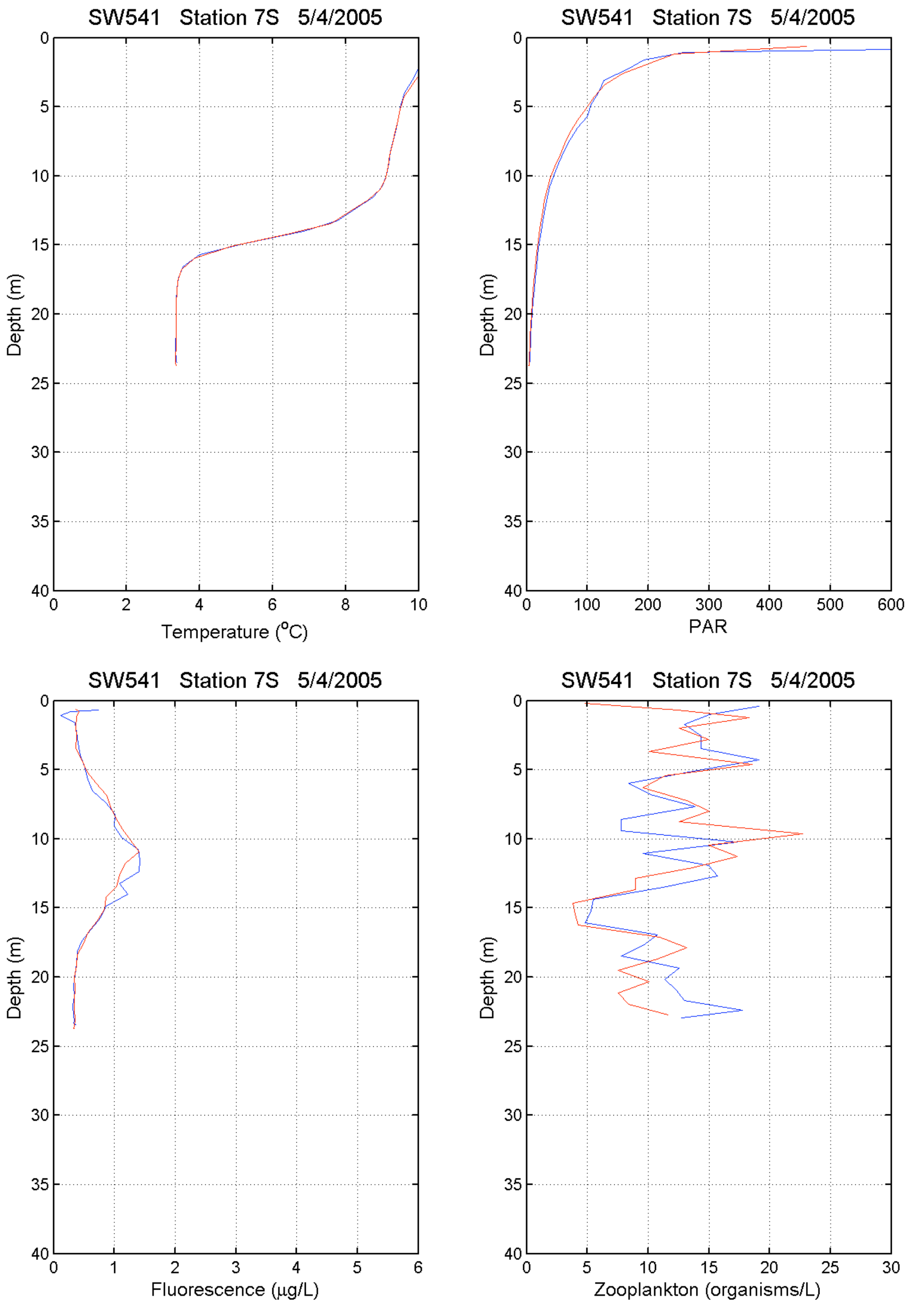


Figure 4. Sample plots for the evaluation of replicate vertical profiles. Replicate casts collected at a specific location (station 7S on 4 May 2005 in this case) are plotted on the same set of axes to assess each sensor's ability to reproduce trends in the measurements.

4.6. Future Work

Although a thorough assessment of the validity of the OPC's measurements is an essential step in our movement toward the incorporation of this equipment into Cape Cod Bay habitat monitoring, time and effort constraints prevented the completion of a rigorous evaluation. Comparative quantitative analyses with net and pump samples are currently ongoing. A brief inspection of replicate cast data has quite convincingly shown the reproducibility of major features in the vertical profile data. Nonetheless, further scrutiny of the OPC's (as well as the CTD's) capabilities is needed, and should be a priority of future work.

As the 2005 field season demonstrated, the use of these instruments in future applications will require vigilance and innovation. If the logistical difficulties can be overcome, then these techniques have great potential to make a significant contribution to right whale conservation and management in the Cape Cod Bay Critical Habitat.

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