Surveillance, Monitoring and Management of North Atlantic Right Whales in Cape Cod Bay and Adjacent Waters - 2008

Final Report

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EXECUTIVE SUMMARY

In 2008, the right whale surveillance program supported by the Commonwealth of Massachusetts Division of Marine Fisheries (DMF) was conducted in Cape Cod Bay (CCB) and adjacent waters from 1 January through 15 May by the right whale research team at the Provincetown Center for Coastal Studies (PCCS). Weather permitting, the program included bi-weekly aerial surveys and weekly habitat sampling. 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 2008 winter and spring season, PCCS observers performed 28 aerial surveys totaling 158.5 hours of flight time covering CCB and adjacent waters east of the Cape. Although a large proportion of the identification photographs taken during these flights and during habitat sampling cruises 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. Therefore, the results outlined in the present report may change slightly once confirmation is obtained.

In 2008, right whales were observed in CCB and adjacent waters during 125 days (from 12 January to 15 May). This period of occupation of the area was considerably longer than in previous years (92 days in 2007; 100 days in 2006; 97 days in 2005). A very large number of individuals were identified in CCB and adjacent waters in 2008, compared to previous years of the project. To date, sightings of 148 unique individual whales have been confirmed, and a number of other individuals have yet to be identified. This is comparable with 2007, when 161 different individuals were identified in the area, a number which is twice the yearly average between 1998 and 2006. 47 right whales that had never been identified before in the area since photographic records of right whales began in the bay in 1958, were observed in CCB and adjacent waters in 2008. This likely implies that resources in CCB were exceptionally favorable in 2008.

There was an average of 11.1 days between the first and last sighting of an individual right whale. This is substantially shorter than in 2007 (average of 18.4 d) and 2005 (13.2 d), but longer than in 2006 (average of 7.4 days), suggesting that whilst more whales than usual visited CCB and adjacent waters in 2007, their residency time was somewhat reduced compared to recent years.

In 2008, as in 2007, right whales abundance increased from a mean of 0.1 and 0.9 individuals per 100 nm in January and February, respectively, to 7.3 in March and a maximum of 28.6 per 100 nm in April, before then dropping dramatically in May to 0.6 individuals per 100 nm. Right whale distribution in CCB varies considerably between years. Sightings were distributed throughout the bay, with some concentrations in southern and western areas. Right whales were also abundant at Race Point during April, in 2008, a pattern which has been observed in previous years. 15 sightings of 22 individuals occurred outside of the critical habitat boundary.

78% of all right whales in CCB and adjacent waters were adult whales. Of those individuals of known sex, 34% were female and 66% were male. In 2008, the length of time between the first and last sighting of individuals in Cape Cod Bay averaged 11.3

days. The maximum possible residency time for an individual in CCB (time from first to last sighting) was 63 days, for an adult female whale. The mean maximum possible residency time was 11.3 days, and unlike 2007, there was no significant difference between female and male maximum possible residency times. Three mother and calf pairs were sighted in CCB and adjacent waters. Mother-calf pairs were, on average, sighted on more days (minimum residency time) than males or females, but the period over which they were sighted (maximum residency time) was shorter, suggesting that mother-calf pairs are more resident in the bay once they arrive, but, at least in 2008, used this habitat over a shorter period than other whales.

The mean cluster size was 1.7 individuals, and clusters ranged in size from one to 13. Clusters of one or two whales were the most numerous. Larger clusters were more frequently observed in March and April. Mean cluster size in 2008 was greater then the mean cluster size for all clusters documented between 1999 and 2007. 31 SAGs were observed in 2008, involving between two and 13 individuals. Mean SAG size was 4.1 individuals. In 2008, SAGs in CCB were only sighted during March and April.

A summary is given of the studies on right whale vocalization behavior, made in 2006 and 2007. 111 hours of recordings were made, resulting in 3,506 right whale vocalizations which were of suitable quality for analysis. Tonal calls were by far the dominant call type. Only 15.4 % of all vocalizations recorded occurred during feeding behavior, and foraging or traveling whales produced a mean of just four vocalizations per hour. No upcalls were recorded from traveling whales. In contrast, 83.4% of the vocalizations recorded came from whales engaged in SAG behavior, and these whales produced a mean of 165 vocalizations per hour.

During 2008, Cornell University ran three cell phone-linked acoustic buoys in CCB. A basic cross-validation analysis of the coarse-scale buoy data with aerial survey data was possible. Visual and acoustic techniques provided the same daily presence-absence results on 64% of days for which both datasets were available. There was also a positive association between the number of up-calls per operational buoy, and number of right whales sighted per 100 nm of survey effort on a given day.

Support of the PCCS Disentanglement Team formed a major part of the work carried out by the Aerial Survey Team in 2008, due to the unusually high number of entangled right whales sighted this season. Entangled or seriously injured right whales were sighted on nine of 28 survey days carried out; these sightings involved four individual whales (EG 1140, 1980, 2645, all entangled, and 3530, severely injured). Hours spent in support of the Disentanglement Team amounted to 20 h 35 min over the course of the survey season; this was 12.9% of all flight hours undertaken by the Aerial Survey Team and represents a significant proportion of the survey time.

Interactions between vessels and right whales were observed and recorded four times during the 2008 season. In addition to right whales, seven other species of cetacean and two pinniped species were sighted during aerial surveys in 2008. Baleen whale sightings were more numerous in April and May than earlier in the year. Sightings of both odontocetes and baleen whales were distributed throughout the study area, but were especially abundant around Race Point and near to Provincetown harbor.

During the 2008 field season, 19 habitat study cruises were conducted, during which 521 zooplankton samples were collected and analyzed to describe the zooplanktonic food resources that control the distribution of right whales in Cape Cod Bay. This year's sampling focused on characterizing the distribution, composition, and density of the winter-spring Cape Cod Bay zooplanktonic resource, which serves as a continuum of the last 29 years of habitat studies at PCCS. Collections were taken by surface and oblique net tows at eight regular stations throughout the bay, as well as by horizontal transect samples and discrete depth pump samples in locations of particular interest to zooplankton-right whale ecology. Information collected and analyzed during the season was delivered to the Division of Marine Fisheries of the Commonwealth of Massachusetts and to more than 80 colleagues via e-mail in the form of three assessment instruments: the rapidly produced "Preliminary Assessment" and "Right Whale Risk Alert" reports, and the detailed "Right Whale Habitat Assessment" documents. The former reports continue to underpin our effort to alert of the Division of Marine Fisheries of areas that present imminent risk of ship strike or entanglement, while the latter provides detailed background data for forecasting aggregation and feeding by right whales. All documents focus on forecasting the locations where right whales and industrial activities may overlap. In 2008 the rapid production of the preliminary assessment instrument resulted in the dissemination of four management advisories, intended to alert mariners to the probable presence of right whales performing risky behaviors, and at the end of the season, the termination of the risk alerts. In 2008, two special reports were also distributed to the same recipients of the habitat assessments. These reports were intended to describe some of our directed habitat research aimed at honing our understanding of right whale-zooplankton dynamics.

The 2008 zooplankton resource followed previously documented patterns of enrichment and impoverishment with the primary food resources being the three dominant calanoid copepod taxa: *Centropages* spp., *Pseudocalanus* spp., and *Calanus finmarchicus*. The pattern of productivity of these three taxa overlapped, as in past years, to produce a fairly steady and increasing total zooplankton resource from January through May. The cycle of increased *Centropages* resource in the early winter, likely the remains of the late summer and fall stock, was again observed in 2008. The enrichment of *Pseudocalanus* spp., usually peaking during March, was also observed; this resource was extremely rich in the surface waters compared with previous years, peaking in mid-March. Typical of most other years, the *Calanus* resource increased from very low densities before late February to relatively high concentrations in April, but unlike past years, the resource steeply declined in both surface waters and the water column.

The 2008 season was extraordinary in that the aerial survey reported an unprecedented high number of right whales in the bay, with peak abundance occurring between the *Pseudocalanus* spp. and *Calanus finmarchicus* peaks. While *Pseudocalanus* spp. abundance also reached a maximum higher than any previous year, an analysis of whale abundance and *Pseudocalanus* spp. density in the past eight years showed no strong correlation. Additionally, in 2008, as in 2007, right whales left Cape Cod Bay during a period in May when zooplankton, principally *Calanus*, remained broadly available and occasionally at densities exceeding the feeding threshold throughout large areas of the bay system. This pattern, the departure of right whales from a habitat that appeared acceptable, was also observed and noted in previous years (e.g. 2004) and we believe

may be explained by the "competition between habitats" that we have proposed in past years. The temporal and spatial stability of the zooplankton resource may have a profound influence upon the medium-term acceptability of Cape Cod Bay as a foraging habitat for right whales. The instability in the zooplankton resource observed at the end of the 2008 season appeared, at least in part, to be the result of major counter clockwise flushing currents within the Bay. Because of the importance of determining the departure time of whales, future research will likely focus on comparing the temporal and spatial stability with the distributional stability of the whales within Cape Cod Bay.

Another area explored in 2008, which will be a focus of research in 2009, is that of varying levels of risk to right whales, associated with different zooplankton taxa, which are present at different times of the year and at different depths in the water column. A fine-scale study is planned for 2009, to comprehensively investigate this issue.

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The aerial survey team is especially grateful to the PCCS Board of Directors who, in light of the exceptionally busy field season in 2008, provided additional funding to facilitate the extension of the field season and completion of the processing of the season's data.

This report and the 2008 season's work is dedicated to the memory of John Ambroult, who was integral to the design and development of the PCCS right whale aerial survey program since its inception in 1998. His skills as a pilot and mechanic, his involvement in the project and his sense of humor will be greatly missed.

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GENERAL INTRODUCTION

The Cape Cod Bay (CCB) 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 ten years (1998 – 2007) 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 148 individuals during some years, around 40% of the known living catalogued population (Brown and Marx 1998, 1999, 2000, Brown *et al*. 2001b, 2002, 2003, Mayo *et al.* 2004, Jaquet *et al.* 2005, 2006, 2007).

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 400 individuals remain (CeTAP 1982, Brownell *et al*.1986, Kraus *et al*. 1988, NMFS 1991, Knowlton *et al*. 1994, IWC 2001, Kraus *et al*., 2005, Kraus and Rolland 2007). 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

[*] 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.

survival rate (Caswell *et al*. 1999, Fujiwara and Caswell 2001, Kraus *et al.*, 2005) suggest we should view the present situation with increasing concern.

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, Kraus *et al.*, 2005). A total of 79 right whale deaths were documented from 1970 through May 2008 (A. Knowlton pers. comm.). Of those 79 mortalities, 28 (35%) were attributed to ship strikes, 9 (11%) were a result of entanglement in fixed fishing gear, 22 (28%) were adult and juveniles that died of unknown causes, and 20 (25%) were calves that died of neonatal or unknown causes. Since January 2006, 11 right whales mortalities have been documented, of which four were attributed to ship strike. Three mortalities were of neonate right whales, two were a result of entanglements, whilst the remaining two whales' causes of death were unknown, but both individuals showed evidence of entanglement interaction.

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). 2008 was a significant year for right whale entanglements in Cape Cod Bay, with four entangled individuals sighted on numerous occasions throughout the season. 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 135 as of August 2008 (Hamilton *et al*. 2004; P. Hamilton pers. comm.), 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. 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 being 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 response to this, the Massachusetts Division of Marine Fisheries (DMF) has taken management action to mitigate the threat to right whales. In Cape Cod Bay Critical Habitat, the use of gillnet gear is prohibited between January 1 and May 15, while lobster gear fished during that period must be modified to comply with seasonal restrictions. These gear modifications include requiring traps be 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 on all buoy lines (322 CMR 12.05). The modified gear is marked with twin orange flags on the buoy stick to identify it. The use of floating groundline in the pot and gillnet fisheries is prohibited year-round in Massachusetts state waters. This sinking groundline requirement went into effect on January 1, 2007. Prior to that, sinking groundline had been a year-round requirement in CCB since 2003 and a seasonal requirement since 1997. In addition to the above conservation measures, the Division of Marine Fisheries has carried out "ghost gear removal" projects in the winter months to further reduce entanglement risk. DMF is also working with the Massachusetts Environmental Police to ensure compliance with the sinking groundline regulations.

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 2007 as part of the program described in this report (Brown and Marx 1998, 1999, 2000, Brown *et al*. 2001b, 2002, 2003, Mayo *et al.*, 2004, Jaquet *et al.*, 2005, 2006, 2007). 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 – 2008

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 eleven years (Brown and Marx 1998, 1999, 2000, Brown *et al*. 2001b, 2002, 2003, Mayo *et al*. 2004, Jaquet *et al*., 2005, 2006, 2007). 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 2008 as described below. The objectives of the 2008 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 early 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 section.

SECTION 1: SURVEILLANCE, RESIDENCY AND DEMOGRAPHICS OF NORTH ATLANTIC RIGHT WHALES IN CAPE COD BAY AND ADJACENT WATERS - 2008

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.

1.2. Methods

1.2.1 Aerial Surveys

Aerial surveys were conducted regularly, from January to mid-May, 2008, in the Cape Cod Bay Critical Habitat and adjacent waters. The aerial survey protocol for Cape Cod Bay, as described in Kraus *et al.* (1997), was adopted with some modifications. Fifteen track lines were flown latitudinally at 1.5 nautical mile (nm) intervals from the mainland to the Cape Cod Bay shoreline (Figure 1). 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 1, 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 (Appendix I, 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.

The surveys were flown under pre-determined flight conditions of sea states 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 (N48WP), 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 right 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 5-second intervals. At each event, latitude, longitude, time, altitude, and heading were obtained through an interface with the aircraft GPS. All sightings were logged by one observer recording the sighting data into a digital voice recorder (Sony ICD-ST10). A distinct voice file was created for each event which included the time to the second (read off the NMEA screen on the laptop), the sighting and the distance of the sighting from plane. The voice recordings were later transcribed into the database created by Logger 2000 with each recording being assigned to the nearest second. Logger 2000 records at 5-second intervals, thus the event to which a voice recording is assigned was never more then two seconds from the time recorded. At a survey speed of 100 knots, 102 meters is covered in two seconds. Therefore, the position of the event in the Logger database that the recording was assigned to was never more then 102 meters from the exact position of the sighting. 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 another large whale not immediately identified by species, the aircraft departed from the track 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.

Fig. 1: Map of CCB and adjacent waters, showing aerial survey track lines (numbered 1 to 16 and E1 – E12 for tracks east of CCB), habitat sampling stations (grey boxes) and DMF's cell phone-linked acoustic monitoring buoys, operated in collaboration with Cornell University (black points; DMF1-3).

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 2007 (Mayo 1997, 1998, Mayo *et al*. 1999, 2000, 2001a, 2001b, 2004, Mayo and Bessinger 2002, Bessinger *et al.* 2003, Jaquet *et al*., 2005, 2006, 2007). The results of this part of the program are reported in Section 2 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. Due to the opportunistic and infrequent nature of this photographic data collection, these data have not been analyzed with the aerial survey data. These data are summarized separately in the Results, section 1.3.2.

1.2.3. Photo-Identification Techniques

i) Identification Photographs

During aerial and shipboard surveys, photographs were taken using hand-held 35-mm Canon 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. Photographs were taken from a rear, opening window to prevent distortion of the image. 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, Kraus and Rolland 2007). 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 44,639 sightings of 528 individual right whales have been archived, of which 368 were thought to be alive as of 10 August 2008 (P. Hamilton pers. comm.).

The matching process consists of separating photographs of right whales into individuals and inter-matching between days within the season. To match different sightings of the same whale, composite drawings and photographs of the callosity patterns of individual right whales are compared to a limited subset of the catalogue that includes animals with a similar appearance. For whales that look alike in the first sort, the original photographs of all probable matches are examined for callosity similarities and supplementary features, including scars, pigmentation, lip crenulations, and morphometric ratios. A match between different sightings is considered positive when the callosity pattern and at least one other feature can be independently matched by at least two experienced researchers (Kraus *et al.* 1986). Exceptions to this multiple identifying feature requirement include whales that have unusual callosity patterns, large scars or birthmarks, or deformities so unique that matches from clear photographs can be based on only one feature. Preliminary photo-analysis and inter-matching was carried out at 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 two external hard drives. As digital photography has only been used for the last four 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. However, in 2008, the PCCS aerial survey team created a small online matching database using the "Multiply" website. The PCCS group on this website is accessible to members only, and contains a series of images for each right whale sighted during PCCS aerial surveys in 2008. This proved an extremely efficient way to match whales which were resighted on several days, and also allowed researchers outside of PCCS to aid in real-time with the matching process for individuals already identified from other regions earlier in the season. All PCCS digital images from the 2008 season have been archived at NEAq and are available for access by collaborators per North Atlantic Right Whale Consortium protocols.

1.2.4. Data Management

At the end of each aerial survey, data from the voice recorder and track data from the day were downloaded and backed up on CD-R and two external hard drives. 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 were submitted to Dr. Robert D. Kenney, curator of the Consortium Database maintained at the University of Rhode Island.

1.2.5. Data Analyses

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. Sightings data analyzed and presented here comprises only right whales for

which NEAq has confirmed the identification number; that is, whales known in the 2008 database only by intermatch codes have not been included. 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 2008. Sightings 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. Sightings of other cetacean species were likewise mapped. 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).

In order to assess the utilization of an area by right whales, it is important not only to quantify the number of different individuals identified in an area, but also to take into account the residency time of individuals. The variable "whale-day", the number of different individuals multiplied by the number of days each had been identified, provides a measure of overall habitat use. Although meaningful, this new variable is negatively biased by long periods without survey effort (such as during periods of bad weather. Furthermore, the number of different individuals is also important in providing an understanding of the proportion of the population utilizing a given area at any stage, and in understanding the number of whales that may be threatened by entanglements or ship strike in this area. We have therefore used both of these variables to describe habitat utilization of right whales.

Standard statistical tests were used to determined trends in the data. Significance was accepted at the 5% level and standard deviations (SD) were usually given with means except when standard errors (SE) were more appropriate (see Zar, 1996).

1.2.6 Assessment of vocalization behavior of right whales (2006 & 2007)

In 2006 and 2007, a focused study was carried out in order to investigate right whale surface and diving behavior, small-scale movements and vocalization behavior in relation to observable behavior. The results of the acoustic monitoring have only recently been finalized and are presented here; all other aspects of this study were presented in Jaquet *et al*. (2007).

This study involved acoustic monitoring in parallel with focal follows of one or more right whales, over several hours. Between March 1 and May 15, 2007, fieldwork was

conducted in Cape Cod Bay with the vessel *F/V Ezyduzit* (a 32-foot tuna fishing vessel, with a 440 Hp inboard diesel engine and an observation/driving tower about 17 feet above the water). Right whales were found by surveying the bay visually from the vessel, and with the help of the PCCS aerial survey team. Once in visual contact with right whales, identification photographs were taken using a Canon EOS 20D digital camera and a Sigma100-300 mm zoom lens (f4). Behavior of the focal whale was recorded using a Sony digital voice recorder equipped with a time stamp. Simultaneously, we documented the behavior and spatial distribution of all whales in the vicinity using the digital voice recorder. For each whale at the surface, we recorded its approximate distance as well as its bearing using a handheld compass. A towed hydrophone array connected to an amplifier/filter box (Magrec) and then to a Tascam HD-P2 solid state recorder (sample rate 48 kHz) was used to record vocalizations, anthropogenic-related noise and ambient noise continuously. The towed array consisted of three Benthos AQ4 elements with custom preamplifier (gain 30 db), and eight meters separation between the two furthest elements. The array was contained in a plastic tube filled with Isopar M oil, and custom build by Dr. Jonathan Gordon (Ecologic). The array was trailed behind the vessel on 30 meters of cable. The *F/V Ezyduzit* had been designed for tuna fishing with harpoons and thus engine and propeller noise were minimal allowing continuous recordings. To increase the sample size for the analyses, the data collected in April/May 2006 as part of a pilot project funded by the National Fish and Wildlife Foundation (Jaquet and Webster 2007) were added to the data collected in 2007.

Acoustic recordings were first entered into the computer using Raven 2.1 (Bioacoustics Research Program, Cornell Lab. of Ornithology Software). The recordings were acquired at a 48.0 kHz and 16-bit sampling rate, and then analyzed using the same program. Each sound produced by right whales was labeled as one of the following sound types: screams, gunshots, broadband, up-calls, down-calls, and unclassifiable (see Results; Figure 10), based on visual inspection of the spectrogram and aural similarity to categories described in Parks and Tyack (2005). Underwater blow sounds, produced occasionally during exhalation, were not taken into account in this study. The type and proportion of sound types were analyzed as a function of aggregation size and behavior. The aggregation was defined as the maximum number of whales identified or seen at the surface at the same time within about two nautical miles of the research vessel. Data collected during the aerial surveys on the corresponding day provided confirmation of estimations of aggregation size as estimated during this study. Behavior was grouped into broad categories:

- Skim-feeding: whales feeding at the surface with mouth open and baleen showing above the water line;
- Sub-surface feeding: whales feeding just below the surface and open mouth and baleen can be seen from the observation tower;
- Apparent feeding: whales diving and going back and forth over a relatively small area;
- SAG behavior: two or more whales interacting at the surface with frequent physical contact;
- Traveling: whales moving rapidly in a more or less straight line.

1.2.7. Acoustic Monitoring in Cape Cod Bay during the 2008 winter-spring season

Right whales produce a great variety of sounds, with most call energy below 1000 Hz (Clark 1983; Parks & Tyack 2005). Both North Atlantic and Southern right whales have been documented to produce a wide variety of call types (Clark 1982, 1983; Parks & Tyack 2005), including the up-call, a rising call in the 80-400 Hz frequency band, generally lasting 1-2 seconds (Clark *et al*. 2008). Up-calls function as contact calls, and detections of up-calls have been assumed to be the most suitable means of determining right whale presence from acoustic data (Clark *et al*. 2008).

There were two types of acoustic monitoring efforts conducted in Cape Cod Bay by Cornell during the 2008 winter-spring season. The first form of monitoring relied on autonomous seafloor recording units referred to as "pop-ups" (Clark and Clapham 2004), while the second type of monitoring used moored auto-detection buoys, referred to as Auto-buoys (www.listenforwhales.com). Three Auto-buoys were installed in the bay on 21 September 2007 (Figure 1), and operated from 1 January through 15 June 2008. These units contain a computer system continuously running automatic right whale up-call detection software. The Auto-buoys operated throughout the winter-spring period with several periods of lost operation due to battery failure, antenna failure, or loss of cell phone coverage.

Auto-buoys were programmed to transmit data packages every six hours, where a data packaged contained as many as eight 2-second sound clips. Data were transmitted via cell phone back to a server at Cornell where the packages were decoded. Analysts with expertise in recognizing right whale calls evaluated all sound clips and logged all up-call sounds into the server database.

Data on number of clips and number of up-calls detected per day was analyzed for seasonal patterns in vocalization rate, and was compared with the aerial survey data to investigate the relationship between number of detections and number of whales.

1.2.8. Notification of Agencies

Prior to and following an aerial survey, both US Coast Guard Sector Southeastern New England and Air Station Cape Cod at Otis Air National Guard Base were notified of our planned survey, departure time and estimated time of return. 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. Any additional sightings made by PCCS research vessels were also included in this report. A daily summary of the location and number of right whale sightings from each aerial survey was emailed 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 2008, the PCCS/DMF aerial survey team was in position to survey for 136 days, from 1 January through 15 May. 28 surveys, complete or incomplete, were flown during these 4.5 months: 26 surveys were flown in Cape Cod Bay, and two surveys were flown exclusively over adjacent waters, covering 12 tracklines east of Cape Cod Bay (January 17 & February 25). Out of these 28 surveys, four were aborted due to inclement weather, one was aborted due to mechanical problems with the aircraft and six were not completed as high numbers of whales meant that the surveys continued late into the day and were limited by daylight hours. In addition, five surveys were abandoned when an entangled whale was sighted and effort was focused on "standing by" to assist the PCCS Disentanglement Team. Stand-by time amounted to 20.6 hours (13% of all flight time in 2008). In total, 5,630 miles were flown, involving 158.5 hours of flight time, but excluding stand-by time, this amounted to a net 138.4 of actual survey time. Most of the aerial survey effort was concentrated within CCB with 4,106 miles of transects flown in CCB (tracks 3-15), and 1,513 miles flown in adjacent waters (tracks 1, 2, 16). We flew an average of 1.4 surveys per week in CCB (excluding the surveys in adjacent waters) compared to 1.5 surveys per week in 2007, 1.6 per week in 2006 and 1.9 per week in 2005 (Table 1).

Table 1: Summary of aerial survey effort, 2004 - 2008

	Number of surveys in CCB (include track 16)	**Number of surveys in adjacent waters**	**Total number of nautical miles flown**	**Total number of hours flown**
2004	25	3	7,164	139
2005	37	4	10,855	175
2006	32	4	9,219	170
2007	30	1	8,262	157
2008	26	2	5,630	159*

* 20.6 h were spent in support of the disentanglement team in 2008, resulting in a net 138.4 h of actual survey effort.

The first flight of 2008 was conducted on the 5th of January. There were several periods of bad weather throughout the survey season which accounts for gaps in survey coverage between 3 – 21 February, 25 February – 10 March, 27 March – 8 April, 23 April – 1 May and 6 – 15 May. The first right whale was sighted in CCB by the aerial team on 12 January, which is early compared to recent years (February 21 in 2007, and February 7 in 2006). A single right whale was still present in the bay on May 15, but bad weather after this date prevented any additional surveys. In 2007, right whales were last recorded in the

bay on May 13. However, during August of 2008, there were acoustic detections and sightings of right whales in the vicinity of Cape Cod Bay, indicating that whales were still present in the general area several months after the end of the PCCS aerial survey season.

Excluding surveys that were aborted due to inclement weather or mechanical problems, the average duration of a standard (but not necessarily complete) Cape Cod Bay survey was 5.8 hours. This is 0.2 h longer than the mean for 2007 and 2004, and 0.9 h longer than for 2006. This increase in average CCB survey duration in 2008 in comparison to previous years was due to the very high number of right whales present in the bay during any one day, especially during the month of April. The highest number of individuals photographed on a single day was 59 (a total of 64 sighted, but several individuals were unphotographed), on April 15. This is substantially greater than in previous years - up to 40 photographed sightings in a single day in 2007, and maxima of 37 in 2006, 22 in 2005 and 27 in 2004 (Table 2; Jaquet *et al.*, 2005, 2006, 2007).

The standard Cape Cod Bay survey includes track 16 and thus encompasses about 35 nautical miles of survey outside the Bay (Fig. 1). However, as noted in previous reports (Jaquet *et al*., 2005, 2006, 2007), right whales seen on track 16 are seldom observed within the Bay, and as the residency time of individuals on track 16 suggests that these whales are transiting through the area, all the analyses below differentiate between Cape Cod Bay and adjacent waters (outside CCB). According to the delineation of Cape Cod Bay in the Right Whale Consortium photo-identification database, CCB encompasses only the water south of 42°04' and thus only tracks 3 to 15. However, in previous reports, tracks 1 and 2 were included in the CCB delineation. In this report, therefore, it is always stated whether the analysis are for CCB exclusively (track 3 to 15) or whether they also include the water just north of CCB (track 1 to 15). This differentiation allows comparisons with previous years and previous reports, and allows analyses that are compatible with the definitions of the New England Aquarium.

1.3.2. Shipboard Data Collection

The R/V *Shearwater* completed a total of 19 habitat sampling cruises between 12 January and 5 May 2008 (Table 3). The primary purpose of habitat 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 Section 2 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 first right whales documented during a habitat cruise were sighted on 12 January. Many of the shipboard 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 right whale habitat team spent 145 hours at sea in 2008.

In addition to habitat sampling and recording opportunistic sighting data, the habitat team also collected photographic data on 19 cruises, from which 35 individual right whales

have, to date, been identified. Only one of these individuals (EGNO 3139, sighted April 10) was not identified during aerial surveys, thus shipboard cruises did not document a significant number of additional individuals in the study area.

1.3.3. Sightings and Photo-Identification

In 2008, a total of 650 (112 from habitat surveys + 538 from aerial surveys) right whale sightings were recorded from all platforms. In a departure from previous years' analyses, only the sightings from aerial surveys have been analyzed in this report (Tables 2 and 3), as all the right whales photo-identified from the habitat cruises were also sighted during aerial surveys, and because photographic effort on the habitat cruises was not consistent. 531 sightings were made during aerial surveys (Tables 2 and 3), resulting in the identification, so far, of 148 different individuals including 3 first year calves. Of all sightings, 12 were made during surveys east of CCB, whilst 526 were made on CCB surveys (including tracks 16, 1 & 2). 115 right whale sightings have not yet been matched to known individuals, as the individuals may be new whales or yearlings from last year and thus may not yet have a good record in the catalogue.

The number of photographed sightings and different individuals identified by platform and location are outlined in Table 2.

Table 2: Survey effort and number of individual right whales identified by platform and location in 2008.

Platform and Location	Number of different individuals *	Sightings not yet matched	Number of miles flown or number of days on the water
Aerial – CCB (tracks 3 to 15)	137	109 **	4106 nm
Aerial – Adjacent waters (tracks 1,2, 16 and east of CCB surveys)	11	1	1513 nm
Habitat Cruises - CCB	35	63	19 days
Total	**183**	**173**	

* Includes matched sightings which have not yet been confirmed by NEAq (data from surveys after April 10), but does not include any individual with an intermatch code.
** Likely involves resightings of several individuals.

The 148 individual right whales identified from the aerial survey platform and from all areas (CCB and adjacent waters) represents 40% of the population known to be alive in 2008 (P. Hamilton, Pers. Com.). Considering the large number of individual whales for which matching attempts have been made, but which have yet to be identified, there are likely a number of additional unique individuals to add to this figure. As a minimum estimate, at least 28 unmatched individuals are currently considered to be unique and have been given 'intermatch codes'. If all of these are in fact additional, unique individuals, the total number of individuals in CCB and adjacent waters in 2008 will then amount to 176.

Out of the 148 individuals identified by the aerial platform, 105 were seen exclusively in CCB (track 3-15), 11 were seen exclusively in adjacent waters (track 1, 2, 16 and east of CCB) and 32 individuals were observed in both areas. However, overall aerial survey

effort was considerably lower in adjacent waters than in Cape Cod Bay. For the sake of comparison, if we include track 1 and 2 in the CCB area (as it had been done in previous reports), 126 individuals were seen exclusively in CCB and/or just north of CCB (track 1-15), 8 individuals were seen exclusively in adjacent waters (track 16 and eastern tracks) and 14 individuals were observed in both areas. If we count the number of individuals sighted in an area, regardless of its other sightings, 137 individuals were seen in CCB (track 3-15), 21 individuals were seen north of Cape Cod (track 1-2) and 22 individuals were seen in adjacent waters (track 16 and eastern tracks).

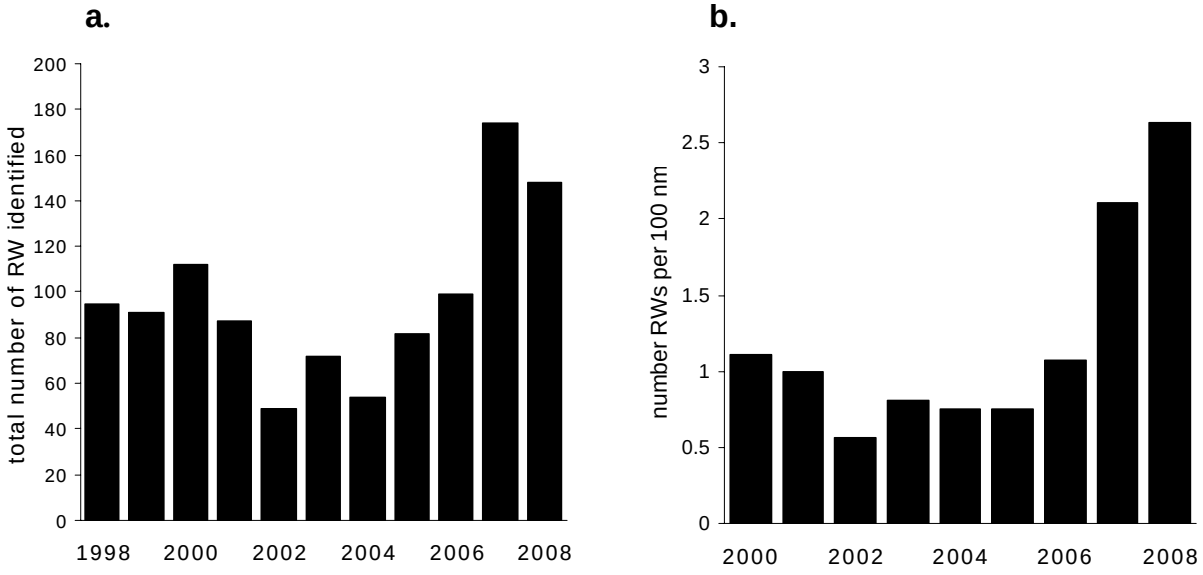


Fig. 2: (a) Total number of individual right whales sighted per year, 1998-2008, and (b) number of right whales sighted per nm of aerial survey effort, 2000-2008 (effort data unavailable for 1998-1999). Includes whales identified in CCB and adjacent waters. (The figure for 2008 will likely increase as matching work continues. Data comprises all matched individuals but excludes those given only intermatch codes.)

The number of individual whales observed collectively in CCB and adjacent waters was slightly lower in 2008 (148 individuals) than in 2007 (174 individuals; Fig.2a). However, when corrected for survey effort, the number of whales sighted per nautical mile flown was considerable higher in 2008 than in 2007 and all previous years (Fig. 2b). Since these data do not include a number of unique but as yet unmatched individuals, the sightings rate in 2008 will likely increase further once data processing has been completed, further increasing the whale sightings rate for 2008.

Considering CCB (tracks 1-15) and adjacent waters separately, Figure 2 shows two measures of whale abundance. As individual right whales have different residency times within CCB (see section 1.3.7), and as the individual residency time may also depend on the relative amount of food resources (untested to date) or other factors, the total number of different individuals identified within CCB each year may not reflect the yearly utilization of the Bay. Therefore, to take some proxy of the residency time into consideration, for each year, the number of individuals identified has been multiplied by the number of days each individual was observed in CCB, providing a variable called "whale-day" (Jaquet et al. 2007). In CCB, both number of whale-days per 100 nm effort

and number of unique individuals are highly variable amongst years (Figure 3a). During the eleven years of the project, an average of 74.5 individuals (SD = 35.8, range 20 - 140) was present each year in CCB and just north of it (tracks 1-15) representing 14% of all profiled right whales since 1980 (528 individuals, Philip Hamilton pers. comm.). Since 2002, there appears to be a pattern of increase in both whale-days per unit effort and number of individuals per unit effort. In 2008, both number of whale-days (7.6 per 100 nm), and number of individuals (2.9 individuals per 100 nm) were at their highest level since 2000.

In adjacent waters, no trend is apparent among years (Figure 3b). Survey effort in adjacent waters has been very variable over the years (min of 974 nm in 2008, max of 2,234 nm in 2002, mean=1,687 nm, SD=418.9). The 2008 data for adjacent waters does not therefore provide a good insight into this region, as very little survey time was spent in there. Between 1998 and 2008, an average of 40.7 whales (SD = 25.6, range 1 - 84) have been sighted in adjacent waters.

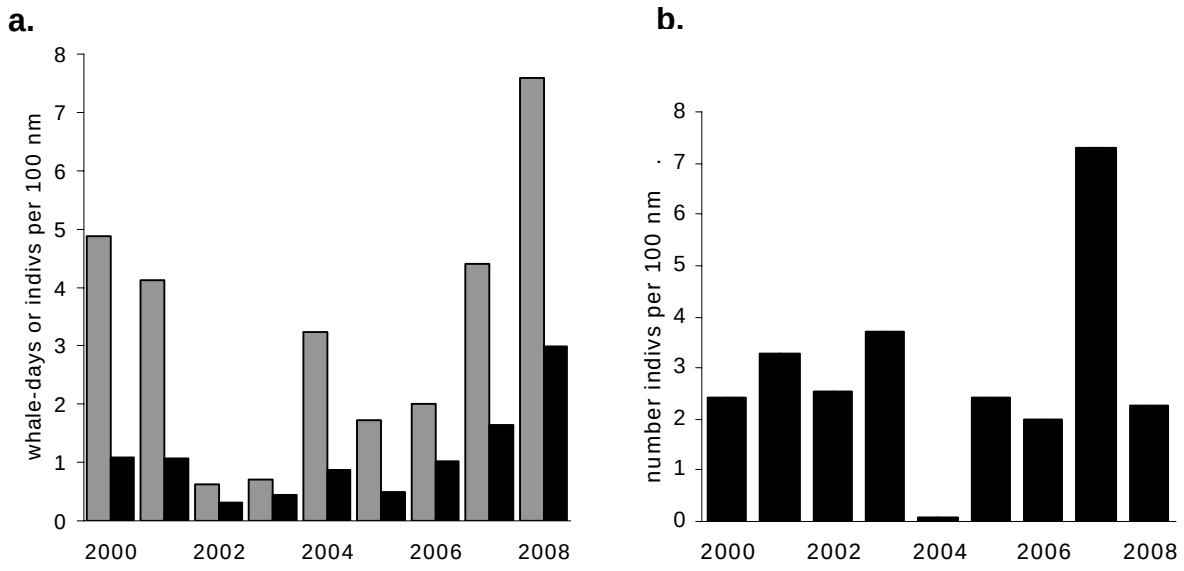


Fig 3: Number of whale-days per 100 nm effort (grey bars) and number of unique individuals per 100 nm effort (black bars) in (a) CCB, 2000-2008 (CCB is defined here as tracks 1-15) and (b) adjacent waters. No whale-day data available for previous years for adjacent waters.

Not surprisingly, there is a highly significant correlation between number of whale-days and number of unique individuals in the bay (Pearson product-moment correlation, r = 0.917, $P = 0.001$). This indicates that, in years when more whales visit CCB, the overall amount of time for which this habitat is utilized increases correspondingly. Thus both variables give a good indication of overall right whale habitat use.

Between 1998 and 2007, 315 individual right whales were identified within CCB (tracks 3-15) by all observers and all platforms. Numbers of "new" individuals (previously not sighted in CCB) sighted each year appeared to be diminishing in recent years, suggesting

that most of the individuals which utilize CCB had been identified in the first seven years of the project and thus implying that a proportion of the right whale population rarely or never enters the study area. However, in 2007, 34 new individuals were documented in the bay, and in 2008, an additional 47 individuals were sighted for the first time in the region (excluding all unmatched whales which have been given intermatch codes). This brings the total number of individuals documented in CCB to 362, which represents 69% of all profiled North Atlantic right whales. This influx of whales previously never sighted in the area could be the result of higher concentrations of particular food resource species in CCB (see Section 2 of this report for details). These results also suggest that CCB may be becoming a more important habitat for right whales and further stress the importance of continuing to monitor this area closely.

1.3.4 Seasonality and abundance of right whales within CCB

Right whales photographed and identified during aerial surveys of Cape Cod Bay and adjacent waters are plotted by in Figure 4. The first right whale was sighted in CCB on 12 January 2008, during the second aerial survey of the season. On two subsequent surveys, no right whales were sighted, but from the February 3rd survey until the final aerial survey on May 15th, right whales were sighted during every survey and can be assumed to be resident in the bay during that period. In both 2007 and 2008, sightings rates can be seen to increase slowly between late January and early March, and to be most numerous during April, after which sightings rates decrease abruptly. In 2008, right whale sightings were particularly numerous during the month of April, reaching a maximum of 88.9 whales per 100 nm on the 10th of April.

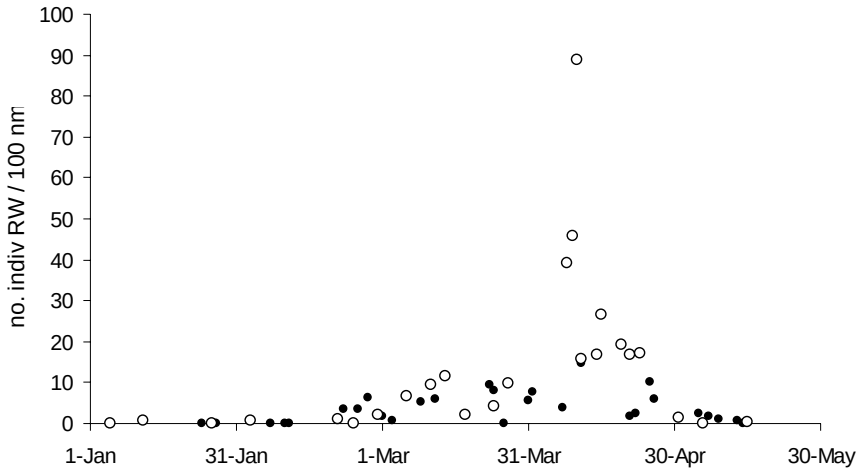


Fig. 4: Number of individual right whales sighted per 100 nm survey effort, in 2007 (black points) and 2008 (white points). (a) CCB (tracks 3-15); (b) adjacent waters (tracks, 1, 2, 16 and eastern tracks). Data comprises only whales for which ID has been confirmed by NEAq.

Table 3 shows the dates when right whales were first and last sighted in CCB. During the eleven years of this study, right whales were present for the longest period (assuming

constant presence between the first and last sighting each season) in 1999. However, these data are not strictly comparable since the date of the first aerial survey has varied considerably amongst years. Between 1998 and 2008, right whales have been present in CCB for a mean of 97 days each year. In 2008, right whales were present over a period of 125 days, considerably higher than the average.

Table 3: Right whale residency in CCB, 1998-2008. 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. (CCB is defined here as tracks 1-15).

Year	Date of 1st aerial survey	Date of 1st aerial sighting of RW in CCB	Date of last aerial sighting of RW in CCB	Minimum no. days when right whales were present in CCB
1998	04 Jan (9)	04 Jan (9)	21 Apr (1)	108 [75]
1999	13 Dec (5)	13 Dec (5)	02 May (1)	140 [86]
2000	20 Jan (1)	20 Jan (1)	11 Apr (3)	82 [86]
2001	19 Dec (5)	19 Dec (5)	29 Apr (2)	132 [87]
2002	06 Jan (0)	07 Feb (1)	15 Mar (3)	36 [24]
2003	10 Dec (0)	25 Jan (5)	30 Apr (8)	95 [26]
2004	21 Jan (0)	10 Feb (2)	10 May (1)	90 [54]
2005	09 Dec (0)	30 Jan (3)	26 Apr (6)	86 [45]
2006	10 Jan (0)	04 Feb (1)	06 May (12)	91 [59]
2007	24 Jan (0)	21 Feb (2)	13 May (2)	82 [116]
2008	05 Jan (0)	12 Jan (1)	15 May (1)	125 [148]

1.3.5 Spatial distribution of right whale sightings

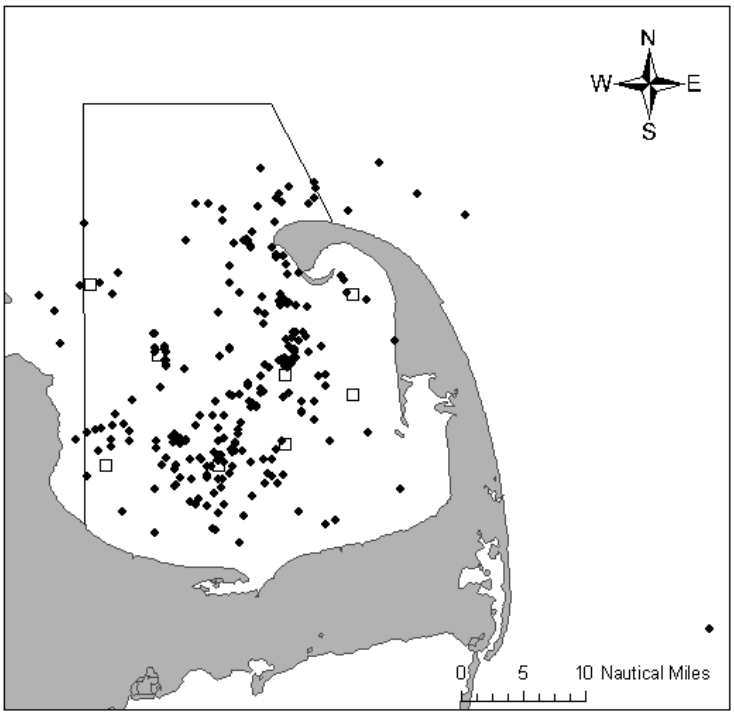


Fig. 5: Distribution of all confirmed sightings of right whales from aerial surveys in 2008 (black points). White squares indicate standard habitat sampling stations; solid line indicates boundary of CCB critical habitat.

Of the 532 sightings of individual right whales in 2008 (including unidentified and unconfirmed individuals), 22 individuals (4%) were located outside the CCB designated critical habitat.

Figure 5 shows the distribution of all sightings made by the aerial survey team in 2008. Sightings were concentrated in the bay, particularly in the central and northeastern parts of the bay area. A large number of sightings also occurred off Herring Cove and offshore of Race Point. In Figure 6, sightings are plotted on a month-by-month basis. This shows the distinct seasonality in right whale abundance in CCB, as previously described. These maps also indicate the distribution of whales throughout the bay as abundance increases. In early months, small numbers of individuals utilize distinct parts of the bay, whereas in April, distribution is much more spread out. During April, it is evident that right whales were using all areas within the bay, although distribution was perhaps slightly higher in the southern and western parts of the bay (Figure 6c).

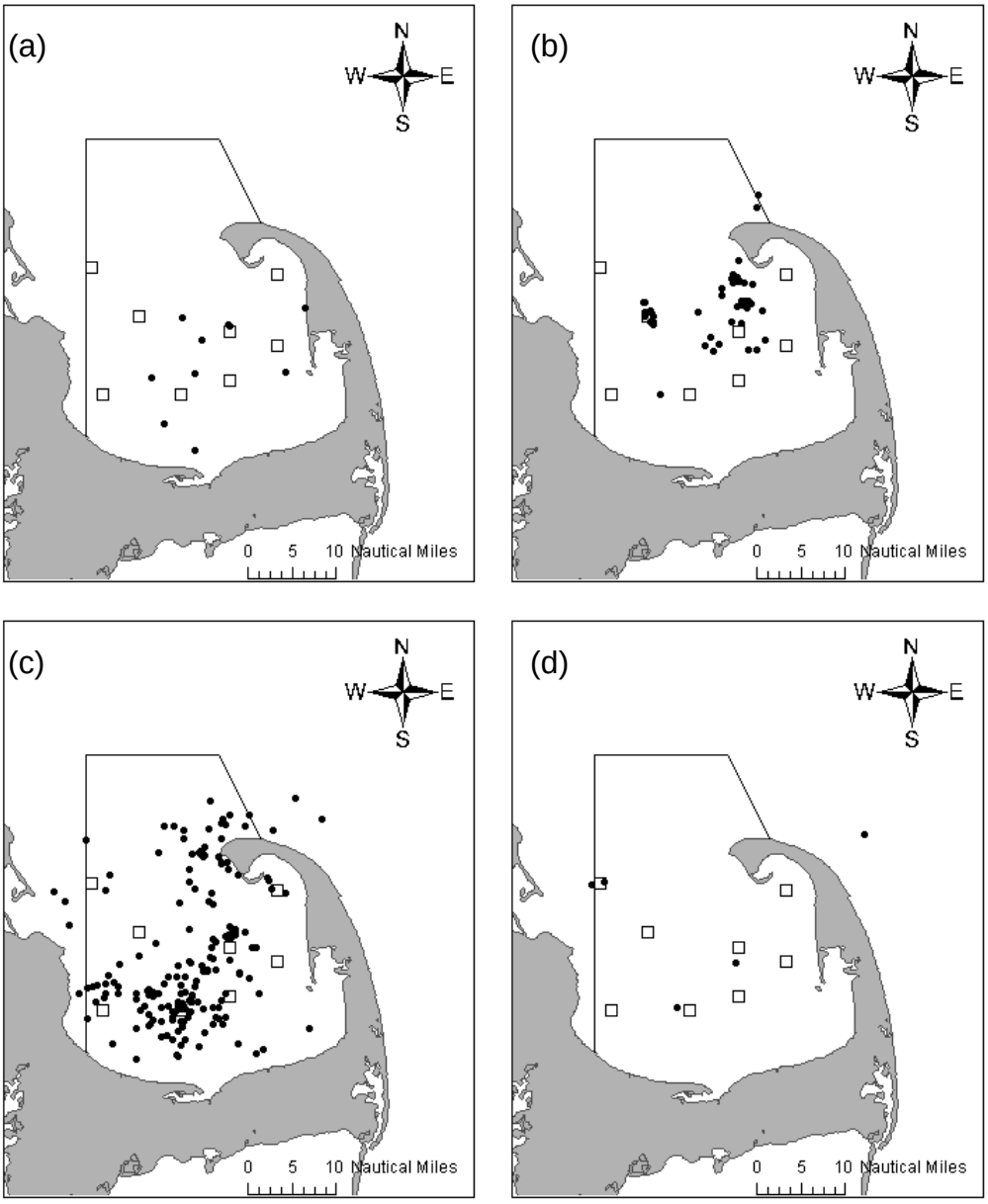


Fig. 6: Distribution of all confirmed sightings of right whales from aerial surveys in 2008, by month; (a) January & February combined (only 1 individual sighted in January); (b) March; (c) April; (d) May. Includes all sightings from tracks 1-16 but excludes sightings made on track lines east of CCB.

1.3.6 Demographics

In 2008, 19 mother-calf pairs were observed in the southeastern United States, the same number as in 2007 (in both 2007 and 2008, one of the calves died early in the season). Three of the surviving 18 calves (16.7 %) were photographed with their mothers in Cape Cod Bay and adjacent waters in 2008 (Table 4). All three mothers documented in CCB in 2008 have been sighted in the region in previous years. Of the other 16 mothers in 2008, seven have never been documented in CCB, and several other individuals have not been sighted in the region in the last seven or more years (*Digits* data, as of August 2008). All CCB mother-calf pairs were sighted in the month of April only, between the 10th and the 23rd.

Table 4: Identities, histories and residency of the 2008 mothers sighted in CCB and adjacent waters.

EG number	Number of previous calves	Number of days seen	Time first to last sighting (days)
1245	3	4	9
1802	2	3	6
2790	1	5	11

Figure 7 shows the number of calves seen in CCB and adjacent waters in recent years as a proportion of total number of calves born in the southeast US that year. Since 2001, 178 calves have been born in the southeast, of which 38 have been sighted in CCB and adjacent waters. Between 2001 and 2008, a mean of 22% of calves documented in the southeast have been sighted each year in CCB and adjacent waters. The proportion in 2008 was thus somewhat lower than this average.

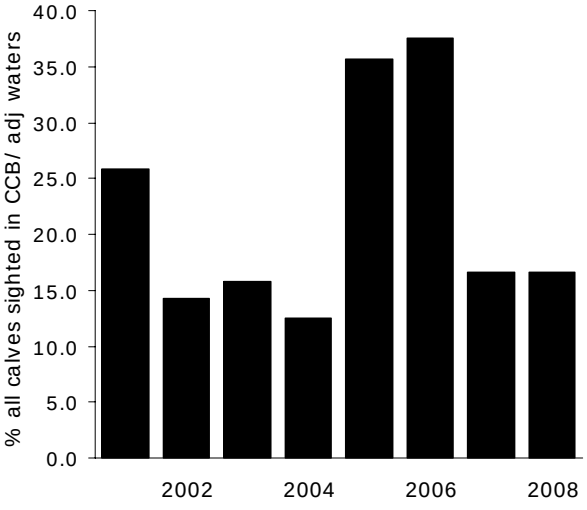


Fig. 7: Proportion of all calves born in the southeast US which were sighted in CCB & adjacent waters, 2001-2008. Between 1998 & 2000, no calves were sighted in the study area.

Of all right whales sighted in CCB and adjacent waters in 2008, 78% were adults, 9% were juveniles, 2% were calves and 11% were of unknown age. 75% of the entire living North Atlantic right whale population are adults (nine years of age or older, as defined in Hamilton et al. 1998), 21% are juveniles with the remainder of unknown age (as of September 2008; P. Hamilton pers. comm.). The age profile of whales in CCB is therefore similar to that of the entire population.

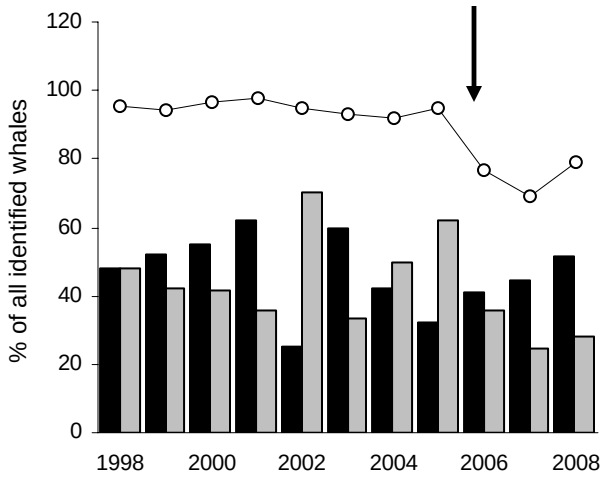


Fig. 8: Proportion of all identified whales (including individuals of unknown gender) in CCB (tracks 1-15) which were male (black bars) & female (grey bars), 1998-2008, and whales of known gender as a proportion of all identified individuals (points).

Of all right whales sighted in CCB and adjacent waters in 2008, for which gender is known (116 individuals), 34% were females and 66% were males. Because the gender of a large proportion of the right whales sighted in the study area is unknown (22% of all individuals in 2008), it could be misleading to analyze sex ratios. However, for comparative purposes, Figure 8 shows the number of males and females as proportions of all whales identified in CCB (tracks 1-15), between 1998 and 2008. It is apparent that in most years, a greater proportion of known males are present in CCB than known females. This pattern is not always observed in CCB, however; most notably in 2002 when 70% of all known individuals in the bay were females. Before 2006, relatively high proportions of individuals identified every year in the bay were of known gender (Figure 8), but this proportion has dropped in recent years (2006-2008; points on graph & arrow, Figure 7). A timeline, detailing in two-week periods the demographic composition (by age group and gender) of right whales identified in CCB in 2008 is presented in Appendix I (Table VI).

Table 5: Breakdown of sex ratio and age groups for all identified right whales sighted in CCB and adjacent waters by the aerial survey team, 2008.

gender	adult	juvenile	calf	unknown age	total
female	38	2	0	0	40
male	69	6	0	1	76
unknown	9	5	3	15	32
ALL	116	13	3	16	148

1.3.7 Residency

Right whales are often seen multiple times in CCB over the four and a half month field season. Table VII (Appendix I) shows the sightings history for each of the 148 right whales of confirmed identity, sighted in CCB and adjacent waters in 2008. Aerial surveys were not conducted every day, and many of the individual whales using CCB habitat likely leave and re-enter the bay during the survey season (see below). It is thus difficult to surmise true patterns of residency from intermittent sightings of individuals. Two parameters have therefore been defined; "*maximum possible residency time*" is the time span between the first and last sighting of an individual, and "*minimum residency time*" is the sum of all the days on which a whale was sighted; this is equivalent to the "whale day" parameter described earlier. Data for 2008 mother-calf pairs have been excluded from analyses of whales in CCB, and are described separately, since the movements of calves are not independent of their mothers' and since the behavior of this demographic group is likely determined by different factors.

Right whales were recorded as present in the study area (CCB and adjacent waters) for 125 days in 2008 (January 12 to May 15), considerably longer than the recorded time periods between 2005 and 2007 (97, 100 and 92 days, respectively). The longest time span between first and last sighting of an individual whale was 71 days, and mean maximum possible residency time was 12.7 days. In 2007, mean maximum possible residency time was 18.4 days, which was considerably greater than in 2006 (7.4 days). The value for 2008 falls between these two values and demonstrates the variability among years in residency in CCB.

Of the 138 right whales identified in CCB (tracks 3-15) in 2008, 39 (28.3%) were sighted only once; a similar proportion were sighted only once in 2007 (21.4%). In previous years, individual right whales in CCB have been sighted more frequently than individuals identified only from adjacent waters, suggesting transitory behavior for individuals who do not enter the bay. Sightings of whales in adjacent waters are discussed below. In CCB (tracks 3-15), the maximum possible residency time was 63 days, for whale 2710. This adult female was first sighted in the bay on March 14, and was the only individual sighted on the final aerial survey of the season, on May 15. However, this individual was not sighted at all between April 9 and May 15, suggesting that she may have left the bay and re-entered at a later date. The mean maximum possible residency time for whales in CCB was 11.3 days. There was no significant difference between maximum possible residency time for males and females (Figure 9; mean maximum possible residencies of 10.0 d and 13.4 d, respectively; Mann-Whitney U-test, $Z = -0.394$, $P = 0.694$; NS); in contrast to the data from 2007 (means of 17.6 and 21.7 for males and females, respectively). Maximum possible residency times in 2007 were also much greater for both genders than in 2008 (Jaquet *et al*. 2007).

The minimum residency time for whales in the bay (tracks 3-15) ranged between one and seven days, with a mean of 2.4 days. This is comparable with the 2007 mean of 3.0 days. There was also no significant difference between the minimum residency time in CCB for males and females (Mann-Whitney U-test, $Z = -0.249$, $P = 0.803$; NS). Female whales were sighted on an average of 2.6 days in CCB, whilst for males this value was 2.4 days.

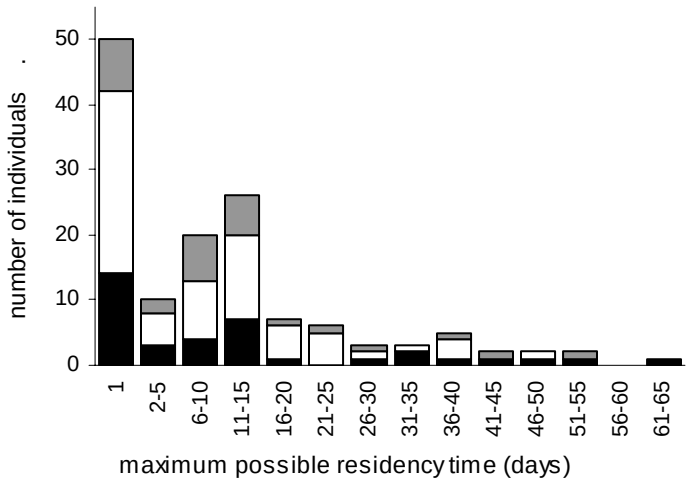


Fig. 9: Frequency distribution for maximum possible residency times for female (black), male (white) and unknown (grey) right whales in CCB (tracks 3-15) in 2008.

On April 23, 16 right whales were sighted in the bay, but the next aerial survey 8 days later, on May 1, documented only 3 right whales in this area. The lack of surveys in the final week of April, due to bad weather, prevents a better understanding of the movements of whales in the bay during this peak month, and residency times may thus be somewhat truncated.

In 2007, 55 individuals were sighted exclusively in adjacent waters, and 80% of these individuals were sighted only once, suggesting that these whales were in transit rather than remaining in the area for a period of time. In 2008, 10 of the 11 individuals sighted exclusively in adjacent waters (tracks 1, 2, 16 and eastern track lines) were only sighted a single time and the remaining whale was sighted twice. However, since the eastern tracks were surveyed only twice, early in the season (January 17 and February 25), and since overall effort in adjacent waters was very low compared to effort in CCB, it is difficult to draw conclusions about residency time of the individuals sighted in this region. Since none of the individuals sighted on the eastern track lines were sighted on subsequent surveys in CCB, they clearly form a subset of whales which do not utilize the CCB habitat and were likely transiting through the area, as has been documented in previous years (Jaquet *et al*. 2006, 2007).

Four of the right whales which were documented in adjacent waters had been previously sighted in CCB, and were subsequently re-sighted in the bay, providing evidence that whales sighted in the bay do transit in and out of this discrete area throughout the study period. For example, EGNO 1911 was first sighted on March 11 in CCB, and was seen a further three times in the bay before being sighted in adjacent waters on April 14. This individual was subsequently sighted twice more in CCB, on April 19 and 21. Likewise, within ten days in April, EGNO 3411 was sighted twice in CCB, once in adjacent waters and then again in the bay. Likewise, several right whales sighted multiple times in CCB were not seen on all full-bay surveys during the time from first to last sighting, suggesting that these individuals may also have left the bay and later re-entered.

Mother-calf pairs were sighted on a mean of 4 days, which is higher than the values for male and female right whales (2.4 and 2.6 days respectively). The mean maximum possible residency time for mother-calf pairs, however, was lower than the values for both male and female right whales in CCB (9.6 days, compared with 10.0 and 13.4), suggesting that in 2008, mother-calf pairs spent less time in the bay than the rest of the

whales in this area. Indeed, all sightings in 2008 of new calves with their mothers, in the CCB region, took place only in April.

In a comparison of all identified whales sighted in 2007 and 2008, 90 individuals were sighted in both years. Thus, 56% of identified individuals in 2007 returned to CCB and adjacent waters in 2008. This suggests a high degree of inter-annual site fidelity. 58% (52 individuals) of these returning individuals were males, and 29% (26 individuals) were females. Of the right whales sighted in the study area in 2008, 47 (not including the three 2008 calves) had never previously been recorded here since records began in 1959.

1.3.8 Behavior & cluster size

In baleen whales, a "group" is usually (but not always) defined as two or more individuals within one or two body lengths of each other and coordinating their movements. For the purposes of this report, the term "cluster" will be used to define such an association. Understanding the variability in cluster size may provide insight into some aspects of right whale social organization. Mean cluster size in CCB and adjacent waters was calculated for aerial survey data from 1999 to 2008, as cluster size and behavior was not systematically recorded prior to 1999. We investigated whether cluster size was related to total number of whales present, or with overall food resource level. Mother-calf pairs are excluded from this analysis, but all other sightings of whales have been used, regardless of whether individuals have been identified or not.

In CCB (tracks 3-15), mean cluster size was 1.7 individuals, and 71% of clusters were of single individuals, whilst 16% of all clusters numbered three or more individuals. In adjacent waters, mean cluster size was 1.9 individuals, 73% of clusters were of single individuals, and 15% of clusters numbered 3 or more whales. These mean cluster sizes are somewhat larger than the mean cluster sizes in 2007 (1.26 in CCB and 1.65 in adjacent waters). There was no significant difference in cluster size frequency between CCB and adjacent waters (Mann-Whitney U test, $Z = -0.059$, $P = 0.953$; Figure 9a), but the small dataset for adjacent waters (n = 33 clusters, compared with n = 271 for CCB), limits the validity of this analysis. Nonetheless, the pattern of slightly larger mean cluster size in adjacent waters than in the bay, observed in previous years, is maintained in 2008.

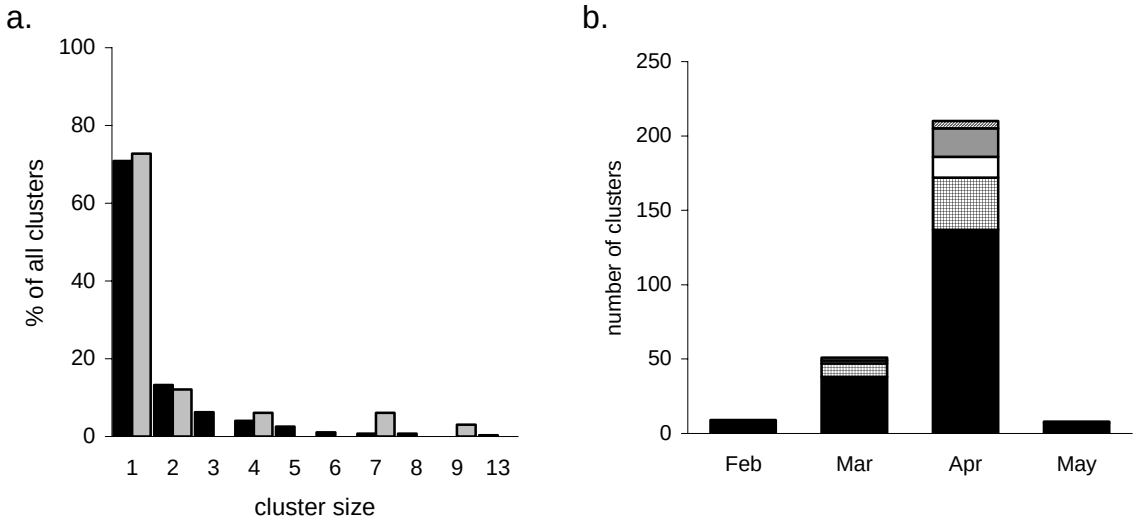


Fig. 10: (a) Cluster size comparison between CCB (tracks 3-15; black bars) and adjacent waters (grey bars); (b) number of clusters of 1 (black), 2 (hatched), 3 (white), 4-6 (grey) and 7-13 (striped bars) whales in CCB for each month. January is not shown as only one right whale was sighted in this month.

Figure 10a shows the proportion of clusters of varying sizes found in CCB and adjacent waters. It is apparent that clusters of one and two individuals are by far the most common. The recording of a small number of large clusters (of 7 and 9 individuals) in adjacent waters give the impression that these large groupings are more common outside of CCB, but the sample size from this area is small and thus the data must be interpreted with caution. In every month, clusters of single individuals are the most common occurrence, but clusters of between two and six individuals become more common in March and even more so in April, when total numbers of individuals increase (Figure 10b). The large clusters of seven to 13 whales are only observed during the month of April.

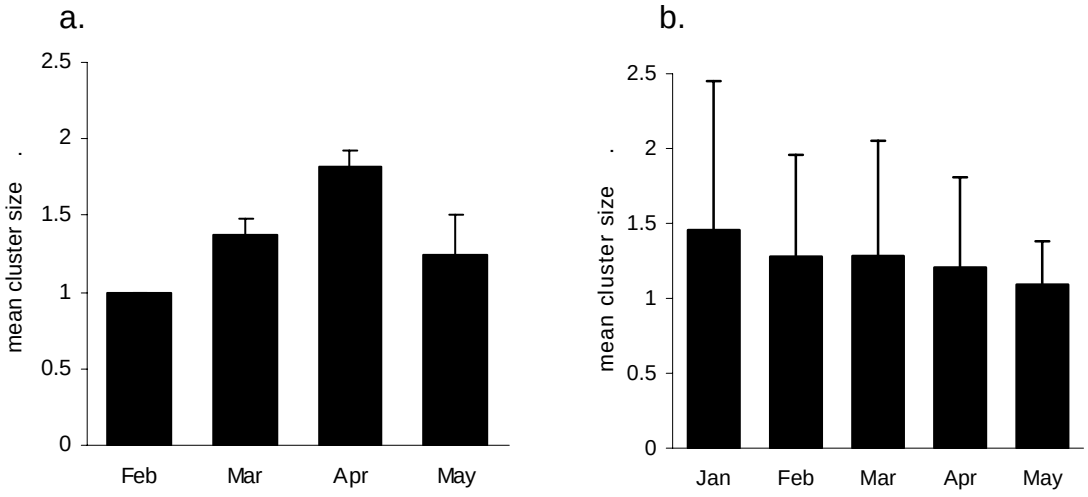


Fig. 11: Mean cluster size in each month of the field season, in (a) 2008 (only one sighting was made during January), and (b) 1999-2007 (Jaquet *et al*. 2007).

A comparison of the 2008 data with cluster size data from the previous years (1999-2007; Jaquet *et al*. 2007) reveals some differences. Mean cluster size for the entire season was higher in 2008 than in 1999-2007 (1.7 and 1.3, respectively), although there is much inter-annual variability in these figures. Whilst Jaquet *et al*. (2007) documented a decrease in cluster size, or in the relative frequency of large clusters, through the season (Figure 11b), a different pattern is apparent in 2008 (Figure 11a). In 2008, mean cluster size increased from February to April, and then decreased again. There were significant differences in cluster size among months (Kruskal-Wallis test; $\chi^2 = 7.8$, $P = 0.05$), and mean cluster size in February was significantly lower than in April (Mann-Whitney test; $Z = -2.11$, $P = 0.035$).

Documenting the behavior of right whales in CCB and adjacent waters is crucial to protecting the species. By understanding how right whales use this habitat and how their behavior might be affected by anthropogenic activities, we can implement better management and mitigation strategies. The surface active group or SAG (two or more whales interacting at the surface with frequent physical contact; Kraus & Hatch 2001) is the most striking aspect of right whale social behavior. Although SAGs were thought to be linked to reproduction, they have been observed in all right whale critical habitats, and during 11 months of the year, despite the highly seasonal nature of calving (Parks 2003). It is thus likely that a large proportion of SAGs do not lead to reproduction and that social and sexual activities, unrelated to conception, have important benefits for right whales.

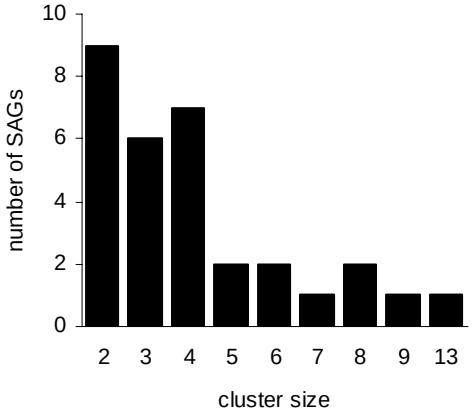


Fig. 12: Size of SAGs observed in CCB and adjacent waters (all but one SAG, of 9 individuals, were observed in CCB), in 2008.

Figure 12 shows the numbers of SAGs of varying sizes, observed throughout the study area in 2008. A total of 31 SAGs were observed in 2008, a figure comparable with that for 2007 (30 SAGs). These groups ranged in size from two to 13 individuals, but most SAGs (71%) comprised between two and four whales. Mean SAG size was 4.1 individuals, similar to the figure for 2007 (3.8 individuals). The number of SAGs as a proportion of all clusters in any given month is extremely variable from year to year, and a combined dataset of all cluster data from 1999 to 2007 revealed no monthly pattern in SAG occurrence (Jaquet *et al*. 2007). Whilst, in some years, SAGs have been observed as early as January and as late as May, in 2008 SAGs were only observed in CCB in March and April in 2008, with one additional SAG observed in February, on track lines east of CCB. 18% of all clusters observed in CCB in March, and 10% of all clusters in April, were SAGs.

Skim feeding and subsurface feeding were only observed in March and April. Figure 13 shows the whales for which sub-surface and skim feeding was the primary activity, as a proportion of all observed whales in each hour of the day. Sub-surface feeding appears to

occur throughout the daytime, although the graph suggests slightly higher proportions of whales sub-surface feeding in the early part of the day. In contrast, a greater proportion of all individuals observed in any hour were engaged in skim feeding later in the day, specifically from 15:00 to 19:00 (Fig. 13). Echelon feeding was observed only in April, and only for whales engaged in sub-surface feeding (although the habitat team also observed echelon formation in skim feeding whales). Three clusters of 3, and one cluster each of 5 and 7 individuals, were observed in echelon formation.

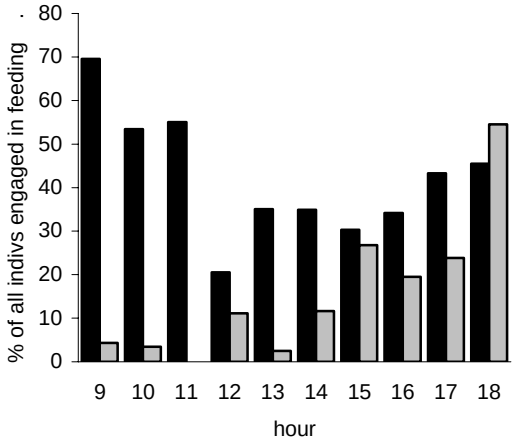


Fig. 13: Proportion of all observed individuals in any hour engaged in sub-surface feeding (black) and skim feeding (grey).

1.3.9 Vocal behavior of right whales – Results of 2006/2007 study

Eleven days were spent at sea in Cape Cod Bay between March 1 and May 15, 2007. A total of 90.5 hours were spent in visual contact with whales and 79.03 h of underwater sounds were recorded. To these data were added the 31.9 hours of recording collected over six days between late March and early May 2006, as well as the 37 hours of behavioral data collected during the same time period. Therefore, for the purpose of this report, we analyzed 111 hours of sounds recordings and 127.5 hours of behavioral data.

The 111 hours of recordings yielded 3,506 right whale vocalizations with high signal to noise ratio. These vocalizations were assigned to six categories (Table 6 and Figure 14), most of them corresponding to the categories described by Parks and Tyack (2005). Overall, tonal calls were the dominant sound produced by right whales in CCB, accounting for 62% of all vocalizations recorded, while up-calls accounted for only 11% of all vocalizations (Figure 15).

Vocalizations were not produced uniformly over time; rather, vocalizations were clustered and these periods were interspersed with periods of silence. When feeding or traveling, periods of total silence were often extensive, up to 8.6 hours in a recording of 9.0 hours (6 May 2006). However, as recording periods were limited, periods of silence are likely longer than those documented by this study.

Table 6: Type of vocalizations recorded in CCB

Vocalization type	Total recorded	Description
Scream/ tonal	2160	Highly variable call with clear harmonic structure that may contain rapid frequency modulation. Major energy between 300 and 2000 Hz.
Gunshot	468	Short, broadband, sharp onset sound with major energy between 50 and 2000 Hz
Broadband	127	Low frequency, long and uniformly tonal sound without any clear harmonic, major energy between 50 and 200 Hz.
Up-calls	401	Low frequency tonal up sweep with major energy between 50 and 200 Hz
Down-calls	99	Low frequency tonal down sweep with major energy between 100 and 400 Hz
Unclassified	251	Sounds that could not be classified in any of the above categories

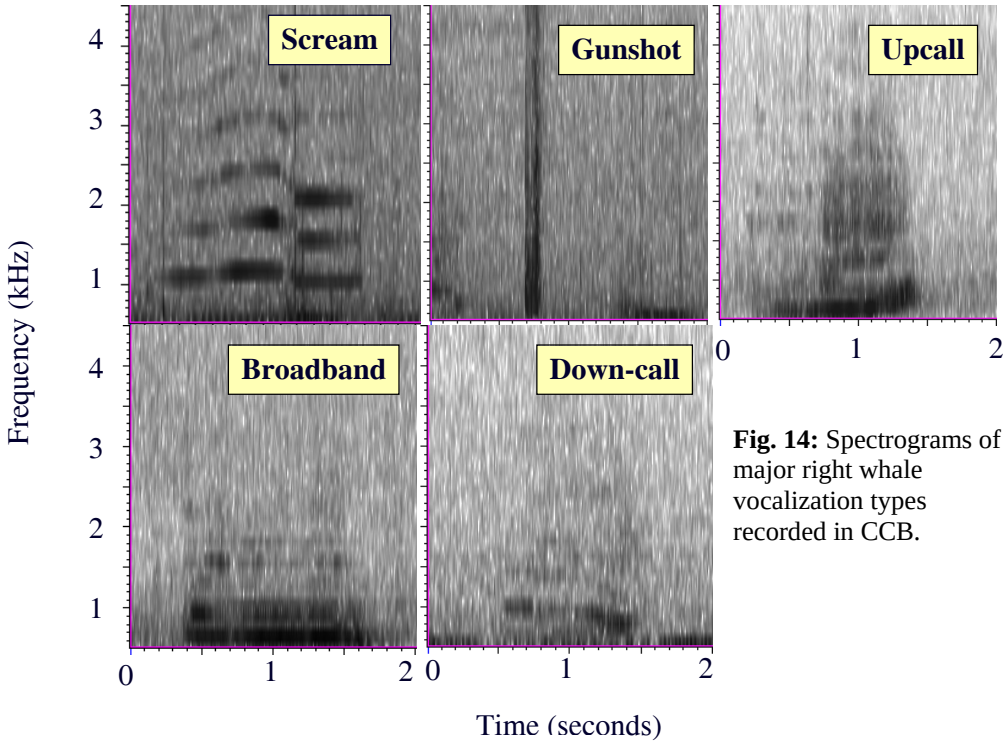


Fig. 14: Spectrograms of major right whale vocalization types recorded in CCB.

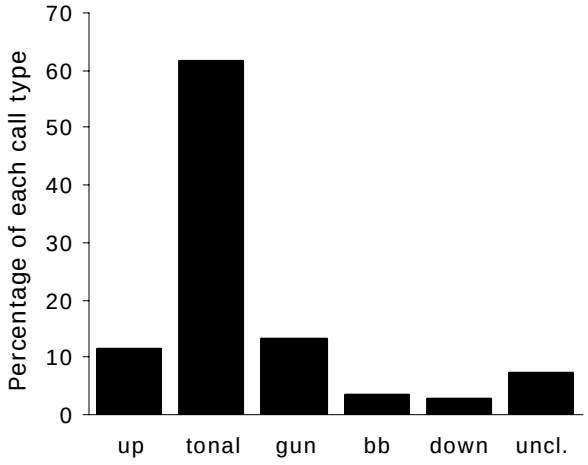


Fig. 15: Percentage of call types recorded in CCB in spring 2006 & 2007. Call types: up-calls (up), tonal, gunshots (gun), broadband (bb), down-call (down), unclassifiable (uncl.).

During 116 h of sampling time, whales were in close enough proximity that their behavior could be assessed unequivocally. Figure 16a shows the proportion of time that focal individuals spent in each behavior category. From Figure 16a it is evident that during the study, right whales spent most of their time feeding at the surface or just under the surface. Whilst SAG behavior represented only 14% of all behavior categories, at least some SAG behavior was observed on over half of the days (9 out of 16). Although right whales spent most of their time feeding (78% of all behaviors, Figure 15a), only 15.4% of the vocalizations were heard during this behavior (Figure 16b). Furthermore, when foraging or traveling, only four vocalizations were heard on average per hour and the longest period of silence recorded was 8.6 hours. This result suggests that right whales are mainly silent when feeding. In contrast, 83.4% of all vocalizations recorded were heard when right whales were engaging in SAG behavior (Fig. 16b), although they spent only 14% of their time in this behavior (Fig. 16a), and an average of 165 vocalizations per hour was recorded in the vicinity of whales in SAGs.

Very few calls (1.2% of all vocalizations) were produced while traveling (Fig. 16b), and no up-calls were heard whilst recording traveling whales. Up-calls were heard in roughly similar proportion when whales were in a SAG or foraging (45% and 55% respectively).

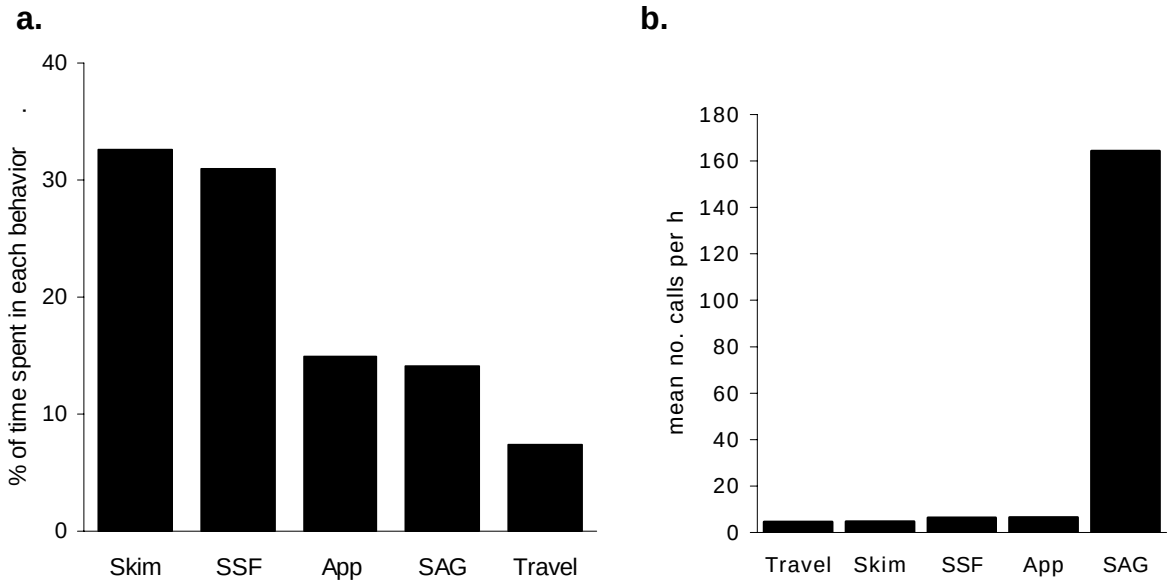


Fig. 16: (a) Proportion of all time during focal follows that whales spent engaging in each behavioral category. (b) Mean number of calls recorded per hour, for each behavioral category. Behaviors: skim feeding (Skim), sub-surface feeding (SSF), apparent feeding (App), surface-active group behavior (SAG) or traveling (Travel). 2006 and 2007 data combined.

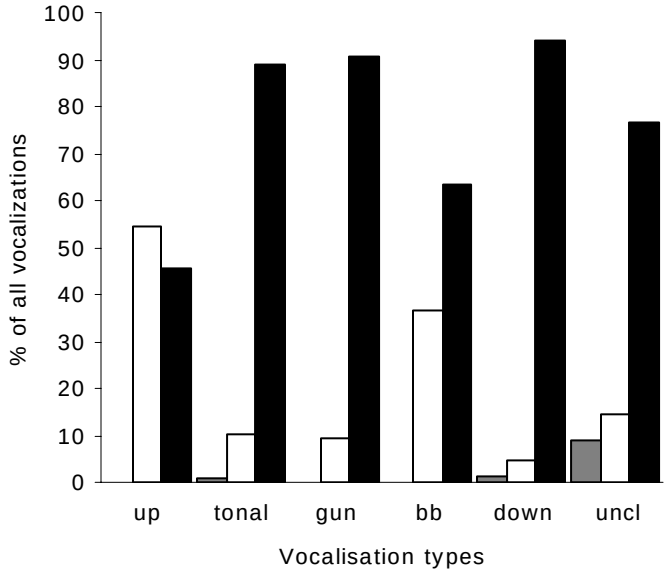


Fig. 17: Proportions of each type of vocalization produced by whales engaged in travel (grey), foraging (white) and SAG behavior (black).

However, there were large differences in the production of tonal calls, gunshots and down-calls between SAG behavior and foraging behavior. These vocalizations were produced almost exclusively when engaging in SAG behavior and represented 10% or less of the vocalizations produced while foraging (Figure 17). Small-scale movements of individual whales were also recorded during this study and were reported in Jaquet *et al.* (2007).

1.3.10 Acoustic detection of right whales

Right whale acoustic activity was extremely high during the 2008 winter-spring season, and the Auto-buoys detected a total of 3,512 right whale calls in 5,428 sound clips from 21 January through 23 May 2008. Data collection was patchy over this period, and at least two of the buoys were not simultaneously operational until March 5, due to battery and cell-phone connectivity issues prior to this time. The first confirmed call was detected on January 21, on the Wellfleet buoy. The Sandwich and Race Point buoys were more fully operational by March. By mid-May, only the Wellfleet buoy's batteries were still running, and call detections had dropped. The final confirmed call detection was on May 10.

A basic cross-validation of acoustic and visual datasets was carried out. A comparison of acoustic and visual (aerial) survey methods was made, for days when data from both methods were available. On 14 days (56%), right whales were detected by both methods, and on 2 days (8%), neither method detected whales. On two days (8%), right whales were acoustically detected but not sighted, and on seven days (28%), sightings of whales were made but no acoustic detections occurred. Thus, in a simplistic comparison between methods, acoustic and visual techniques provided the same presence/absence data on 64% of days.

Figure 17a shows the number of clips per day (sum of all three buoys), and the number of up-calls recorded per clip, per day (when the number of clips per day exceeded four) over the entire deployment period. The number of clips increased noticeably in March and peaked in April. Whilst high numbers of up-calls per clip were detected sporadically in January and February, they did not occur on a daily basis until March. Figure 17b shows calls per operational buoy, with number of individual whales sighted per day overlaid, for days when aerial surveillance was carried out and when the number of clips per day exceeded four. Figure 18 shows the correlation between number of calls per operational buoy per day and number of right whales sighted per 100 nm survey effort, for all aerial survey days. Pearson product-moment correlation indicates a significant positive association between these two variables ($r = 0.682$, $df = 24$, $P < 0.001$); thus number of calls per day increases as more right whales are detected in the bay.

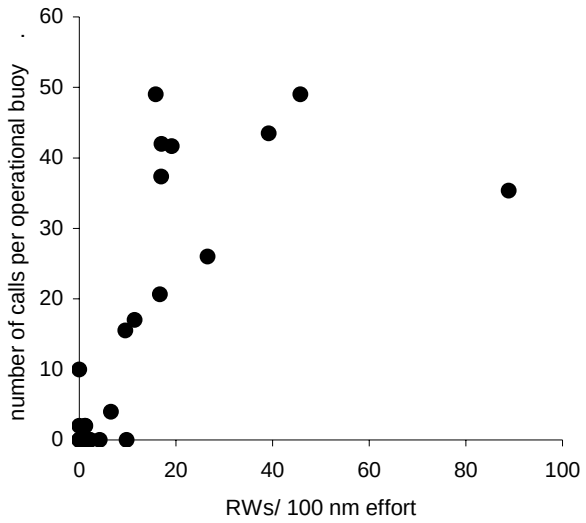


Fig. 18: Correlation between number of right whales sighted per 100 nm survey effort and number of calls per operational buoy, for days when both acoustic and aerial survey data were available.

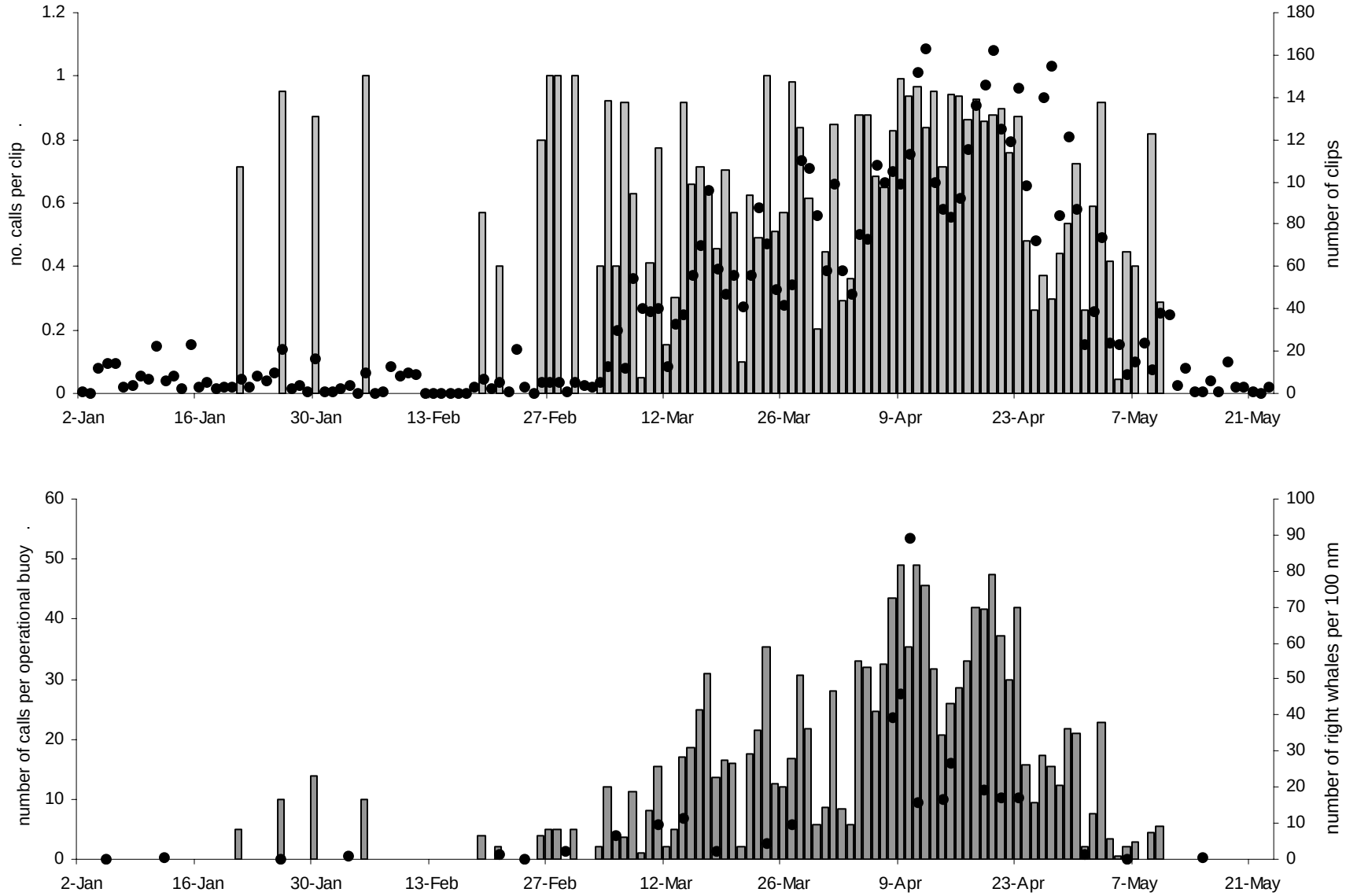


Fig. 19: (a) Number of calls per clip detected by the acoustic buoys, for all days when >4 clips were transmitted (grey bars, left axis), and number of clips (black points, right axis); (b) number of calls per operational buoy (grey bars, left axis) and number of right whales sighted per 100 nm of aerial survey effort (black points, right axis); January 02 – May 23, 2008.

1.3.11 Monitoring entangled right whales

Support of the PCCS Disentanglement Team formed a major part of the work carried out by the Aerial Survey Team in 2008, due to the unusually high number of entangled right whales sighted this season. Entangled or injured right whales were sighted on nine of 28 survey days carried out; these sightings involved five individual whales (Table 7). Hours spent in support of the Disentanglement Team amounted to 20 h 35 min over the course of the survey season; this was 12.9% of all flight hours undertaken by the Aerial Survey Team and represents a significant proportion of the survey time.

Aerial surveys continue to be the major source of entangled right whale sightings in US waters, representing 85% (n=39) of entanglement sightings in 2007 to date (the remainder of right whale entanglement reports were sighted by boat-based research effort). In 2008, by survey region, Cape Cod Bay had the highest proportion of right whale entanglement sightings, with 19 sightings of five unique entanglement cases (2645, 1140, 1980, 3346 and 3530 - not currently carrying gear but being monitored), making the region a key site for entanglement detection and intervention. (It should be noted that entanglement sightings locations, especially in right whales, do not likely represent the site of entanglement considering none of the whales were anchored by their entanglements and right whales are known to carry gear over considerable distances; Robbins *et al*. 2007.) The CCB aerial survey team reported 16 real-time sightings of entanglement cases, leading to 10 on-water responses for ongoing assessment or disentanglement attempts. This effort resulted in partial disentanglement of two whales: 1140 and 2645.

Table 7: Summary of all right whales attended by the PCCS disentanglement team, during the 2008 aerial survey season.

Whale ID	Aerial sightings	Attempts/assessments	Assessment
2645	6	3	Non-lethal
1140	3	3	Non-lethal
1980	2	2	Lethal
3346	1	0	Lethal, monitor
3530	5	2	Gear shed, monitor

1.3.12 Distribution of vessel traffic & vessel-whale interactions

Figure 20 shows the distribution of vessels by type as recorded during aerial surveys in 2008. Fishing vessels are largely concentrated in the east and southern portions of the bay, and in the northwest corner (Fig. 20a). Draggers are the most common vessel in the southeastern region, whilst pot fishery vessels are more numerous in the northwest. Fishing vessels were also frequently sighted along the ocean side of Cape Cod. Other vessel types were sighted throughout the bay, but were slightly more numerous in the western area (Fig. 20b).

Several interactions between vessels and right whales were observed and recorded during the 2008 aerial surveys. These interactions, all involving recreational vessels, are summarized in Table 8. Many more such interactions likely occur during the peak right whale season and these data suggest that not all boat users in the CCB area are aware of

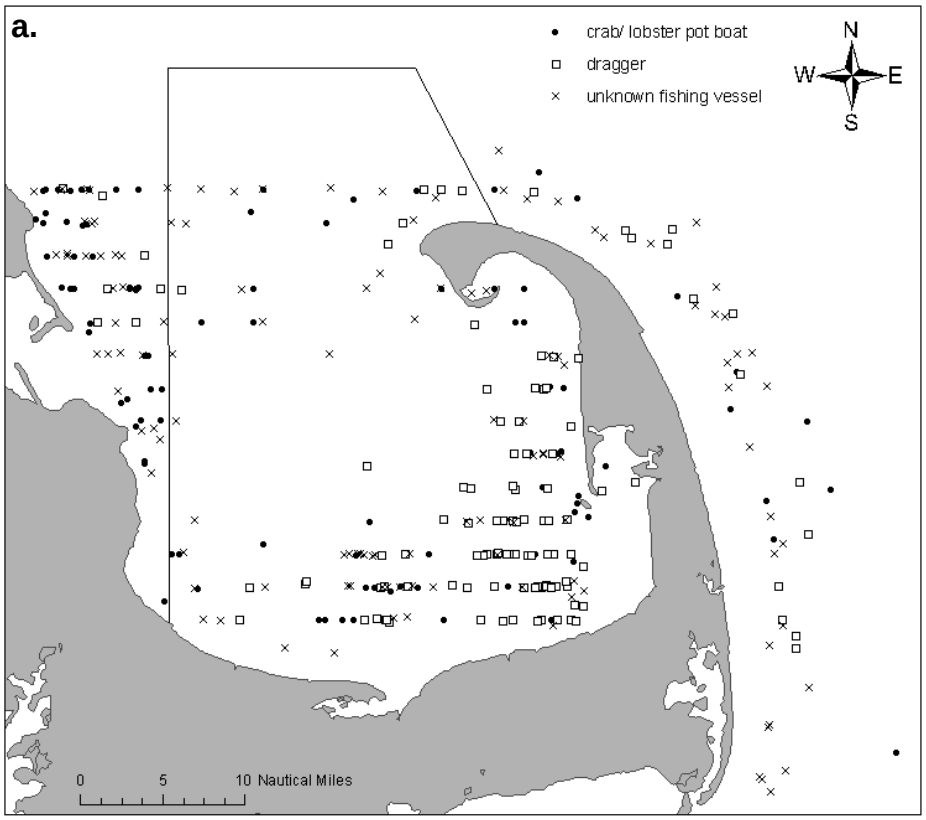
the seasonal presence of right whales, the correct way to behave around them or of the implications of unsuitable behavior.
All documentation was passed on to DMF to be followed up, where appropriate.

Table 8: Summary of observed interactions between right whales and vessels during the aerial survey season 2008.

Date	Vessel type & length	Vessel behavior	Hailed by skymaster?	Did vessel respond?	Outcome
Apr 09	Recreational vessel, ~10m	Traveling at speed	Y	N	Passed within 15m of a group of right whales
Apr 10	Recreational vessel, ~14m	In an area with numerous right whales, off Provincetown	Y	Y	Complied to request by Skymaster for a change in heading to avoid whales
Apr 16	Recreational vessel, ~7m	Within 50m of numerous right whales, traveling slowly	Y	N	Appeared to be watching humpback and fin whales and was later sighted some distance from the right whales
Apr 16	Recreational/ fishing craft, ~7m	Traveling at ~20 kn through an area of numerous right whales	Y	Y	Did not comply to request for reduction in speed, despite repeated communication. Photographs were taken of the vessel.

1.3.13 Notification of agencies and management measures

At the completion of each survey and cruise, the information on the number and locations of right whales 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 by phone 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. During surveys and cruises in CCB, the USACE Field Office was contacted directly by VHF radio or cell phone at the time of any sighting in close proximity to traffic exiting or entering the Cape Cod Canal. A total of 47 emails were sent to the DMF offices in Boston and New Bedford (one for each aerial survey and habitat sampling cruise in CCB and adjacent waters). The DMF/PCCS surveys are the principle source of right whale sighting information in the northeast region (north of latitude 41° N) for the NOAA Fisheries/ SAS program between January and March.



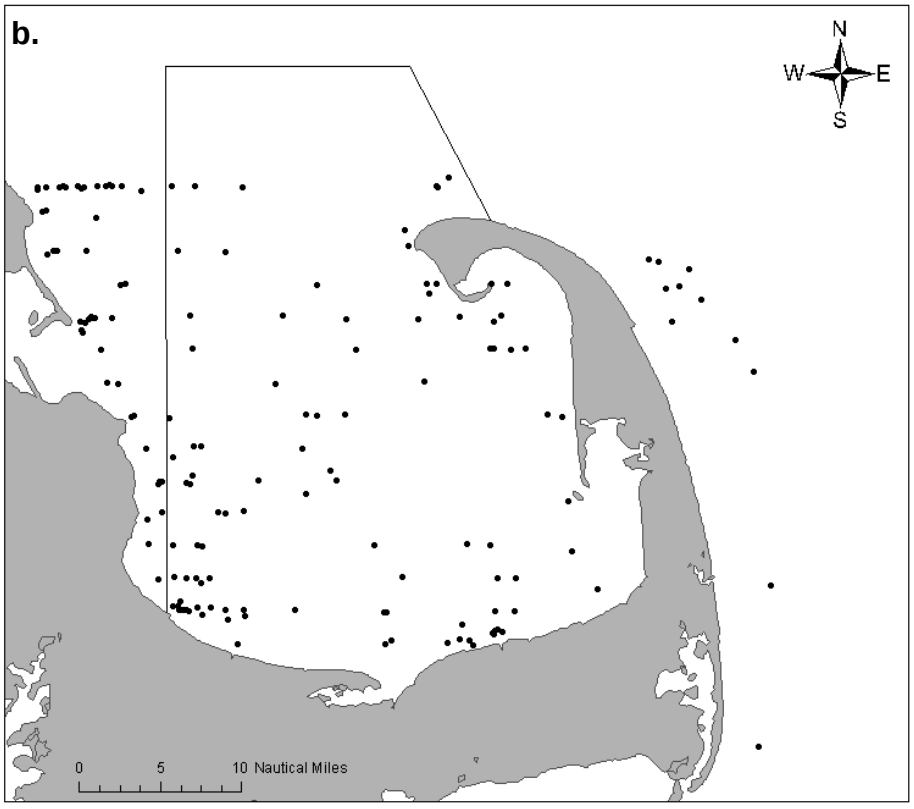


Fig. 20: Distribution of (a) fishing vessels, and (b) all other vessels (including recreational vessel, tug & barge, coastguard vessels, container ship, sailboat, merchant vessel, research vessel), January 12 – May 15, 2008.

1.3.14 Sightings of other species

In addition to right whales, seven other species of cetacean and two pinniped species were sighted during aerial surveys in 2008. Figure 21 shows seasonality in number of sightings of the three most commonly-sighted species, per 100 nm of survey effort. There were unusually high numbers of humpback whales sighted in January, but overall numbers of baleen whales were low in the early part of the year. Sightings rates are significantly higher for fin and humpback whales in April and May, whilst minkes are sighted in relatively lower numbers throughout the winter and spring. These species were observed both inside CCB and in adjacent waters. Figure 22 shows the distribution of baleen whale sightings throughout the aerial survey season. Fin whales were sighted throughout the bay, but particularly in the eastern part of the bay and around Race Point. Humpbacks were especially concentrated around Race Point and around the Provincetown harbor, and were often observed lunge feeding in these areas. Minke whales were most frequently sighted along the ocean side of Cape Cod.

Other species sighted were harbor porpoise and Atlantic white-sided dolphin, which were seen in large numbers during April, especially around Race Point, where they were often associated with large groups of feeding whales (Figure 23). Group size for Atlantic white-sided dolphins and "unidentified dolphins" (most likely also *L. acutus*) ranged between one and 150 individuals. Both harbor and grey seals were observed in large numbers between January and March, particularly at haul-out areas out on Jeremy Point and in the vicinity of Plymouth.

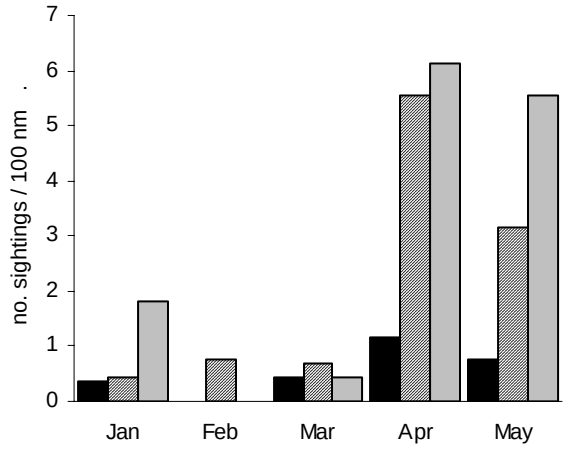


Fig. 21: Number of sightings per 100 nm of minke whales (black bars), fin whales (striped bars) and humpbacks (grey bars), January – May 2008.

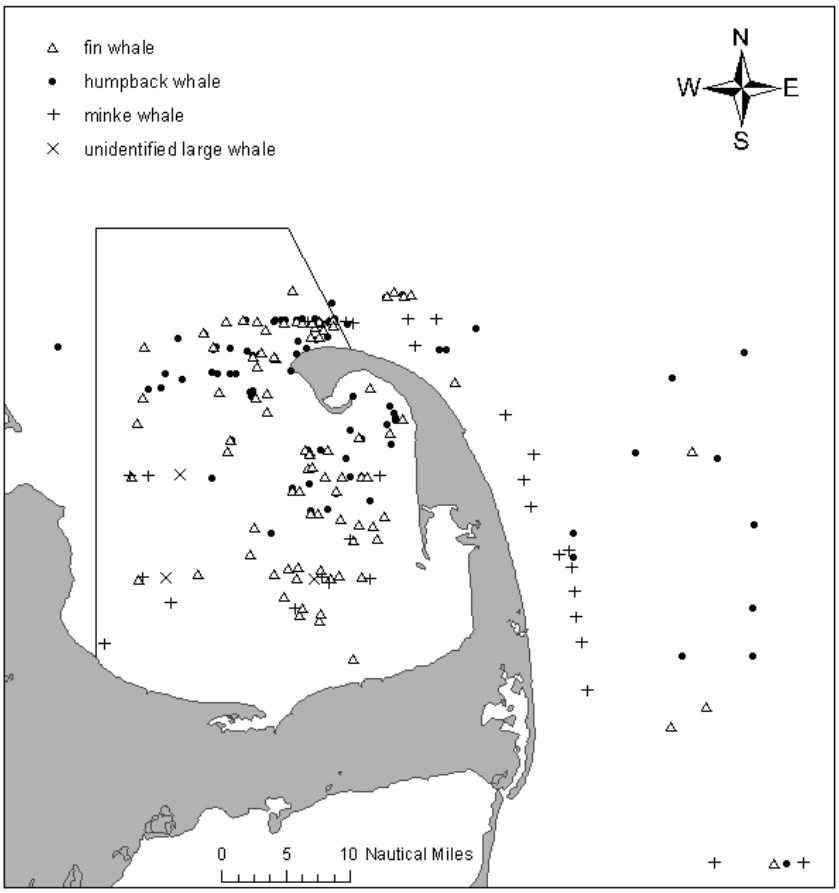


Fig. 22: Distribution of baleen whale sightings during aerial surveys, January 12 – May 15, 2008.

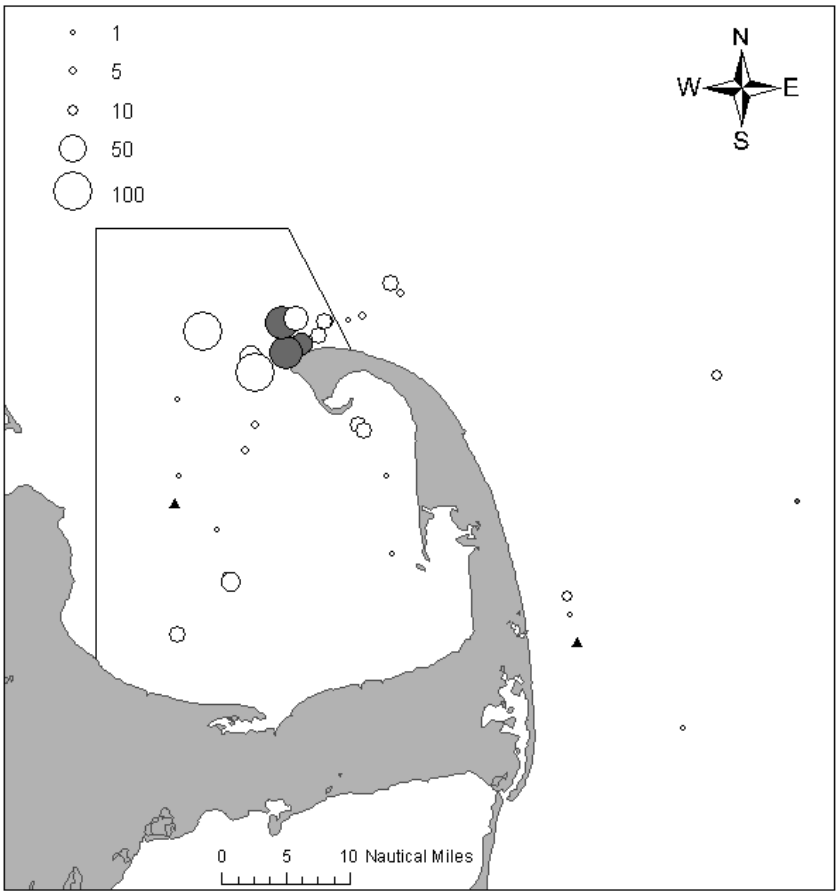


Fig. 23: Distribution of odontocete sightings from aerial surveys, January 12 – May 15, 2008. Unidentified dolphins (white circles), Atlantic white-sided dolphins (grey circles); harbor porpoises (triangles). Symbols are scaled to represent number of individuals sighted in a group (see key, top left).

1.4 Discussion

1.4.1 CCB Right Whale Population: Characteristics, abundance & seasonality

In 2008, as in 2007, right whales were far more abundant in CCB and adjacent waters than in previous years. In 2008, the number of whales sighted per nautical mile of survey effort was at its highest recorded level. 40% of the entire right whale population was sighted in these waters, and this figure will likely increase once the photo-identification work has been completed and a full list of individuals sighted in the bay is available. This is comparable with 2007, the year in which a substantially greater number of right whales were identified in CCB and adjacent waters than in any other year since the beginning of these aerial surveys/habitat cruises in 1998 (161 individuals; Brown and Marx 1998, 1999, 2000, Brown *et al*. 2001b, 2002, 2003, Mayo *et al.*, 2004, Jaquet *et al.*, 2005, 2006, 2007). In 2008, both number of whale-days and number of individuals per unit effort were at their highest level since 2000, and looking at the data from 2002 onwards only, there appears to be a pattern of increase of utilization of CCB. Jaquet *et al*. (2007) note that food resources in the bay are highly variable amongst years, and many other factors likely influence right whale abundance in CCB; however, the pattern observed in recent years may suggest that this region is becoming a more important habitat for the species as a whole.

Jaquet *et al*. (2006, 2007) suggested that the whales sighted in CCB are repeat visitors, more likely to be sighted in CCB than in other areas, whilst conversely, a subset of the right whale population may rarely or never be observed in CCB. Certainly, a comparison of data from 2007 and 2008 revealed that over half of all individuals sighted in the study area last year, were also documented in 2008. This is consistent with findings by Malik *et al*. (1999) who reported that some reproductive females show site fidelity for the Bay of Fundy, whereas other reproducing females are almost never seen there. The females with new calves, sighted in CCB in 2008, were all whales that had previously been sighted in the region, whereas many of the other mothers in 2008 have never been documented in CCB. Thus, mothers who do not visit CCB with their calves may be individuals that rarely use this habitat in any year. Conversely, the mother-calf pairs sighted in CCB usually involve adult females that are never or rarely sighted in the Bay of Fundy, where the majority of each year's new mother-calf pairs are usually sighted, later in the season (M. Marx pers. comm.). In light of these theories, however, it is interesting to note that in 2008, 47 of the right whales sighted in CCB (not including 2008 calves) had never previously been documented in the area since photographic records of right whales in the bay began, in 1958. In 2007 this figure was 27. The recent influx of individuals that are 'new' to the area may suggest a change in site fidelity, perhaps due to more favorable resources in CCB or additional pressures in other right whale habitat areas. This is worthy of further investigation.

On average, right whales are present in CCB for just over 3 months every year. The minimum number of days for which right whales were present in CCB in 2008 (125) is in the upper end of the range of values for 1998-2008. Right whales were sighted in small numbers in January and February, after which time abundance increased to a peak in mid-April, and then sharply decreased again. This is consistent with the general pattern

that has been observed in most years of the study, although there is great variability in the time that whales first enter the bay.

1.4.2 Right whales in adjacent waters

Although right whales are often sighted in waters outside CCB, both to the north of the bay and east of the Cape, it is difficult to characterize patterns of abundance for these areas, as effort varies greatly among years. The results of aerial surveys over the past decade suggest that the waters adjacent to CCB are also important for right whales, but mainly as an area through which they transit. The yearly abundance of right whales in adjacent waters is extremely variable among years, perhaps as a result of the nature of the survey design. A single transect line along the east shore of the Cape, which is regularly flown as part of a standard aerial survey, provides only a small swathe of water in which to detect right whales, and if whales are transiting only slightly further offshore there is a greater probability that they will be missed by the observers. Additionally, it is less probable that individuals spending short amounts of time in a region, whilst transiting through, will be documented by bi-weekly surveys than individuals spending longer periods of time in the same area, as is the case in CCB.

More effort in adjacent waters would allow for interesting comparisons of behavior and demographics between this subset of whales and the individuals utilizing CCB.

1.4.3 Spatial distribution

Only 22 individuals (4%) sighted in the region in 2008, were located outside the CCB designated critical habitat. This is a substantially lower proportion than in recent years; 108 (24%) were observed outside critical habitat in 2007, and 35% in 2006. Right whales distribution throughout the bay is variable from year to year. During the peak of the season, right whales were using all areas within the bay, although distribution was perhaps slightly higher in the southern and western parts. Race Point, Wood End and Long Point continue to be a hotspot for sightings, as in previous years. Given the concentration of right whales and other species of baleen whale in this small area, it would be interesting to carry out a focused study on the fine-scale oceanography and productivity of the region. The abundance of feeding whales, seabirds and even delphinids around race Point in April suggests that the tip of Cape Cod somehow physically aggregates food resources, perhaps by means of eddies or tidal streams (Hernández-León *et al.* 2001).

1.4.4 Demographics

Between 2001 and 2008, a mean of 22% of calves documented in the southeast have been sighted each year in CCB and adjacent waters, thus the proportion in 2008 was below average. The use of CCB as a nursery ground is, however, highly variable among years, and there is at present no discernable pattern in mother-calf use of the region.

The age grouping profile of the proportion of right whales visiting CCB is similar to that of the entire population, suggesting that this area is not specifically favored by any one age group. Whilst the lack of gender data for a significant proportion of the right whale

population prevents a comprehensive analysis of sex ratios; in most years, a greater proportion of known males are present in CCB than known females. This is a reflection of the pattern in the population as a whole, where there are a greater number of known males (51%) than females (38%; NEAq data). Before 2006, relatively high proportions of individuals identified every year in the bay were of known gender. Lower proportions of individuals of known gender in recent years are likely due to higher overall numbers of right whales in CCB compared to the previous four years, a proportion of which are poorly documented, perhaps because they are juvenile animals.

1.4.5 Residency

Right whales were recorded as present in CCB and adjacent waters for considerably longer in 2008 than the recorded time periods between 2005 and 2007. There is substantial turnover of individuals during the season; whilst whales were present in the bay for a total of 125 days, the mean maximum possible residency time was 12.7 days. Many whales spend a period of time in the bay, leave and then re-enter the bay, as documented in previous years. The extent to which this occurred in 2008 is difficult to accurately assess, since many of the surveys in April, when whales were most abundant in the bay, did not cover the entire bay, thus individuals may have been present but were unrecorded. Nonetheless, whales seen in CCB early in the season were often not sighted for several subsequent full-bay surveys, before being re-sighted later in the season. This implies that, even during the peak resource period, not all of the whales classified as the 'CCB whale population' are present in the bay at the same time, nor do they all spend a similar time period in the area. Jaquet *et al.* (2007) suggest this is likely a result of a limit on the number of whales that can be supported by the resource in CCB. The feeding efficiency of a right whale will be reduced in the presence of other whales as the resource is depleted (Hooker *et al*. 2002). As whale abundance increases, it may thus occasionally be more beneficial for whales to feed in areas of poorer resource (Jaquet *et al*. 2007).

Past analyses of individual residency times have revealed differences between CCB and adjacent waters, with individuals having significantly longer residency times in CCB than in adjacent waters (Jaquet *et al*. 2007). In 2008, maximum possible residency time for males was not significantly different from that for females, in contrast to the data from 2007, when the time span between first and last sightings was significantly higher for female right whales than for males. Maximum possible residency times were greater for both genders in 2007 than in 2008 (Jaquet *et al*. 2007). Patterns in residency time are likely caused by zooplankton dynamics, and the shorter overall residency of whales in 2008, compared to 2007, may have been caused by a more short-lived peak in copepod abundance. The large number of whales in the bay in 2008 may also have reduced the time any given individual could effectively feed in the bay, as discussed above.

Mother-calf pairs were sighted on a mean of 4 days, which is higher than the values for male and female right whales, suggesting that mother-calf pairs did not move in and out of the bay as much as the other individuals. Overall, however, females with calves spent less time in the bay than the rest of the whales in this area, being only present during the month of April. These results contrast with those from an analysis of data from 1999-2007 (Jaquet *et al*. 2007), which concluded that mother-calf pairs stay the longest in

CCB, and that there are significant differences in the residency times of single females, males, individuals of unknown sex.

1.4.6 Behavior and cluster size

The mean cluster size recorded in 2008 (1.7 individuals) was somewhat larger than the mean cluster sizes in 2007, but nonetheless is similar to the mean cluster size reported by Hamilton (2002) for all critical habitats between 1980 and 2000 (mean of 1.4 individuals). Likewise, the proportion of clusters of single whales in CCB (73%) is similar to Hamilton's figure (81.7%). These findings suggest that right whales in CCB do not, in general, associate closely with conspecifics, and that this behavior is similar in other areas where right whales are abundant. Mean cluster size was slightly larger in 2008 than in the preceding year, perhaps because whales were more numerous and thus there was more potential for larger clusters to form. Jaquet *et al*. (2007) reported larger clusters in adjacent waters than in CCB; a result which was mirrored, though not significantly, in 2008. The predominance of feeding behaviors in CCB is suggested as an influencing factor in the smaller clusters formed inside the bay, in comparison with adjacent waters.

There is an interesting difference in the seasonal pattern in cluster size, between 2008 and the previous years (1999-2007; Jaquet *et al*. 2007). There is considerable variation in the data from 1999-2007, but the pattern of rising mean cluster size from January through April, with a decrease thereafter, is obvious for the 2008 data. This pattern mirrors the overall abundance of whales in CCB, and it seems reasonable to expect that cluster size would increase as the opportunities for larger clusters become more available; that is, as more whales congregate in the bay.

1.4.7 Vocalization behavior

In this study, tonal calls were by far the dominant type of calls, amounting to 62% of all calls produced. Parks and Tyack (2005) showed that tonal calls were mainly produced by adult females engaging in SAG behavior. Our results confirmed their findings as 89% of the tonal calls were recorded when SAGs were close to the research vessels, and adult females were always identified on these days. SAGs were observed in only 14% of the recordings, but 83% (2,570) of all sounds recorded by right whales were produced during these 15.6 hours. This result suggests that right whales vocalize mainly when engaged in social behavior, and that very few calls are produced in other contexts.

Gunshots were the second most common call type, and 91% of all gunshots were recorded when SAGs were observed. It has been hypothesized that gunshots are produced by mature males, either in SAGs or when displaying (Parks and Clark 2007). Our results are consistent with these authors' results, as males were always observed when gunshots were produced. It had been suggested that gunshots are mainly produced in late summer-early fall as part of the reproduction process (Parks and Clark 2007), but very few studies had been conducted at other time of year and in other areas. Matthews (2001) recorded only two gunshots in CCB in April 1999, but his total recording time was only 3.3 hours. As right whales have been shown to be silent for over 8 hours (this study, P. Tyack, pers.

comm.), and as all studies on right whales vocal behavior have shown high variability in call rates, with calls being clustered and followed by periods of silence, it is clear that no conclusions could be drawn from short recordings. Therefore, our study suggests that gunshots are much more common in CCB than previously thought, and that they are also produced at high rates during the spring.

Up-calls made up only 11% of all vocalizations recorded during this study, and they were recorded whilst whales were engaged in both feeding and SAG behavior. This is consistent with Parks and Tyack (2005) who also found that up-calls were occasionally produced by whales in SAGs, and that they represented only 7% of all vocalizations. Up-calls were frequent when a mother and calf pair was close to the research vessel. Eighty-five hours of recording were made when whales were foraging, and during these 85 hours we recorded 153 up-calls. Sixty-four of these up-calls were recorded over 2.9 hours when a mother and calf pair was close to the vessel. The calf often got separated from his mother by a few hundred of meters and this always resulted in a high number of up-calls heard on the hydrophone. Our study therefore suggests that, in Cape Cod Bay, one may expect a higher rate of up-calls in April early May when calves are present, than in January-March, and that the rate of up-call production may be independent of the total number of whales present in the bay.

A comparison of Parks and Tyack's late summer-early autumn study in the Bay of Fundy (2005) with our data from a spring study in CCB revealed similar proportions of the various call types. This is despite Parks & Tyack's sample involving only whales engaged in SAG behavior, in contrast to the multiple behaviors of the whales recorded in CCB (14% of whales in SAGs, 79% feeding and 7% traveling). The Bay of Fundy study analyzed 3,074 vocalizations (excluding blows), of which 72% were tonal calls, 18% were gunshots, 7% were up-calls, and 1% were down-calls. This study analyzed 3,506 vocalizations (excluding blows), of which 62% were tonal calls, 13% were gunshots, 11% were up-calls, 3% were down-calls and the remaining 11% consisted of unclassified and broadband calls (7% and 4%, respectively). Since 83% of all vocalizations recorded in the CCB study were produced by whales in SAGs, it is not surprising that the proportion of call types was similar between this study and Parks and Tyack's 2005 study, despite the fact that the majority of recording time was spent with foraging or traveling whales.

These results for North Atlantic right whales contrast dramatically with the vocal behavior of Southern right whales where up-calls were the most common type produced (Clark 1983). It seems therefore that, although call types are roughly similar between Southern and North Atlantic right whales, the rate of production of each of these sound types, as well as the context in which they are produced, differ between the hemispheres. This result has very important implications for passive acoustic monitoring, as to date, only up-calls are used in acoustic detection (Clark *et al.* 2007). More information is thus needed on the context of up-call production as well as on the rate. It would also be beneficial to investigate the feasibility of using other call types, in particular tonal calls, for passive acoustic monitoring.

Vocalization rates are linked to overall behavior, and thus are highly variable over time; therefore, it is hardly surprising that vocalization rate did not correlate well with number of right whales in an aggregation, or between total number of whales observed in CCB, on the fine temporal scale documented during this study. On May 6, 2006, at least 12

whales were observed around the research vessel and not a single vocalization was recorded during 8.6 hours. In contrast, a large quantity of vocalizations was recorded on April 14, 2006, while only three whales were in the vicinity of the vessel. These results suggest that, on a fine temporal scale, it is not possible to estimate the number of whales that are aggregating in an area using acoustic monitoring. This issue is, however, addressed further in the next section (1.4.8). The large variance in vocalization rate documented by this study supports the findings of previous studies, that vocalizations are clustered and are separated by periods of silence, when whales are likely engaged in behaviors during which they do not frequently vocalize. In light of management decisions made on the basis of acoustic monitoring data, it is important to quantify the frequency of these silent periods and the behaviors associated with them, to advance the analysis and interpretation of acoustic monitoring data for this species.

Of the 79 hours of observations during this study, 67 hours (84.4%) involved skim feeding or sub-surface feeding right whales. Right whales are very vulnerable to ship strikes when they are engaged in these behaviors, as they are located close enough to the surface to be hit by a ship, but are also completely oblivious to disturbance, and are difficult to detect visually from a vessel. Skim-feeding is also observed in the Great South Channel, but seldom in any other critical habitat. Therefore, this result suggests that right whales may be particularly vulnerable to ship strike in CCB, and even more so during mid-April to early May.

This study showed that North Atlantic right whales' call rates and call types are highly correlated with behavior, reflecting findings by similar studies on blue whales (Oleson *et al*. 2007) and humpback whales (Payne and McVay 1971). Right whale behavior in CCB is likely specific to the region, however, and it is not possible to draw broader conclusions about right whale behavior or vocal activity from these data. Up-calls represented only 11% of the vocalizations produced by right whales in CCB, and thus may not be the most suitable sounds to use for passive acoustic monitoring. It would be useful to investigate whether it is possible to also use tonal calls in automatic detections, or whether their intrinsic variability prohibits their use. Future investigations of right whale vocalization behavior and call rates in all five critical habitats as well as on migration routes should be a priority, if acoustic monitoring is to be utilized as a method for management and conservation. It will also be critical to determine the range at which right whale up-calls can be detected in different habitats, as this has implications for the collection of passive acoustic monitoring data. To date, there is no consensus regarding the distance to which right whale vocalizations can be heard, and for CCB these vary between a few kilometers to a few tens of kilometers (P. Tyack and C. Clark pers. comm.).

1.4.8 Acoustic buoy data

Acoustic and visual techniques provided the same presence/absence data on 64% of days. A degree of disparity between these two data sets can be expected, for several reasons. The aerial survey time window is very small, providing a 'snapshot' view of the bay within a few hours. It is possible that whales may enter the bay after the survey is complete. The acoustic data considered in this study, however, is on a longer time-scale in which data for the whole day have been summed and are considered as one value. This

affords many more opportunities (24 hours) in which a right whale can be detected. This would explain how the aerial data may be detection-negative for a given day, but the acoustic data for that day might be detection-positive. Observers can also miss whales during surveys, if the whales are engaging in long dives, or the sea state or sighting conditions are unfavorable, which could also cause a false-negative result in the aerial survey data. The lack of detections on days when right whales were sighted in the bay is likely due to the behaviorally-dependent nature of vocalization production. Right whales do not vocalize constantly and vocalization type and frequency depends on the behavior in which the whale is engaging, as detailed in Results section 1.3.9. Additionally, on days where not all three acoustic buoys were operational, a vocalizing right whale in CCB may not have been within detection range. The detection radius of the buoys is assumed to be around 5 nm, although it can be 8-15 nm on days with low ambient noise.

This study found that number of calls per day positively correlated with right whale abundance in the bay. This contrasts with the findings of Clark *et al*. (2008), who investigated the fine-scale temporal match between sighting and calls. They found a little correspondence in datasets which, they hypothesized, was because most aerial survey time is concentrated around the middle of the day, when calling activity is lowest. Right whales are most vocally active from sunset to midnight, often with another increase before dawn through early morning. However, our analysis was done on a coarser scale, using two datasets which encompassed very different temporal windows. Vocalization activity was summed over the entire day, whereas for aerial surveys, the temporal window was small. The behaviorally-dependent nature of vocalizations means that at any given time, vocalizations could be detected in large numbers, or not at all. It is thus a better measure of overall vocal activity in the bay, to use a long time scale, such as 24 hours, as a unit of comparison. In contrast, since right whales in CCB are not transiting through the area but tend to stay for a period of at least several days, an aerial survey over a few hours is likely to be representative of the right whale abundance in the bay for the entire day. Intuitively, therefore, the best comparison of acoustic and visual datasets may then be on these apparently differing scales. This holds only as long as right whales do not have a diurnal pattern of movement into or out of the bay.

The sporadic functioning of the CCB acoustic buoys over the 2008 season resulted in a patchy dataset which was not suitable for inter-buoy, spatial comparisons or analyses for the entire season. It is hoped that in 2009, the buoys will be fully operational and the scope of this valuable work will develop.

1.4.9 Entangled right whales

In 2008, there was an unusually high number of sightings of entangled right whales. Only one entangled right whale was sighted in 2007, whereas in 2008, 12 sightings of 4 entangled individuals, and 5 additional sightings of one severely injured, previously-entangled whale, were made by the aerial survey team. The PCCS disentanglement team gathered important information from the aerial survey team's reports and from observing these individuals in the field, and were in two cases able to significantly improve the whales' chances of surviving the entanglement. Both of these whales are calving females and are thus extremely valuable to the population.

Of all documented mortalities since January 2006, an equal proportion (36%) is due to entanglements (confirmed or suspected) as to ship strike, historically the main cause of death for right whales. This may suggest that entanglements are becoming an increasing problem for right whales. Thus, as measures to reduce ship strike incidence, such as the relocation of shipping lanes, come into effect, the management focus may need to be shifted to the prevention of right whale entanglements.

SECTION 2: THE HABITAT OF NORTH ATLANTIC RIGHT WHALES IN CAPE COD BAY: CONDITIONS, ASSESSMENT, AND PREDICTION

2.1 Introduction

Studies conducted during the 2008 winter-spring season by the PCCS Right Whale Habitat Studies Program in Cape Cod Bay were focused on monitoring the distribution and abundance of right whales in the context of their habitat, characterized by the quality and quantity of their zooplanktonic food resources available in the bay. Past annual reports have illustrated the strength of the relationship between right whale and zooplankton distribution; we continued to document this interaction, while exploring new patterns and processes that contribute to the movement of right whales and their prey.

Ten years of partnered study and management by PCCS and DMF have demonstrated the application of habitat studies to conservation. In accordance with the goals set forth in Objective IV by PCCS/DMF (see General Introduction), surveillance and monitoring activities were aimed to provide management agencies with information to assist in their time-critical decision making (e.g., amendments to seasonal gear restrictions or the issuance of vessel speed restrictions), intended to mitigate human impacts on right whales in the waters of Cape Cod Bay. As in 2007, immediate post-cruise "Preliminary Assessments" and the more lengthy "Habitat Assessments" were distributed electronically to interested managers and colleagues during the 2008 season of right whale residency in Cape Cod Bay; these documents provided descriptions, analyses and forecasts concerning the interaction of right whales, habitat conditions and potential risks. During the 2008 season, the reports were stream-lined to include only essential information for management decisions, and briefer summaries of habitat conditions; however, detailed Special Reports were also introduced as a tool for exploring ecological phenomena of particular interest. To address the need to alert DMF to conditions in Cape Cod Bay deserving immediate management attention, PCCS continued to disseminate critical observations and predictions through a rapid reporting system, a "Right Whale Risk Alert" document, which in 2008 was combined with the "Preliminary Assessments" when necessary.

In addition to the bay-wide study of right whales and zooplankton, the 2008 habitat studies were also aimed at homing in on the intricacies of and scale at which these right whale-zooplankton interactions are strongest. With a greater understanding of these dynamics we hope to improve our ability to predict the behavior and movement of the whales, thereby better informing DMF's management efforts. The conditions particular to the 2008 field season strongly demonstrate the importance of attention to scale and bay-wide coverage of our observation; for example, the inclusion of a single sampling station during a research cruise on March seventh suggested an unusual trend that otherwise would not have been revealed by our work.

In this section of the 2008 annual report, we review and summarize the foundational relationship between right whales and their prey, the dynamics of the prey fields, and the strategies and movement of whales that, when documented, permit the predictive parts of the assessment analysis and risk alerts. The principal spatial and temporal dynamics that were observed in Cape Cod Bay habitat in 2008 are presented, integrating detailed analyses of the zooplankton resource

with right whale distributional information. We also explore the more intricate patterns of zooplankton distribution that were observed during the season: patterns that reveal pertinent details about the relationship between right whales and the dynamics of Cape Cod Bay food resources. Finally, the scale-dependent nature of the surveillance program is discussed in light of extreme trends seen in the 2008 season's zooplankton data.

2.2. Application of Habitat Studies to the Management Process

The on-going efforts of the PCCS Right Whale Habitat Studies program to understand the physical and biological processes governing the distribution of zooplankton and right whales in Cape Cod Bay is integral to the management of human activities that may threaten North Atlantic right whale population recovery. As detailed in previous reports, zooplankton may be seen to "control" the distribution and occurrence of the whales within the federally designated Right Whale Critical Habitat. Therefore, the characteristics of the zooplankton resource may be used to monitor and predict the movement, aggregation, and behavior of the whales, thereby informing management.

In order to assess the habitat conditions controlling the occurrence of right whales in Cape Cod Bay, the Right Whale Habitat Studies program surveys the zooplankton resource in the bay, along with a variety of physical parameters, and produces a forecast of movement and occurrence patterns of the whales based on the distribution of their food. As described in further detail in the 2007 Right Whale Habitat Studies Program Report, the aggregative property of zooplankton combined with the foraging patterns of right whales leads the whales to gather in areas of rich food patches, optimizing their energy intake. The nature of the whales' feeding behavior while aggregated around these zooplankton patches puts the whales at higher risk of injury from industrial activities, particularly shipping and fishing, when the whales and human activities overlap. By understanding both the broad characteristics and the nuances of the relationship between the zooplankton patches and the whales' foraging strategies, it is possible to predict the distribution patterns of the whales in Cape Cod Bay. The more refined the scale and understanding of these distribution patterns, the more accurately human activities can be managed to avoid the co-occurrence of anthropogenic risks and whales.

Our assessment reporting system is aimed at forecasting locations where whales may occur as a reflection of zooplankton patch formation and movement. Zooplankton samples collected systematically on weekly habitat cruises are analyzed in the laboratory and used to characterize the zooplankton resource throughout Cape Cod Bay. This data provides providing information such as zooplankton abundance, spatial distribution, and species composition, on which short- to medium-term movement and aggregation of whales may be forecast. During each cruise, fishing gear and vessel locations are also recorded, as they represent the two of major anthropogenic threats to right whales: ship strike and entanglement. *Immediately* following each cruise, a "Preliminary Assessment" and, when necessary, a "Right Whale Risk Alert" are issued and sent to managers, alerting them of potentially high-risk conditions for right whales in the bay.

Upon analyzing the collected samples, we author and electronically distribute a more detailed "Cape Cod Bay Habitat Assessment" document to inform the DMF and interested agencies of the intricacies of the zooplankton resource present in the bay, where right whales may aggregate

in the near future, and where human activities that place whales at risk are likely to overlap the forecasted distribution of whales. For several years these assessment instruments have been developed and refined, contributing significantly to the management of the Cape Cod Bay Critical Habitat. Nineteen such "Preliminary Assessment" reports and several "Risk Alerts" were distributed in 2008 (compiled in Appendix II), identifying the distribution and quality of the zooplankton resource that influenced the aggregation of right whales in locations where vessel strike risk was particularly high. Examples of Preliminary Assessments and combined Risk Alerts, as well as the subsequent DMF formal management Advisories and notification to government agencies and the shipping community, are given in Appendix III, boxes 1 through 8. These documents taken together demonstrate the evolving interaction between the PCCS surveillance program and state agencies leading to management action triggered by the habitat assessment studies.

Special Reports are a recent addition of the habitat studies reporting scheme. They create the opportunity for the Habitat Studies program to share findings with significant management implications; the reports contain more detail and are more technical than the preliminary and habitat assessments. In 2008, two Special Reports were issued to highlight and discuss vertical migration and taxon-specific behavior in zooplankton, as well as the effects that such vertical distribution has on the movement and exposure to risk of right whales (Appendix IVa and IVb).

The sentinel role played by habitat assessment and reporting, in conjunction with aircraft survey observations, underpins the capacity of DMF to respond with management action to forecasted changes in whale distribution and occurrence. As the exchanges between DMF and PCCS demonstrate, it has proven possible to translate field observations into predictions and then alerts over appropriately short time scales. Such alerts are reviewed by DMF and, if deemed necessary, converted into advisories that apply to various user groups that may interact with right whales in the field. The forecasting of right whale presence and subsequent management action and advisories are unique in the management of threats to whales. The tight connection between field observation, science, and the management process described represents a model scenario for the management of one of the most endangered marine mammals in the world, and sets a precedent for management based soundly in ecosystem science.

2.3. Methods: Data Collection and General Protocols

Observations reported here are based upon collections and field notes made during Cape Cod Bay habitat surveys and directed sampling on board the R/V *Shearwater* in 2008. R/V *Shearwater* is a 40ft (12m) twin diesel engine research vessel equipped with plankton nets, a vertical plankton pump, and a CTD (Conductivity-Temperature-Depth profiler) to satisfy the need for a variety of oceanographic and marine biological observations.

The zooplankton samples that form the core of the assessment and risk-alert system were collected at eight fixed ("regular") stations in Cape Cod Bay; the techniques used to sample the surface water have been relatively unchanged since right whale habitat observations started in 1984; the uniformity of the techniques over decades permits the comparison of contemporary zooplankton data with a long time-series data, lending context to the forecasting process. The stations, many of which have been sampled by PCCS annually for more than two decades, are located throughout the Bay (Figure 1); they provide spatial coverage of the entire system, allowing characterization of zooplankton distribution and dynamics during the season of right whale residency in the Bay. Weather-permitting, from 1 January 2008 to mid-May, these stations were visited regularly to collect zooplankton from the surface waters and in the upper 19 meters of the water column. Samples were collected using standard 333-micrometer (μm) mesh conical nets fitted with General Oceanics helical flow meters. At each station, surface sampling involved towing a 30cm-diameter net in a circle horizontally for 5 minutes; towing along a circular path permitted net sampling on the margin of the vessel's wake in relatively undisturbed water.

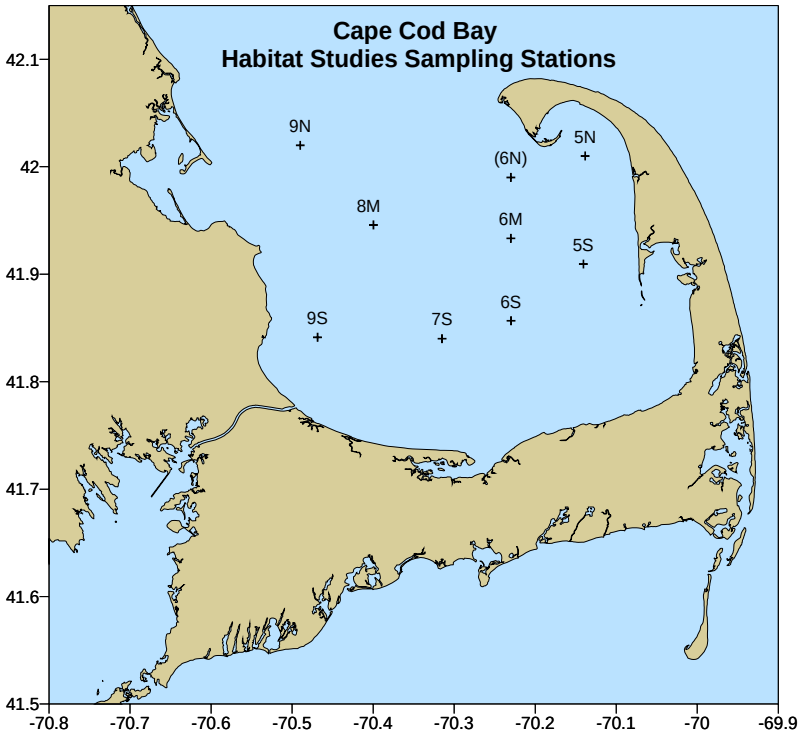


Figure 1. Map of "regular" sampling stations in Cape Cod Bay that were visited approximately weekly between 12 January and 5 May 2008.
****Note: station 6N was used as a regular station in 2008, but was not included in previous years.**

Water column collections were made by vertically dropping a 60 cm-diameter net on-station and retrieving it obliquely through the upper 19 meters of the water column. Because the same surface sampling techniques have been employed every winter since 1984, the collected samples provide an invaluable comparative measure of the conditions that have supported the feeding activities of right whales in Cape Cod Bay over the last two decades.

All field samples were kept in seawater and preserved with 6-8% formalin on board the vessel. In the laboratory, the zooplankton samples were again preserved in fresh 6-8% formalin and settled overnight in graduated cylinders in order to estimate the "settled volume" as part of the evaluation of the quality of the habitat. Zooplankton were identified and counted within 12-24 hours of collection and the results of the counts were expressed in organisms per cubic meter (organisms/m^3). Estimates of relative caloric value were made from the enumerated zooplankton density and individual genera identification.

In addition to the regular station sampling regime, directed or "special" samples were collected near feeding right whales in order to characterize the abundance, species composition, and spatial extent of the zooplankton resource on which the animals were feeding. Fifty-two special station samples were collected during the 2008 field season. Analysis and interpretation of the samples was then used to characterize the durability of the resource, as well as to forecast the likelihood of continued whale aggregation and residency in those specific areas. The special station analyses were important to the formulation of the assessments and alerts on which appropriate management responses (e.g., delineating zones where vessel speeds should be limited) were made by DMF.

During the 2008 season of right whale residency, the behavior of the whales and distribution of the zooplankton was such that vertical pump sampling was at times more appropriate for describing the availability of the controlling zooplankton resource than surface and water column plankton net tows. The 3-dimensional structure of zooplankton patches upon which whales fed was investigated on several occasions, with collections from pump profiles, both vertical and horizontal, yielding 299 zooplankton samples in addition to the traditional net collections. In particular, a set of horizontal sampling transects through an area of active feeding by approximately twenty whales just outside Provincetown Harbor on 11 April were used to determine the structure of the zooplankton patches influencing movement of the whales. Further, vertical pump samples were used on 14 and 27 March to investigate preferential feeding of right whales on different copepod taxa at different depths. For vertical pump collections, zooplankton samples were obtained at targeted depths using a pump sampler deployed on a CTD frame, while horizontal samples were collected from the near-surface as the vessel steamed along a horizontal transect. All samples were concentrated by filtering through a 333μm mesh and the volume of the water sampled by the pump system was recorded.

Although the intensive collection of food resource data from Cape Cod Bay did not permit the application of traditional survey methods for systematically sighting whales, all observations of right whales during the cruises were both recorded and, as possible, photographed by observers aboard *Shearwater*. These vessel-based opportunistic whale observations served as supplements to the aerial survey's data; because R/V *Shearwater* surveys were non-systematic, such opportunistically collected data were not included as part of analyses that yield right whale density estimates used in both sections of this report. The photographic information collected from *Shearwater* was processed in much the same fashion as that collected from the aerial surveillance effort.

Using a computer data logging system developed by PCCS, information on all species of marine mammals and on a variety of human activities in Cape Cod Bay was collected on cruises during

the 2008 winter-spring season. In particular, because of the interest of DMF in fixed fishing gear, special note was made of the types and locations of fixed fishing gear which might pose a risk to right whales. After every cruise, DMF was informed via a post-cruise report of the activities of the day and of fixed fishing gear records from that day's cruise. Observations of immediately threatening conditions were relayed to DMF via cell phone and in post-cruise Risk Alert reports. In support of the general goal of documenting any conditions that may deserve management action, PCCS maintained a database including extensive observations on fixed fishing gear and vessel locations throughout the 2008 surveillance season.

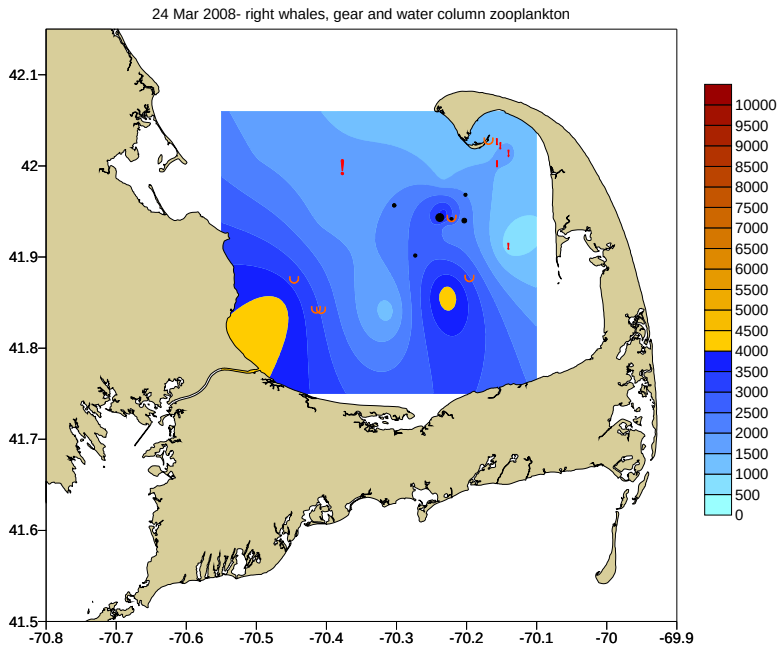


Figure 2. Above is an example of the types of data we collect, presented as a map. Vessels (∪), gear (!), and right whales (●) are represented, as is water column zooplankton concentration.

Post-cruise sample analysis, data processing, and reporting were conducted as rapidly as possible with the goal of delivering to DMF time-critical information that could assist in the management of the Critical Habitat. During each cruise and in the laboratory analyses particular attention was paid to food resource distribution and right whale aggregation when conditions were predicted to place whales at a significant risk of ship strike and entanglement.

2.4. Results and Discussion

2.4.1. Habitat Cruises and Reporting, 2008

R/V *Shearwater* completed 19 habitat sampling cruises, respectively, in the Cape Cod Bay Right Whale Critical Habitat and adjacent waters between 12 January and 5 May 2008. On each *Shearwater* cruise the data logging computer was used to record information on sample collections, right whale observations, information on other marine mammals, and a wide variety of physical, biological and human activity information that underpin PCCS habitat studies. During the 2008 cruises a total of 521 zooplankton samples were collected and analyzed (Table 1). CTD profiles were recorded on-station during # cruises that were paired with the PCCS Cape Cod Bay Monitoring Program, as well as coincident with some vertical pump sample stations. The profiles taken by the Monitoring Program have been archived in the program's database.

During the 2008 season, 72 right whale sightings were photographed opportunistically during habitat sampling cruises for inclusion in the analysis of individual whales. A total of 47 unique individual right whales were represented in the collected photographs.

Maps detailing the spatial dynamics of zooplankton distributions throughout the sampling season are compiled in Appendix I, Figures A1 through A12. To review the actual assessment reports circulated after each cruise, the reader is referred to Appendix II where all Habitat Assessment, Preliminary Assessment and Risk Alert documents are reproduced.

Table 1. 2008 Cape Cod Bay Habitat Cruises and Collected Zooplankton Samples.

		ZOOPLANKTON SAMPLES					
Cruise	**Date**	**On-Station Surface Tows**	**Off-Station Surface Tows**	**On-Station Oblique Tows**	**Off-Station Oblique Tows**	**Pump Samples***	**Total**
SW679	12 Jan	4	.	4	.	.	**8**
SW681	17 Jan	8	.	8	.	.	**16**
SW682	24 Jan	8	.	8	.	.	**16**
SW683	4 Feb	8	1	8	1	.	**18**
SW684	22 Feb	6	.	6	.	.	**12**
SW687	7 Mar	7	3	7	3	.	**20**
SW688	11 Mar	1	.	1	.	.	**2**
SW689	14 Mar	1	3	1	2	66	**73**
SW690	24 Mar	8	2	8	2	.	**20**
SW691	27 Mar	.	3	.	3	55	**61**
SW692	9 Apr	2	2	2	.	20	**26**
SW693	10 Apr	3	3	3	.	12	**21**
SW694	11 Apr	.	2	.	1	105	**108**
SW696	15 Apr	7	3	7	3	31	**51**
SW697	21 Apr	1	4	1	2	.	**8**
SW698	23 Apr	6	3	6	1	.	**16**
SW699	25 Apr	8	1	8	2	10	**29**
SW700	3 May	7	1	7	1	.	**16**
SW701	5 May	8	.	8	.	.	
	Totals	**93**	**31**	**93**	**21**	**299**	**521**

2.4.2. Zooplankton Analysis and Research

The conceptual basis for the relationship between habitat assessment and management of right whales is thoroughly detailed in the 2006 report (see Sections 2.4.1 – 2.4.3 of the 2006 report) and summarized briefly in the Introduction to this Section. A simplified version of the concept follows.

In this section of the report we present basic information on the character of the zooplankton resource which was made available to DMF and to the wider list of coordinating agencies and individuals through preliminary and final assessment documents sent via email after analysis of the food resource collected during each cruise. Here we also evaluate the season as a whole in light of the resource-based paradigm used to predict the occurrence of right whales in Cape Cod Bay. As a foundation for this discussion, we summarize the resource conditions that influenced right whale distribution and activity during the 2008 season.

2.4.2.1. General Pattern of Zooplankton Productivity

Understanding the patterns of right whale residency and distribution in Cape Cod Bay requires knowledge of zooplankton composition, density, and the seasonal cycles driving these factors. The gross average zooplankton density at regular sampling stations (Figure 3) shows some anomalous features compared with previous years. While water column densities are on average historically higher than surface densities at the beginning of the season, followed by surface water enrichment around mid-April, the 2008 surface zooplankton curve in Figure 3 shows an early-season peak between the 60^{th} and 70^{th} Julian days, or early March. Not only is the timing of this surface water enrichment unique, but the intensity is strikingly different from any measured before; a maximum value of approximately 8839 organisms/m^3 was reached, compared to previous anomalous maxima such as 6000 and 6500 organisms/m^3 in 2004 and 2003 respectively. The unusual early-season peak in March is punctuated by a significant decline that is then followed by the typical surface water enrichment curve beginning around the 120^{th} Julian day. This late-season enrichment in surface zooplankton density occurs later in the season than in most other years; the increase usually occurs in mid-April, closer to the 100^{th} Julian day, whereas the 2008 late-season surface enrichment begins in early May, just after a dramatic drop in concentration. The water column zooplankton density drops at the same time, around the beginning of May, before enriching again.

We have observed similarly anomalous patterns in zooplankton densities during two other years; the surface zooplankton in 2003 and 2004 show peaks that are unique compared with other years, but neither is as early nor as large as the early-season peak observed in the 2008 surface zooplankton of early March. Also noteworthy is the fact that the surface zooplankton peaks observed in 2003 and 2004 coincide with peaks in water column zooplankton; the dramatic early-season maximum in 2008 surface zooplankton does not coincide with a significant peak in water column zooplankton. With the exception of these specific anomalies, the usual trend of lower surface water abundance compared with water column abundance continues in the 2008 observations.

An important management consequence of the seasonal pattern of zooplankton density and the anomalies found during the 2008 season should be noted. Because the feeding activity of whales in Cape Cod Bay appears strictly controlled by the density of zooplankton in the Bay, it stands to reason that early arriving whales, those entering the Bay between January and mid-March, *generally* encounter higher concentrations of zooplankton in the water column, while whales entering the Bay later in the season *generally* encounter higher concentrations closer to the surface. Previous studies supported by DMF have demonstrated that zooplankton in the water column form high density bottom layers that probably elicit active bottom feeding by whales. Vertical profile samples taken and analyzed during the 2008 field season demonstrate such bottom layers (Appendix IVa and IVb). Observations of such early to mid winter bottom layers suggest that in Cape Cod Bay entanglement in ground lines, including sinking ground lines, would be more threatening in the first three months of the winter than later in the season. It is likely, though not certain, that floating ground lines would represent an even greater threat.

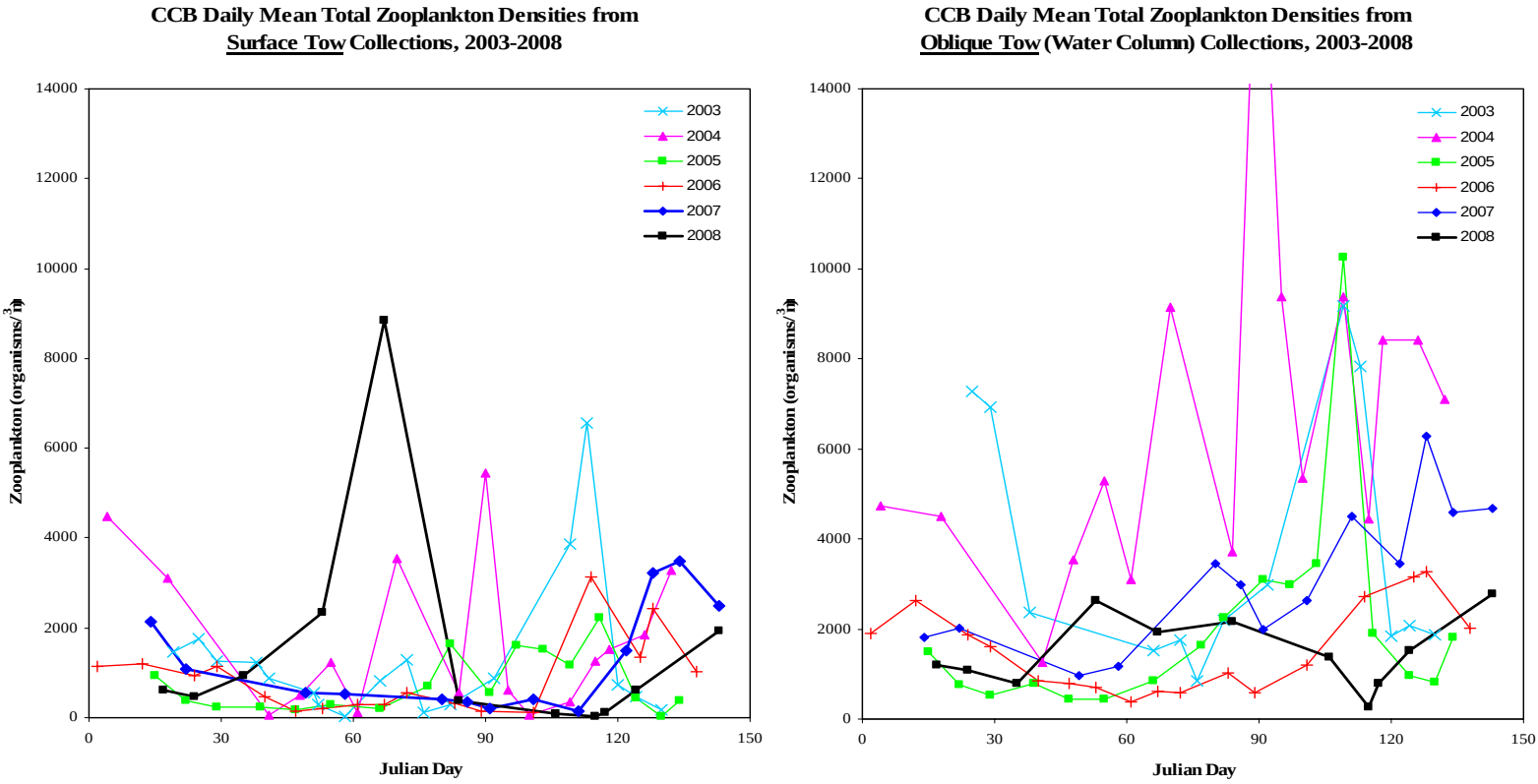


Figure 3. Temporal progression of the daily mean total zooplankton density in Cape Cod Bay surface waters (left graph) and in the water column (right graph), January to mid-May for each year 2003-2008.

2.4.2.2. General Pattern of Zooplankton Species Composition and Cycles

Elevated zooplankton concentrations regularly appear both in the surface and mid-water environments during the very early winter of many years, though to a lesser degree in 2008 (Figure 3). These early winter resources are likely a reflection of the tail end of an annual productivity cycle of late summer and fall species of copepods.

As previously reported, three genera of copepods appear to have the greatest influence on occurrence and behavior of whales in Cape Cod Bay: *Centropages* spp., *Pseudocalanus* spp. and *Calanus finmarchicus*. This assertion is again supported by the 2008 observations; the dominance of water column density of these three taxa over other copepods and forms of zooplankton is illustrated in appendix figures A13-A28. Figure 4 illustrates the mean surface densities recorded from individual cruises for the three controlling copepod genera during the last ten years. Samples from regular stations only are shown. The cycling of these genera in past years broadly follows similar patterns. *Centropages* plays the role of the fall and early winter dominant taxon, and is responsible for the early winter zooplankton productivity noted in Figure 3, while *Pseudocalanus* is relatively ubiquitous with no strict peak. The *Pseudocalanus* resource however fills in between the early winter *Centropages* and the peaking of the early spring *Calanus*. While all three genera appear to release feeding behavior in right whales, it is clear that the three copepod taxa exhibit seasonal abundance patterns that together spread out the occurrence of right whales over the entire winter and controls their pattern of distribution within the Bay. The patterns of surface genera are unique in 2008 in that the density of P*seudocalanus* spp. is at least as high as *Centropages* at the beginning of the season and remains high late into the spring.

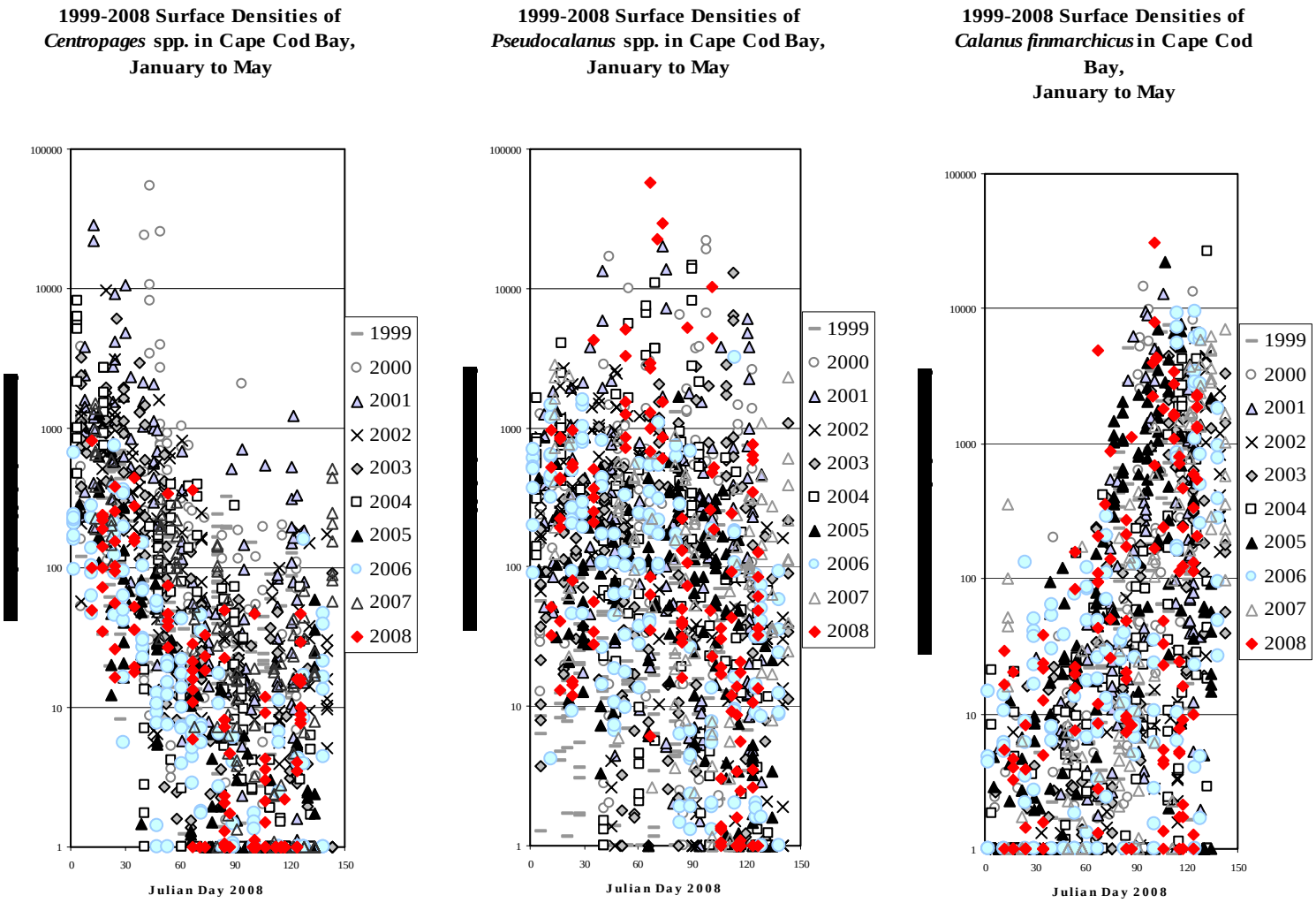


Figure 4. Scatter plots showing temporal changes in surface densities of the three principal copepod taxa at Cape Cod Bay sampling stations in 2008: *Centropages* spp. (left plot), *Pseudocalanus* spp. (center plot) and *Calanus finmarchicus* (right plot). Note that all axes have identical scales.

Density information for the three genera found in the water column is presented in Figure 5 and shows similar patterns to those found in the surface observations. Differences between the two sets of panels in Figures 2 and 3 demonstrate that historically, water column concentration tends to be more consistent, with a higher minimum than that for surface concentration, but also with a lower maximum; these details are hidden by the averaging of concentrations shown in Figure 5. This consistency found in the water column concentrations, and not in the surface concentrations, is explained by the aggregative nature of zooplankton. Physical forces such as upwelling, tidal currents and fronts, and active behavior of individual zooplankton can cause them to dramatically aggregate in surface waters, and then dissipate back into the water column; rich patch formation and dissipation accounts of the dramatic range of surface concentrations (Figure 4) compared with water column concentrations (Figure 5).

The red diamonds in figures 4 and 5, representing zooplankton concentrations, again demonstrate that 2008 was an unusual year. First, the water column *Pseudocalanus* spp. peak visible in early March in Figure 5, probably coincides with the unusual peak in the surface waters, another feature obscured in the graphs of averages (Figure 3). Another interesting feature of the water column densities is that for *Calanus finmarchicus*, 2008 concentrations show more low points, indicating particularly low concentrations, than are seen in other years. This could mean a) that there was lower over-all zooplankton biomass in the Bay this year, or that b) there were stronger aggregative factors that concentrated the zooplankton in certain areas, leaving other areas void of the resource.

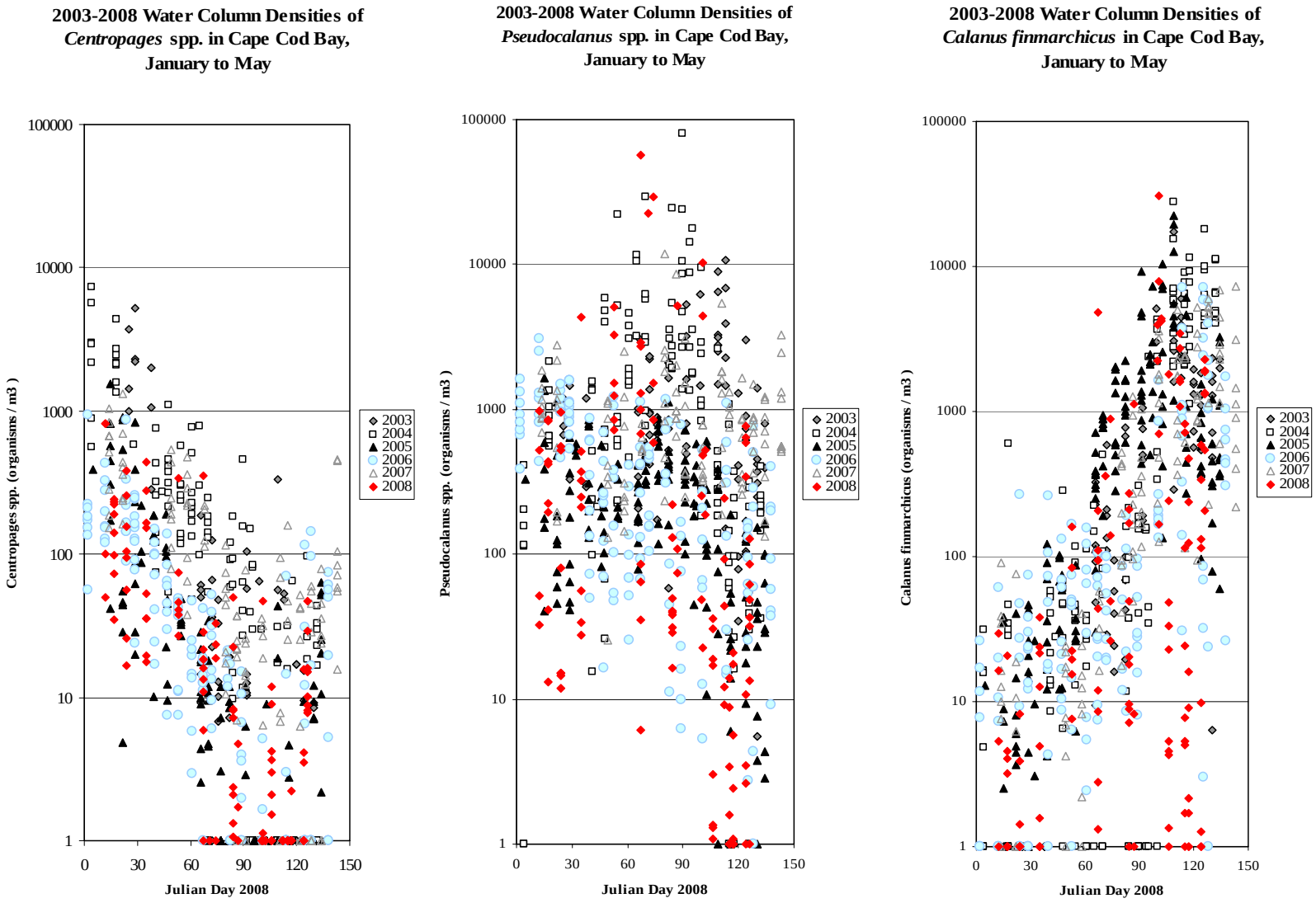


Figure 5. Scatter plots showing temporal changes in water column densities of the three principal copepod taxa at Cape Cod Bay sampling stations: *Centropages* spp. (left plot), *Pseudocalanus* spp. (center plot) and *Calanus finmarchicus* (right plot). Note that all axes have identical scales.

Figure 6 summarizes and compares the patterns of enrichment for the three principal copepod genera. The trend lines compare the 1999 through 2007 data with those for 2008, suggesting very broadly that similar patterns are found each year of the study. Differences between trends in surface water zooplankton for each geneus are illustrated. *Centropages* spp. abundance was much lower in 2008 compared with the general trend over the previous eight years, though the pattern of late-winter enrichment left over from the previous season, followed by decline into the winter and fall, remains consistent. The *Pseudocalanus* spp. trend is dramatic compared with past years, as has already been discussed. Finally, the surface *Calanus finmarchicus* characteristic shows similarity in magnitude to the past years, but not in the pattern of enrichment-decline. In past years, the trend had been that of steady enrichment through the spring, with the beginning of a plateau near mid-May. In 2008, however, surface *Calanus finmarchicus* peaked in April and then steeply dropped. This mortality event was observed in samples collected during cruise SW696, on 16 April. Late stage *Calanus finmarchicus* individuals were observed as clear shells that resembled molts, but which contained congealed oil sacs (Figure 7), indicating that they were dead organisms, rather than molts. It remains unclear as to what may have caused the event, and what the implications of the congealed oil sacs might be.

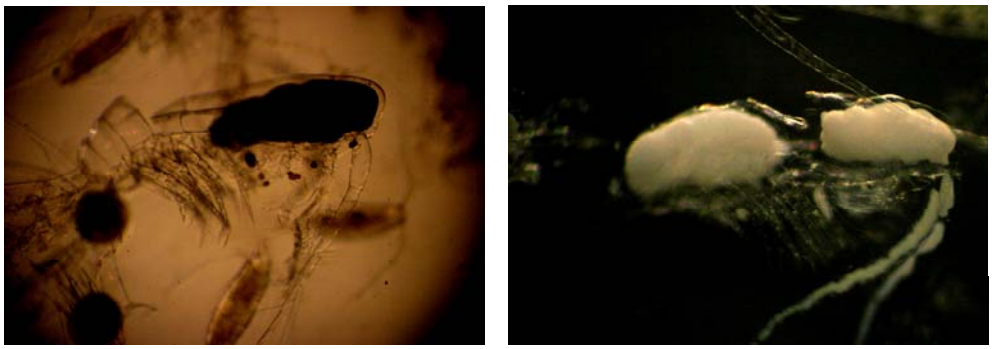


Figure 7. Images of dead late stage *Calanus finmarchicus* collected on cruise SW696 on 16 April. Note the congealed oil sacs, appearing dark in the left image (back lit) and light in the right image (front lit)

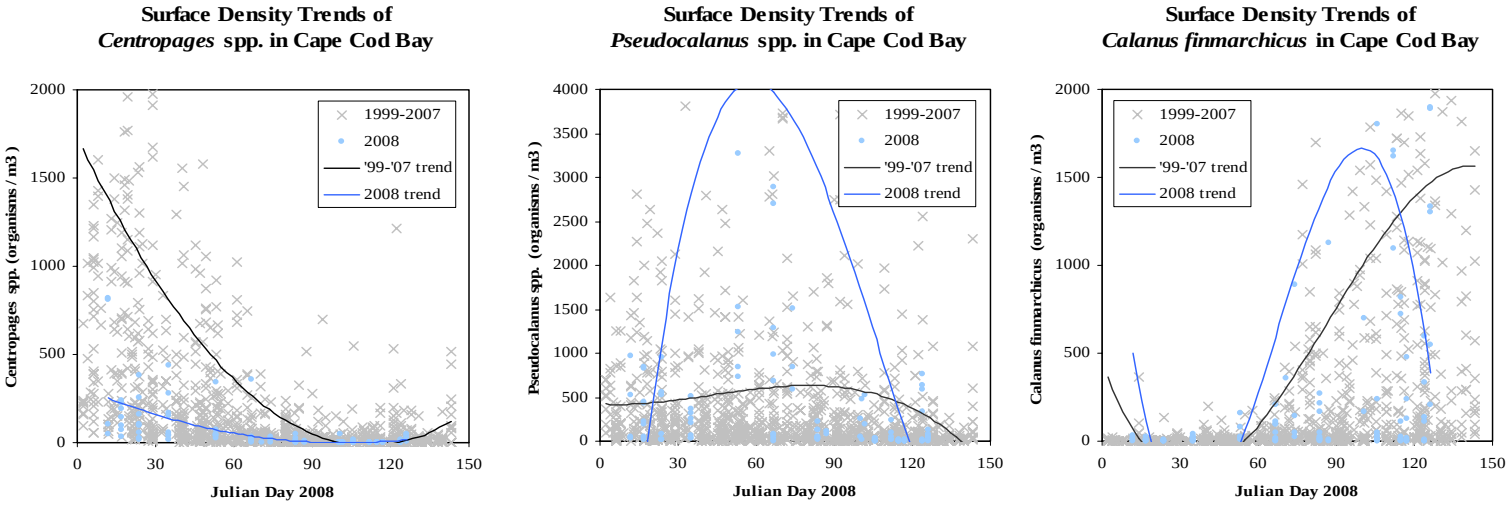


Figure 6. Comparison of 2008 trend against 1999-2007 trend in the temporal progression of Cape Cod Bay surface densities of the three principal copepod taxa. All values of surface abundance for 1999-2007 are combined to illustrate the "typical" progression for the given taxa. Trend lines represent a 3rd-order polynomial regression treatment of the Cape Cod Bay surface density values for 2008 and for the period 1999-2007. Note two-fold scale increase for *Pseudocalanus* spp. chart.

Figure 5 represents 2008's water column trends for the three primary genera compared with the average trend over 2003 through 2007. The *Centropages* spp. trend line shows a similar pattern to that seen in the surface observations; the 2008 pattern of enrichment mirrors that of past years, but shows generally lower concentrations. Again, as with the surface concentrations, *Pseudocalanus* spp. in the water column show a dramatic spike in organism concentration between approximately the 20th and 120th Julian days. However, the trend line shows that in the past five years, a smaller spike occurs a little later than that in 2008, indicating a maximum for *Pseudocalanus* spp. in April. Finally, 2008 water column concentrations of *Calanus finmarchicus* show trends similar to both water column and surface *Centropages* spp. concentrations: the same enrichment trend as past years (enrichment in March April and decline in May), though in lower concentrations.

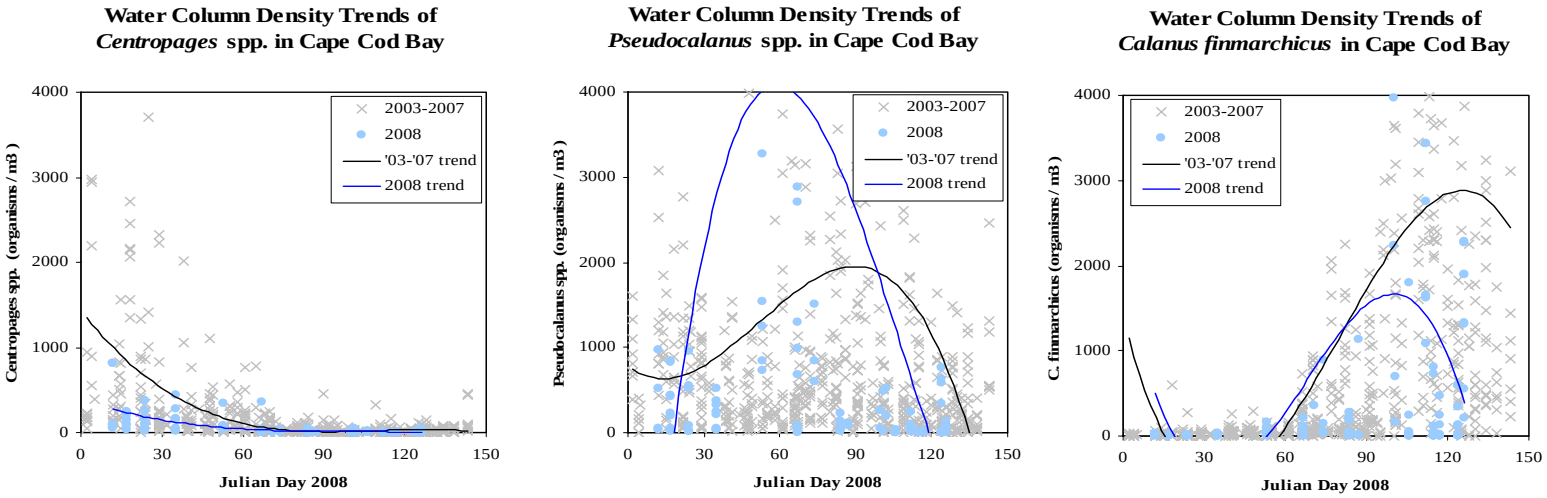


Figure 8. Comparison of 2008 trend against 2003-2007 trends in the temporal progression of Cape Cod Bay water column densities of the three principal copepod taxa. All individual measurements of water column abundance for 2003-2007 are combined to illustrate the "typical" progression for the given taxa. Trend lines represent a 3rd-order polynomial regression treatment of water column density values from Cape Cod Bay samples for 2008 and for the period 2003-2007.

The dependency of right whales upon the overlapping cycles of three genera of Gulf of Maine copepods suggests that a poor cohort of any one of the three could substantially reduce the value of Cape Cod Bay to foraging right whales. Because the highest concentrations of whales are found at the end of the *Pseudocalanus* peak and throughout the period of *Calanus* enrichment, our data suggest that right whales would be particularly sensitive to changes in the productivity of those two genera. In 2008, the most unusual feature of zooplankton concentration in the Bay was the extreme *Pseudocalanus* spp. peak that occurs in early March. Also unique to the 2008 season was an unprecedented number of right whales in the Bay. This *Pseudocalanus* peak, therefore, appears to be a part of the explanation for the large influx of whales.

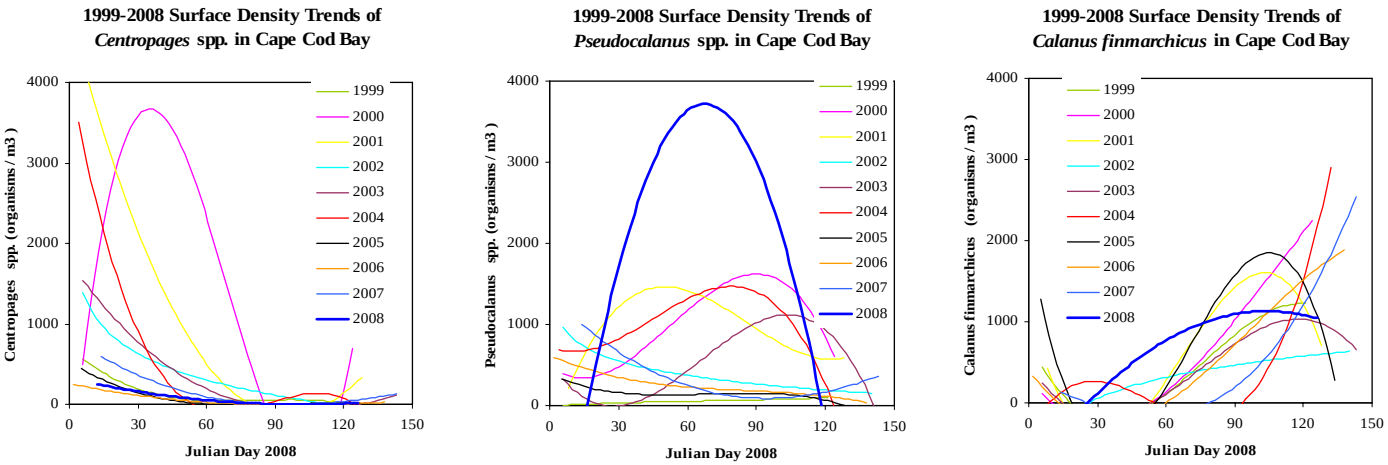


Figure 9. Comparison of 2008 trend against 1999-2007 annual trends in the temporal progression of surface densities of the three principal copepod taxa in Cape Cod Bay. Individual yearly trends are presented for the period 1999-2007 to show historical inter-annual variations in the temporal trends. Each trend lines represents a 3rd-order polynomial regression treatment of all surface density measurements from Cape Cod Bay station sampling for the specified year.

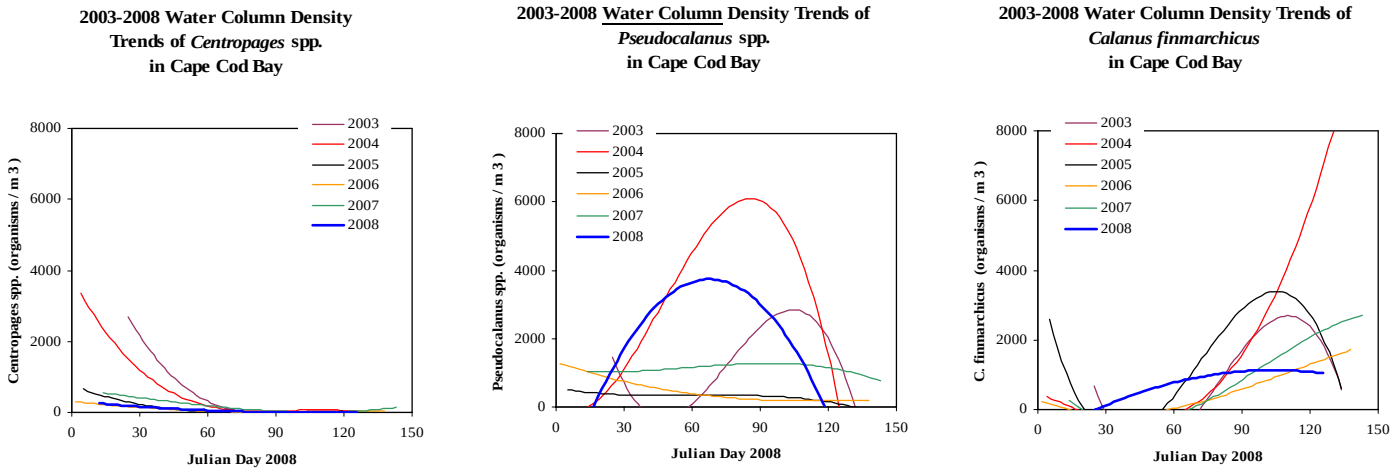


Figure 10. Comparison of 2008 trend against 2003-2007 annual trends in the temporal progression of Cape Cod Bay water column densities of the three principal copepod taxa. Individual yearly trends are shown for the period 2003-2007 to show historical inter-annual variations in the temporal trends. All trend lines represent a 3rd-order polynomial regression treatment of of all water column density measurements from Cape Cod Bay station sampling for the specified year.

When the trends in resource density for each year are taken alone, (Figures 9 and10), the *Pseudocalanus* mid-winter fill-in that appears to be important to the support of early entering right whales shows two distinct patterns implied in previous reports: 1) a mid- to late winter peak in resource (as in 2004, 2007, 2008), and 2) a low and relatively flat trend (as in 2005 and 2006) throughout the season. In reference to the 2008 season, it appears that these differences in pattern likely control the appearance of right whales and influence the degree of early entry and residency in Cape Cod Bay. In 2008, the dramatic *Pseudocalanus* presence in early March may have been part of the reason for the unusually high number of right whales sighted in the Bay this year. Figure 11 indicates right whale locations (•) and surface *Pseudocalanus* concentrations, showing the spatial relationship between this genus and the whales. It was previously thought that *Calanus finmarchicus* was the most important zooplankton species with regard to right whale behavior and distribution. It appears, however, that in Cape Cod Bay, *Pseudocalanus* spp. may play an equally important if different role in controlling right whale habitat use. This theory is not completely fit to explain patterns of right whale entry and exit for every year, however. When one coarsely examines right whale abundance in the Bay (by sightings per 100 nautical miles of effort) and the magnitude of *Pseudocalanus* spp. peak in the last eight years, no strong correlation is apparent (Figure12). Each point is representative of one year. This examination confirms that the appearance of right whales in the Bay is a multi-variant problem that may include such factors as habitat variability outside of Cape Cod Bay, multiple complex factors inside the Bay, oceanographic dynamics, etc. Another potential explanation is that the relationship between the entrance of right whales into Cape Cod Bay and seasonal enrichment of the *Pseudocalanus* spp. resource is of a threshold nature. In the same way that right whale feeding behavior is accepted as being triggered by a certain threshold level of zooplankton concentration, so might be this relationship.

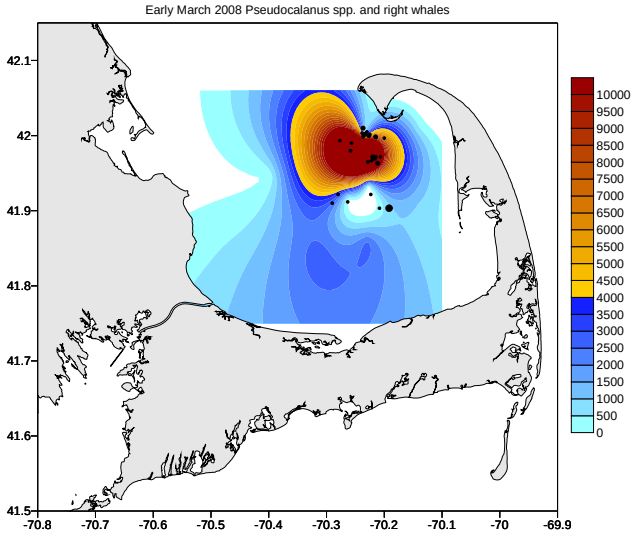


Figure 11. Total right whales (•; *not individuals*) and surface *Pseudocalanus* spp. concentrations (org/m^3) averaged over the first two weeks of March 2008.

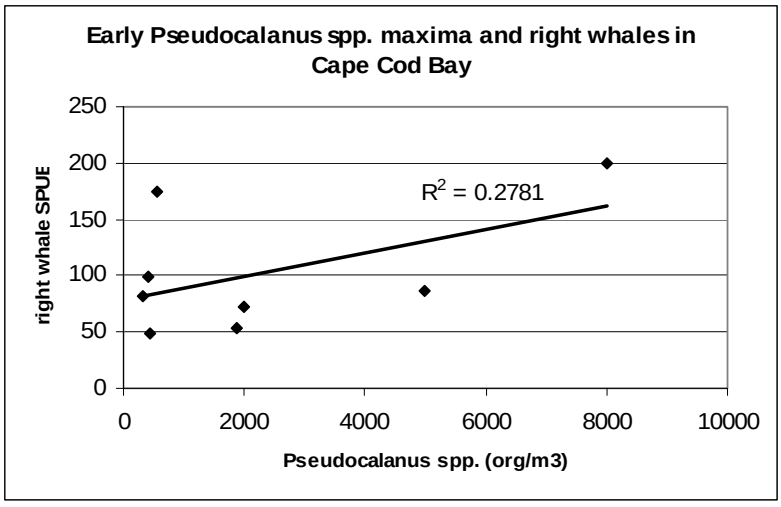


Figure 12. Graph showing *Pseudocalanus* spp. concentration season maxima and right whale sightings per 100 nautical miles of survey effort for years 2001 to 2008.

Taken as a whole the results of our review of the richness of the 2008 food resources in Cape Cod Bay confirm the previous stated view that right whale movement and aggregation and Cape Cod Bay is dependent upon the overlapping enrichment and impoverishment cycles of the three different genera that dominate the Bay system during the winter. Doubtless the stability of the seasonal cycles of zooplankton enrichment in the Bay is an important contributor to the predictability of the occurrence, distribution and movement of right whales.

2.4.2.3. The Zooplankton Resource and the Occurrence of Right Whales

When the density index for sightings of right whales (see Section 1 of this report) is superimposed upon the densities of the three different taxa both at the surface and in the mid-waters (Figure13) it is apparent that the late-season *Calanus* enrichment may, as it is believed to in other habitats, play a central role in the influx of more stable aggregations of right whales during the late winter and early spring. Interestingly, the greatest density of right whales enters Cape Cod Bay during most years at the time of the peak enrichment by *Pseudocalanus*. This time in the cycles of Cape Cod Bay, as mentioned above, precedes the increase in *Calanus* that will eventually dominate Cape Cod Bay's second trophic level productivity during the early to mid-spring.

The 2008 duration of right whale residency in the Bay followed a different pattern from most years: in 2008 the departure of whales from the Bay mirrored the crash of *Calanus finmarchicus* as the dominant food resource (Figure 13). This pattern supports the resource-driven paradigm described in this and other reports. However, a recurring theme in previous years, also apparent in Figure 13, is the departure of right whales (shown in the sharp decline of the relative density index) at a time when zooplankton resources in the form of *Calanus* are *relatively* strong, though declining. In the past we have ascribed this pattern, a common feature of the end of the right whales season and Cape Cod Bay, to a “competition” between habitats. As detailed in the 2006 report to DMF, it seems likely that the departure of whales during a period when their primary food source is higher than when the whales enter the Bay a month or more before is due to attractions not measurable in the limited confines of Cape Cod Bay. The only clear explanation for this counterintuitive event in an environment that would otherwise generally support right whales forging is that other habitats have become super-enriched during early-to mid-May and that, queuing on the changes in the season, associated memories, or some undocumented far-field sense, the whales move to offshore areas that seasonally and predictably increase in resource value late in the Cape Cod Bay season. Notwithstanding this explanation, it remains a mystery as to why whales that are so faithful to our resource-driven paradigm will depart when their principal food resource, *Calanus*, is in *relatively* high concentrations within the Bay. The importance of determining – and thereby developing the capability to predict – the departure of whales is important in our support of the DMF management program because the end of right whales season in the Bay marks the time when the risk of entanglement drops dramatically. This approximate date can be used to inform seasonal gear restrictions and seasonal vessel speed restrictions, because risk to the whales could increase if whales remained to feed on the remaining resource that may be found through May and June. If this were the case, DMF would be adequately informed and modification to seasonal gear/vessel speed restrictions could be made to protect the right whales remaining in the Bay.

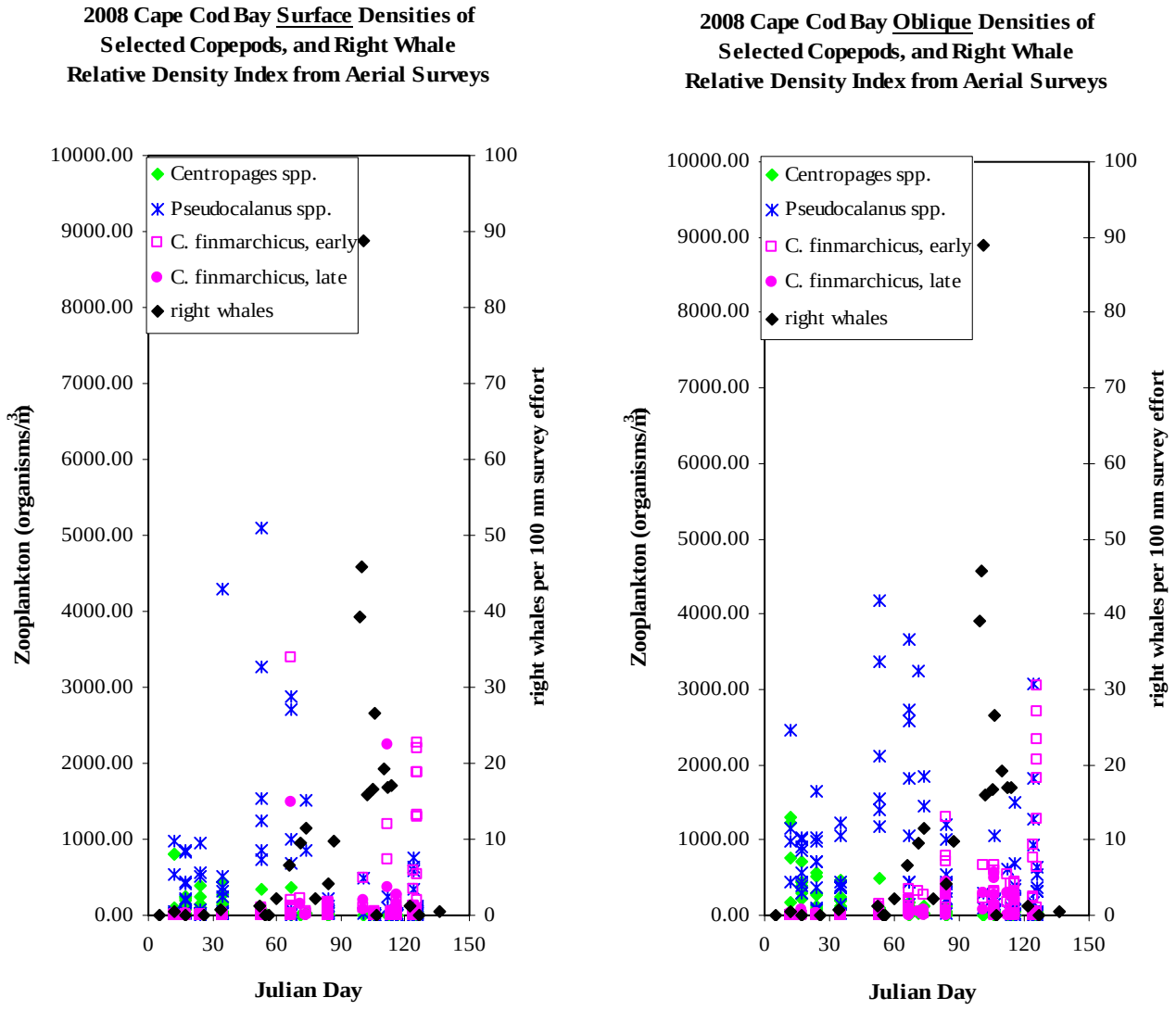


Figure 13. 2008 comparison of right whale relative density index from aerial surveys with the densities of selected copepod taxa in Cape Cod Bay surface waters (left graph) and the water column (right). Right whale relative density index is displayed as a trend line, computed as a 3rd-order regression of 30 daily values of right-whales-per-trackline-kilometer from 2008 aerial surveys. Zooplankton species densities from on-station samples collected between January and mid-May 2008.

Comparing the right whale density index with total zooplankton density at the surface (Figure 14) and in the water column (Figure 15), the patterns of whale sightings in 2003 through 2006, and 2008, approximated the rise and fall in the bay- wide mean zooplankton concentrations relatively well. Surface concentration trends (Figure 14) appear to mirror whale abundance better than water column concentrations (Figure15). This may be because of the energetic demands of right whale foraging; energetically, it makes more sense for a right whale to feed on the most dense food aggregations of zooplankton possible. As shown in Figures 4 and 5 and discussed earlier, surface zooplankton concentrations have greater potential to be very high due to physical aggregating forces particular to the sea-surface/air interface. Further, surface samples are from the upper-most meter of water, while water column samples collect organisms from the upper 19 meters or so of the water column. Therefore, water column samples demonstrate the organisms that may be spread through those 19 meters, rather than aggregated into a one-meter thick layer, typically attractive to right whales. This raises the important point that zooplankton biomass in the Bay must be distinguished from aggregated biomass. For example, one dense patch of zooplankton can have the same biomass as an entire quadrant of Cape Cod Bay, depending on the strength of the aggregative factors (i.e. tides, currents, winds, etc).

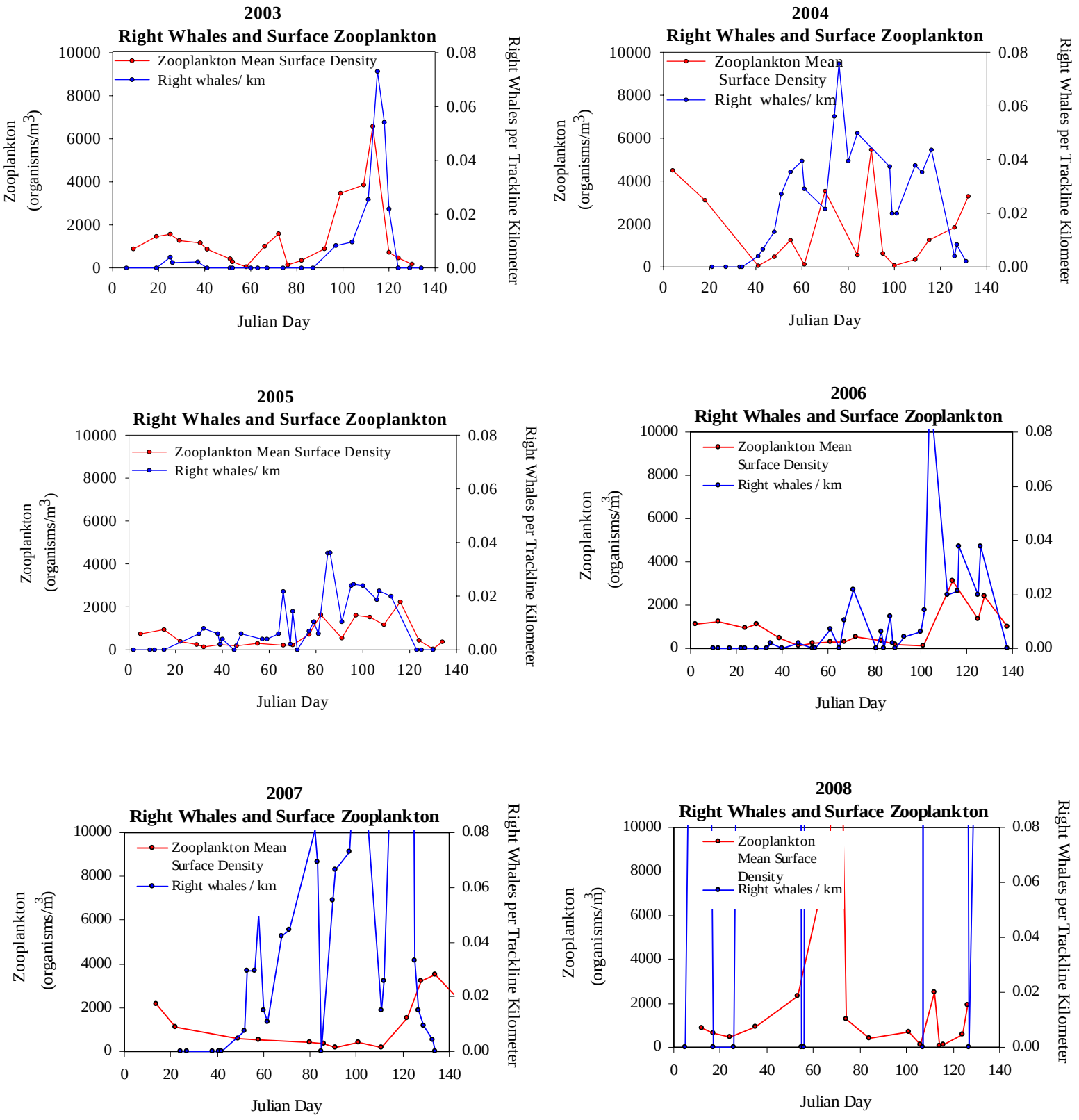


Figure 14. Comparison of right whale sightings and daily mean <u>surface</u> zooplankton densities in Cape Cod Bay, 2003-2008.

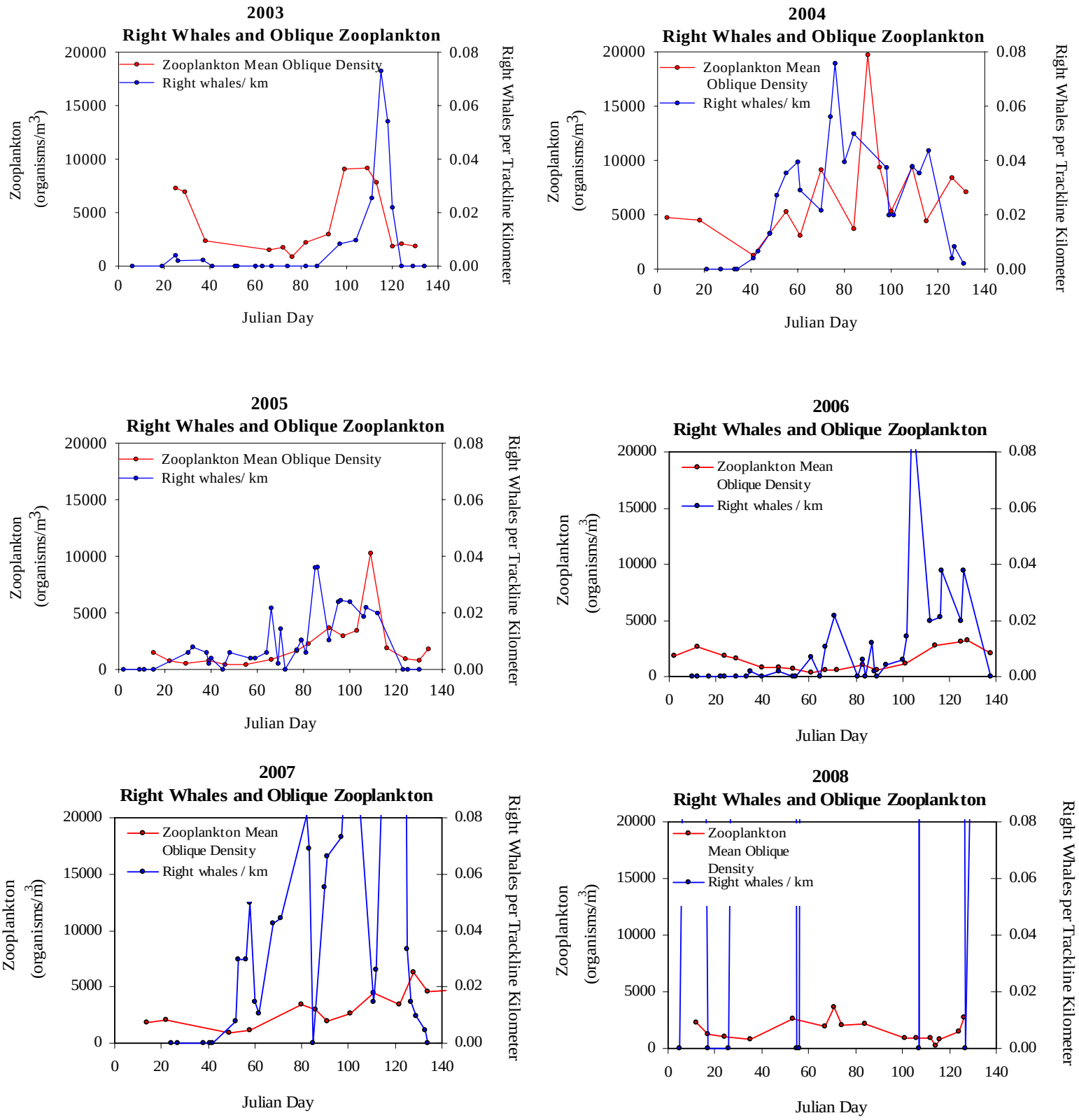


Figure 15. Comparison of right whale sightings and daily mean water column zooplankton densities in Cape Cod Bay, 2003-2008.

Figure 16 illustrates zooplankton density by Cape Cod Bay quadrant. These quadrant views of the bay demonstrate several previously mentioned aspects of the zooplankton resource that control the right whales in the Bay. Generally, in 2008 the northwest quadrant was more impoverished than the other quadrants of the Bay, supporting the general pattern of resource distribution and the historic record of right whale distribution from the last 20 years. An additional spatial pattern apparent in Figure 11 is the difference between surface and water column stock of copepods. As seen in all earlier referenced figures, the water column resource throughout all of the quadrants of the Bay, even during periods of low total resource, exceeded surface concentrations, except for a period at the beginning of March, or around the 50^{th} to the 60^{th} Julian Days during which surface concentrations in the northeast, southeast, and southwest quadrants of the bay all had average surface concentrations that exceeded their water column concentrations. This time–period also marked the entrance of many whales into the bay (Figure 13), indicating again that surface concentrations may have more influence on right whale abundance and behavior than water column concentrations.

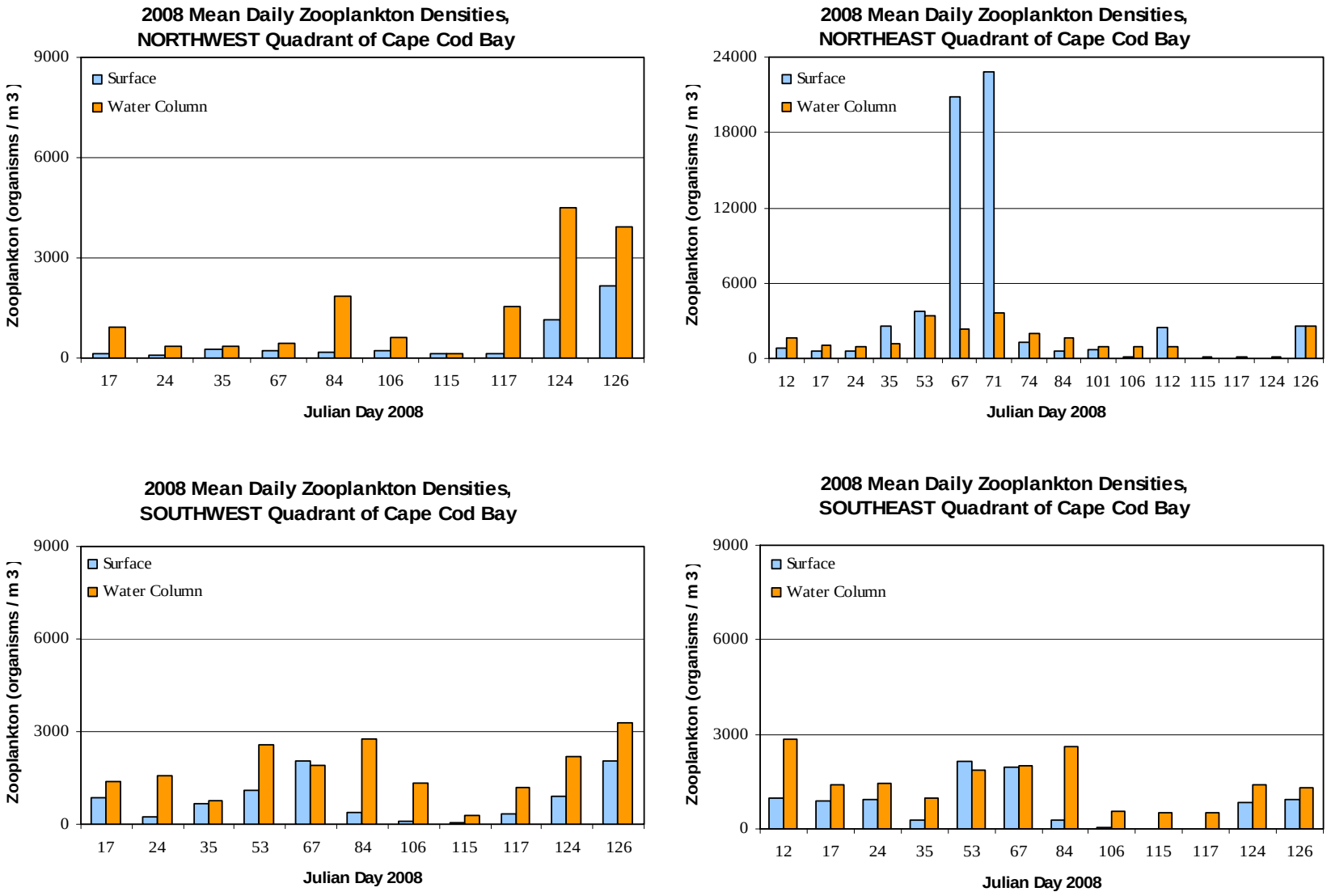


Figure 16. Temporal progression of the daily mean density of surface and water column total zooplankton in each quadrant of Cape Cod Bay. Note scale difference for northeast quadrant.

2.4.2.4. Zooplankton and Right Whale Distribution and Prediction, 2008

We include as part of our results a number of resource descriptions in Appendix I of this report. An interpolated estimation of the spatial density distribution of zooplankton through the 2008 season and the net change in density between any two cruises is found in Appendix I, Figures 1 through 12. These depictions play a central role in the assessment and prediction reports.

From the earliest observations on 12 January 2008 through to 24 January 2008 (Figures 1-3, Appendix I) both water column and surface samples indicated a relatively impoverished environment, not likely to support right whale residency anywhere within the Bay. On 12 January an entangled right whale was spotted, though its presence in the bay could have been an indication of poor health and/or unusual behavior due to entanglement. On 04 February (Figure 4, Appendix I) a slight enrichment of the surface waters was visible, indicating the beginning of zooplankton enrichment that would later attract right whales to the bay; water column concentrations remained quite low. After bad weather prevented cruises for the middle part of February, a 22 February cruise revealed a widely-spread, well developed resource in the northeastern quadrant of the bay. The resource was both horizontally and vertically broad (Figure 5, Appendix I).

Cruise SW687 on 07 March was important for a number of reasons. First, the regular stations (those that we had been sampling during the season to date) revealed a more impoverished resource field than on 22 February; Figure 6, Appendix I contains a representation of this resource distribution. Second, a large number (11 to 13) of whales was sighted from the vessel with the majority concentrated in the northeast quadrant of the bay; this indicated that there should be a strong zooplankton resource in the bay. Third, the research team made a decision to sample 6N, a technically "regular" station (it was marked as a station on the original bay-wide transects designated in 1984), that had not been sampled during the 2008 season; the results of this sampling are not included in Figure 6, Appendix I so that the interpolated density illustration from SW687 is comparable with the other bay-wide distribution charts. However, sampling at station 6N revealed an extraordinarily rich *Pseudocalanus* spp. resource covering the northeast and part of the northwestern quadrants of the bay (Figure 13, Appendix I). Figure 13, Appendix I demonstrates the sensitivity of the habitat studies results to the spatial scale at which the bay is sampled and studied. This issue will be further addressed in the section 2.4.2.6. The water column samples from SW687 revealed an impoverished water column; almost all of the resource was at the surface.

CruiseSW688 on 11 March was shortened by bad weather and cruise SW689 on 14 March was dedicated to vertical pump sampling in one location rather than bay-wide horizontal sampling. The results of the vertical sampling studies will be explored in section 2.4.2.6. Briefly, the vertical pump samples showed that there was an acceptable resource for right whales at least in the north east quadrant of the bay. Bay-wide sampling on 24 March (Figure 7, Appendix I) revealed a depleted resource compared with that seen on 07 March. The highest concentrations were found in the water column in the southeast and southwest quadrants of the bay, while the whales sighted by the *R/V Shearwater* were in the northeast portion of the bay. This could have been because they were foraging on the last of a strong resource that had existed in the area, or

because they were feeding on a bottom resource that we did not reach with our bay-wide sampling techniques.

Cruise SW691 on 27 April was again dedicated to vertical pump sampling; the results of this study are found in section 2.4.2.6. Three cruises (SW692, SW693, SW694) were conducted on 09 April, 10 April and 11 April respectively; too few surface and water column samples were collected to suggest any conclusions about the zooplankton resource in the bay. During cruise SW694 on 11 April horizontal pump sampling was conducted to examine an extensive patch on which approximately 20 whales were feeding; lab analysis showed that the patch was dominated by late stage *Calanus finmarchicus*. This intensive study will be discussed further in 2.4.2.6. On 15 April, a large number of whales (between 21 and 30 individuals sighted by boat; more than 42 by aircraft survey) continued to reside in the bay, feeding on a resource observed in the water column, not at the surface. The whales and the resource were concentrated against the southeastern shore of the bay (Figure 8, Appendix I). SW697 on 21 April was curtailed by poor weather conditions.

During cruise SW698 on 23 April between 16 and 21 right whales were sighted from the *R/V Shearwater*, but the zooplankton resource observed during the cruise was not conducive to right whale feeding; concentrations were between 44 and 612 organisms per cubic meter (Figure 9, Appendix I). During the following cruise (SW699) on 25 April only five right whales were sighted in the southwestern portion of the bay, presumably feeding on a relatively weak resource in the water column (Figure 10, Appendix I). The whales were positioned in the mid-western half of the Bay, an area assumed to be part of the passage into and out of the bay. The final two cruises (SW700 and SW701) on 03 May and 05 May revealed no whales left in the bay, and continued *relatively* impoverished zooplankton resources (Figures 11 and 12, Appendix I). A moderate *Calanus finmarchicus* patch developed however, and was observed during cruises SW700 and SW701 in the middle of the northeastern portion of the bay in the water column. The concentration of resource was not substantial enough to draw the whales back into the bay to support feeding.

These serial observations of changes in the ecosystem of Cape Cod Bay hint at one possible explanation for the departure of right whales from the Bay. It seems likely that a large grazing animal with substantial energetic demands would seek environments that are relatively stable and predictable at least over short periods of time. This hypothesis is based on simple foraging theory that suggests that the best habitats are both rich and require relatively little searching on a daily basis to optimize feeding success. What we observed, particularly in the latter part of the season of 2008 starting in the last week and a half of April, was an environment whose zooplankton resources were in a state of flux throughout the water column. Other habitats known to be important in mid-spring may become more attractive to right whales that would Cape Cod Bay during years, such as 2008, if they seasonally develop more stable and therefore predictable zooplankton resources. If this emerging hypothesis is correct then an understanding of small scale horizontal variability in the richness of the resource may be an essential component in the decision-making processes of right whales. Under this hypothesis right whales feeding actively during late April and early May 2008 confronted periods of low local zooplankton concentrations, which dropped below the feeding threshold; these fluctuating

conditions may have encouraged whales to look elsewhere for more predictable and stable high-quality resources.

2.4.2.5. Zooplankton Summary by Station

The pairs of surface and water column descriptions from individual stations (Figures 14 through 29, Appendix I) reinforce previous comments that:

- The three genera of copepods that have been most implicated in feeding activities followed somewhat the same pattern of enrichment and impoverishment seen in previous years, with the exception of an unusually strong *Pseudocalanus* resource and a somewhat weaker *Calanus* resource than usual.
- Copepod resources in the eastern portion of Cape Cod Bay are more abundant than in the west, particularly late in the season of right whale residence.

A side-by-side comparison of the composition of surface and water column samples at the eight stations in the study (Figures 30 through 37, Appendix I) present a different perspective with the same conclusions. Broadly the patterns of species composition tend to be similar, but comparisons between collections from individual stations on any given cruise often reveal intriguing anomalies, most notably when total zooplankton concentrations are impoverished. These treatments show again the consistent difference between surface and water column zooplankton densities are in many cases quite dramatic, as noted earlier.

Section 2.4.2.6. Fine-scale examination of complex resource patches

2.4.2.6.1 Vertical profile studies

The anomalies mentioned above, as well as the unusual *Pseudocalanus* spp. resource identified in Figure 13, are artifacts of the fine temporal and spatial scales at which zooplankton dynamics occur. Further, the right whale dynamics that are the subject of these studies are reactive to zooplankton dynamics, and therefore subject to the same fine-scale movements and enrichment patterns over time. On a number of occasions during the 2008 season of right whale residence in Cape Cod Bay, the PCCS Habitat Studies team dedicated time to quantifying and trying to understand the fine-scale zooplankton dynamics that appear to often drive right whale behavior. In this section we discuss 1) a study conducted on the vertical distribution of different zooplankton genera and its effect on the vertical distribution of right whales, as well as associated risk and 2) a study of a dense aggregation of skim-feeding right whales and the associated surface patch of zooplankton.

During cruises SW689 and SW691, on 14 and 17 March respectively, study of the vertical structure of zooplankton distribution was examined (see Appendix III for detailed original special reports). During cruise SW689, four water column profiles were sampled; three of them were thoroughly analyzed and compared with one another. The first profile was taken in the presence of right whales performing fluking dives. The behavior of one individual right whale within 100 meters of the sampling station was observed closing its mouth as it surfaced after a

ten-plus minute dive. Within 0.5 meters of the bottom, at 42 meters deep, a zooplankton maximum concentration of 58464 organisms per cubic meter (zpk/m^3) was observed, as was a dense subsurface zooplankton layer with a maximum concentration of 48122 zpk/m^3 at nine meters (Figure 1, Appendix IVa). Both layers were dominated by *Pseudocalanus* spp. It was hypothesized, based upon the whales' dive time, fluking behavior and fluke prints, that they were feeding on one or more of the resource layers present.

Samples for profile C were taken approximately one hour and fifty minutes after those for profile 689A. They were taken in an area where the water parcel containing zooplankton observed in profile A would probably have drifted, based on tide and wind direction. The three to five whales associated with the sample site continued to exhibit fluking dive behavior. The zooplankton resource observed near the surface in profile A was not present at our sample site, but an ultra-dense engybenthic layer dominated by *Pseudocalanus* spp. was observed with a maximum zooplankton concentration of 77562 zpk/m^3 at a depth of 40.25 meters (less then 0.5 meter above the bottom) (Figure 3, Appendix IVa). Again, we hypothesized that the whales were feeding on this engybenthic layer.

Finally, fifty minutes after profile 689C was finished, samples for profile 689D were collected. The samples revealed a dense surface layer with total zooplankton concentration of 21098 zpk/m^3, and a bottom layer centered approximately five meters above the seafloor (35 meters depth) with maximum zooplankton concentration of 20683 zpk/m3 (Figure 5, Appendix IVa). The whales observed in the area where profile 689D was sampled exhibited both fluking dives and skim feeding behavior. It was hypothesized that the whales were changing their feeding behavior based upon the vertical change in zooplankton distribution in the water column. The changes in zooplankton resource distribution observed over the four hours of vertical sampling described here show the importance of fine scale study to understanding zooplankton dynamics; within just hours, critical changes in the zooplankton resource structure were observed. Furthermore, this change represents an important aspect of management; when feeding at the bottom, right whales may be more prone to risk via entanglement in bottom fishing lines, whereas at the surface, they may be more at risk of ship strike.

During cruise SW691 the PCCS habitat studies team returned to the location at which the vertical samples were collected during SW689 to further document the distribution of the food resources described above. The discrete depth sampling methodology from the previous cruise, SW689, was replicated; additionally, a CTD was used to collect physical environmental data. In addition to the vertical profile sampled in the vicinity of the profiles from cruise SW689 (profile 691A), two more sets of mid-water samples were collected at new locations in the northwest portion of the Bay, where an estimated 15 right whales were aggregating (profiles 691B and 691D).

Profile 691A revealed a very weak resource with no whales associated (Figure 1, Appendix IVb). The comparison of this profile to the others again illustrates the importance of fine-scale study, both spatially and temporally, to the understanding the right whale-zooplankton linkage. Only three days apart, the profiles from cruise SW689 and SW691 reveal a local collapse in a resource that had attracted a stable aggregation of right whales. A once-a-week sampling regime is not temporally fine enough to catch these nuances of right whale-zooplankton interface.

Profile 691B revealed the presence of a dense engybenthic layer with a maximum total zooplankton concentration of 10719 organisms/m^3 at 40 meters depth, less than 0.5 meters above the bottom, as well as a less dense layer at 6.0 meters depth, with a maximum total zooplankton concentration of 3,435 organisms/m^3 (Figure 3, Appendix IVb). *Pseudocalanus* spp. dominated the engybenthic layer, while *C. finmarchicus* dominated the shallower layer (Figure 4, Appendix IVb). Several whales, out of the ten to fifteen observed within one kilometer, performed long fluking dives within 20 meters of *R/V Shearwater*. It was hypothesized that they were feeding on the dense bottom layer. This hypothesis implies that the whales were choosing to expend the extra energy to feed on the deeper, denser layer, despite its depth compared with the less dense layer at 6.0 meters depth. Also noteworthy is the fact that *Calanus finmarchicus,* the copepod species assumed to be the primary food of right whales, was observed in the shallower resource layer, but the whales were observed diving probably for the deeper layer. This reinforces the assertion that in Cape Cod Bay *Pseduocalanus* spp., in addition to *C. finmarchicus,* are important to right whale ecology.

2.4.2.6.2 Horizontal patch study

During cruise SW694, the PCCS Habitat Studies team sampled a patch of zooplankton with an estimated surface area of 111.2 km² and combined information on the foraging behavior of 17 skim-feeding whales with data from 105 samples of zooplankton collected over a period of 420 minutes, in order to examine the dynamics of the interaction. Intensive horizontal pump sampling along gridded transects was conducted, in addition to two vertical pump profiles and net collections. In the upper three to four meters of the water column, the patch was dominated by the late-stage copepod *Calanus finmarchicus,* representing an average of 90.4 % of the total zooplankton with the subdominant *Pseudocalanus* spp. 10 %. At the observed zooplankton concentrations, the mean grazing rate of the individual whales was estimated at 2,606 organisms per second; this estimate was based on the gape size and swimming speed of an average-sized adult right whale.

The results of the analysis yielded an estimate of the gross consumption rate at 44,302 organisms per second, and the total number of organisms consumed at 1.86 $x10^7$ for the duration of the study. The results of this consumption rate permit determination of the patch-to-whale caloric transfer rate. If the patch structure were maintained and grazing continued as observed, the patch would maintain acceptable resource conditions for right whale feeding (greater than 4,000 organisms per cubic meter) for approximately 279 hours, or about eleven and a half days. As described above, however, this zooplankton resource and aggregation of whales had dissipated after only three days, thereby suggesting that there are additional factors that contribute to the break-down of an attractive zooplankton resource. One hypothesis is that right whale feeding behavior requires a densely aggregated resource that is mostly continuous. Once being grazed down for a certain amount of time, this resource may have become too spread out to be energetically beneficial for feeding.

Conclusions

The results of the 2008 field study document a season of exceptional right whale abundance. It is expected that, once matching of individuals has been completed, the final count of unique individuals visiting Cape Cod Bay in 2008 will exceed the number for 2007. The area continues to be an important nursery ground for a subset of the year's mother-calf pairs. A large proportion of the whales visiting CCB exhibit site fidelity and have been regularly sighted over the years. Feeding is by far the most prevalent behavior in this critical habitat, and is primarily observed during the months of March and April, when whales are most numerous in the bay. 2008 was also a notable year for right whale entanglements. The documentation and, in two cases, the reduction of the severity of the entanglements by the PCCS disentanglement team is extremely valuable in understanding the nature of entanglements and working towards their prevention. It also has immediate benefit to such a small population, by preventing unnatural mortalities. This emphasizes the essential nature of the disentanglement team's work in the conservation of the North Atlantic right whale.

Many questions still remain regarding spatial and temporal patterns of abundance, demographics, behavior and residency patterns in CCB, but the key questions for this population relate to management and conservation of a species close to extinction, and constantly facing the pressures of an ocean habitat dominated by anthropogenic threats. Particular focus over the coming years will be needed in two areas. The cross-validation of acoustic and visual data, at a range of spatial and temporal scales, is essential if acoustic monitoring is to develop as a tool for management. The link between right whales and their food resources is also crucial towards gaining a better understanding of the dynamics of the population utilizing CCB, and eventually, moving towards prediction of these dynamics. Better bay-wide coverage, as well as fine-scale study of zooplankton resources needs to be incorporated into the regular habitat studies Better bay-wide coverage, as well as fine-scale study of zooplankton resources needs to be incorporated into the regular habitat studies survey design. Finally, the area east of the Cape, which is clearly utilized regularly by substantial numbers of whales, is worthy of more survey time, if resources are available. The threats to whales in this region are less easy to understand and manage, since they are outside of the critical habitat boundary, and the whales documented in this region are, in large part, different individuals from those documented in CCB, thus a more detailed study of waters east of the Cape would greatly benefit the right whale population as a whole.

3.1 Looking to the Future

There are a number of areas in which the DMF/PCCS right whale programs could be improved. Some specific items pertain to the Habitat Studies Program, others to the Aerial Survey Program, and still others pertain to both programs. Here, ways to improve the efficiency and efficacy of the programs are presented.

3.1.1 Habitat Studies Program

As shown in this report, the Habitat Studies Program sampling regime is currently frequent enough to give scientists and managers a coarse picture of the right whale-zooplankton dynamics in Cape Cod Bay. It is suggested and thoroughly illustrated in this report that fine-scale study is extremely important to accurately managing risk to right whales. Therefore, the program would, in the future, benefit from doubled boat time. With double the current allotted boat time, cruises could be spent both surveying the Bay as is currently done, in addition to conducting in-depth studies that reveal the important intricacies of the right whale-zooplankton dynamics of Cape Cod Bay.

The Habitat Studies program would also benefit from a study of the diel patterns in zooplankton distribution and behavior, in combination with right whale distribution and behavior. To date, zooplankton movement and right whale behavior over 24-hour cycles is unknown in Cape Cod Bay; no night work has been completed. This is a major gap in our understanding of right whale behavior, which has important implications for management, as whales may be particularly prone to ship strike at night due to decreased mariner visibility. The Habitat Studies team recognizes the need for such a study and encourages its support so that management of right whales may be as informed as possible. The integration of zooplankton sampling with behavioral observations and, if possible, acoustic monitoring, will provide a discrete, novel data set on the nocturnal habits of right whales and their prey, in Cape Cod Bay.

Finally, the Habitat Studies Program plans to include more environmental factors in next year's reports and analyses. CTD casts will be done, along with the deployment of a PAR sensor and fluorometer. These instruments will give the Habitat Studies reports a new dimension; salinity, temperature, light intensity and chlorophyll abundance will all be incorporated to give a richer picture of the ecosystem processes that the program and state seek to understand.

3.1.2 Aerial Survey Program

During the busiest part of the right whale season in Cape Cod Bay, right whales may be so numerous in the bay that a full survey day is not sufficient to fly all track lines and photograph all individuals. This issue was particularly apparent in 2008, during the month of April. Over a two-week period, all surveys flown were incomplete due to the abundance of whales in the study area. Thus, we never had a complete "best estimate" count for the bay. In the event that this occurs again, a method must be devised in order to allow photo-identification work to continue, but also to collect basic data on whale abundance and distribution throughout the whole study area. Two planes could be used to achieve this; one to carry out the usual photo-identification work, and a second simply flying the track lines and doing counts of whales, on the same day, in

a “Distance sampling” type methodology. A more feasible alternative is for a single survey plane to carry out these two functions on alternating days.

The PCCS aerial survey study area has for many years included track lines to the east of Cape Cod. These track lines are flown with varying frequency each year, and in 2008 were only flown twice. This makes it difficult to deduct any meaningful data from such sporadic surveys, or to compare data amongst years for this region. In 2009, it is hoped that more regular flights of this area will be possible, strategically distributed throughout the season.

3.1.3 Habitat Studies and Aerial Survey Programs Combined

The primary place for improvement of the combined programs lies in communication and joint analysis. Because the Habitat Studies Program focuses on surveys of right whale food resources in Cape Cod Bay, and the Aerial Survey Program focuses on bay-wide surveys for individual whales, it only makes sense to communicate enough so that each survey can be conducted on the same day, covering the same areas of the bay. With this type of collaboration, joint analyses can be made that would greatly benefit management. Right whale distribution and abundance in the whole bay, as assessed by aerial surveys, can then be compared to the nature and distribution of plankton patches. Such investigations will be publishable in peer-reviewed journals, contributing to the right whale research community as a whole.

We also intend to refine the photo-identification methodology used during the habitat surveys, in order to collect high-quality photographs of right whales from sea level and to ensure that these data can be analyzed and informative to the program. Currently, photo-identification by this team is opportunistic and unstructured. The development of this aspect of the program will likely require an additional team member, perhaps an undergraduate or graduate student, who can be present on all boat-based surveys and can carry out the processing and matching of photographs, having been trained by the aerial survey team, whose members are all experienced in this work.

REFERENCES

Allen G.M. 1916. The whalebone whales of New England. Boston Society of Natural History 8(2):105-322.

Baird, R.W. and Dill L. M. 1996. Ecological and social determinants of group size in

Bessinger, M., C. Mayo and M. Brown. 2003. Using zooplankton enumeration to manage the Cape Cod Bay right whale critical habitat in 2003. Chapter Two *in* Surveillance, monitoring, and management of North Atlantic right whales in Cape Cod Bay and adjacent waters – 2003. Final report to the Division of Marine Fisheries, Commonwealth of Massachusetts. Center for Coastal Studies, October 31, 2003.

Brown, M.W. 1994. Population Structure and Seasonal Variation of North Atlantic Right Whales (*Eubalaena glacialis*). PhD Thesis, University of Guelph, Guelph, Ontario, Canada.

Brown, M.W. and M.K. Marx. 1998. Surveillance, Monitoring and Management of North Atlantic Right Whales, *Eubalaena glacialis*, in Cape Cod Bay, Massachusetts: January to Mid-May, 1998. A final report submitted to the Division of Marine Fisheries, Commonwealth of Massachusetts, October 1998, Contract No. SCFWE3000-8365027.

Brown, M.W. and M.K. Marx. 1999. Surveillance, Monitoring and Management of North Atlantic Right Whales, *Eubalaena glacialis*, in Cape Cod Bay, Massachusetts: January to Mid-May, 1999. A final report submitted to the Division of Marine Fisheries, Commonwealth of Massachusetts, October 1999, Contract No. SCFWE3000-8365027.

Brown, M.W. and M.K. Marx. 2000. Surveillance, Monitoring and Management of North Atlantic Right Whales, *Eubalaena glacialis*, in Cape Cod Bay, Massachusetts: January to Mid-May, 2000. A final report submitted to the Division of Marine Fisheries, Commonwealth of Massachusetts, October 2000.

Brown, M.W., M.K. Marx, and O. Nichols. 2001b. Surveillance, Monitoring and Management of North Atlantic Right Whales, *Eubalaena glacialis*, in Cape Cod Bay, Massachusetts: January to Mid-May, 2001. A final report submitted to the Division of Marine Fisheries, Commonwealth of Massachusetts, and to the Massachusetts Environmental Trust, October 2001.

Brown, M.W., O.C. Nichols, M.K. Marx, and J.N. Ciano. 2002. Surveillance of North Atlantic Right Whales in Cape Cod Bay and Adjacent Waters – 2002. Chapter One *in* Surveillance, Monitoring, and Management of North Atlantic Right Whales in Cape Cod Bay and Adjacent Waters – 2002. Final report to the Division of Marine Fisheries, Commonwealth of Massachusetts. Center for Coastal Studies, September 2002.

Brown, M.W., O.C. Nichols and M.K. Marx. 2003. Surveillance of North Atlantic right whales, *Eubalaena glacialis*, in Cape Cod Bay and adjacent waters: January to Mid-May, 2003. Chapter One in: Surveillance, monitoring and management of North Atlantic right whales in Cape Cod Bay and adjacent waters – 2003. Final report

submitted to the Division of Marine Fisheries, Commonwealth of Massachusetts. October 2003.

Brownell, R.L., P.B. Best, and J.H. Prescott, eds. 1986. Report of the workshop on the status of right whales. Reports of the International Whaling Commission (Special Issue 10):1-14.

Caswell, H., M. Fujiwara and S. Brault. 1999. Declining survival probability threatens the North Atlantic right whale. Proceedings of the National Academy of Science 96:3308-3313.

Cetacean and Turtle Assessment Program (CeTAP). 1982. A characterization of marine mammals and turtles in the mid- and north Atlantic areas of the U.S. outer continental shelf. Final Report of the Cetacean and Turtle Assessment Program to the U.S. Dept. of Interior under Contract AA551-CT8-48. H.E. Winn, Scientific Director.

Clark, C. W. and P.J. Clapham. 2004. Acoustic monitoring on a humpback whale (*Megaptera novaeangliae*) feeding ground shows continual singing into late Spring. Proceedings of the Royal Society of London, B. 271: 1051-1057

Clark C., M. Brown, P. Corkeron. 2008. Management implications for North Atlantic right whales from visual and acoustic surveys in Cape Cod Bay, Massachusetts, 2001-2005. Journal of Applied Ecology, 34 pp.

Fujiwara M. and H. Caswell. 2001. Demography of the endangered North Atlantic right whale. Nature 414:537-541.

Hamilton P. K. 2002. Associations among North Atlantic right whales. M.Sc. Thesis, University of Massachusetts Boston, Boston, MA: 105pp.

Hamilton, P.K. and C.A. Mayo. 1990. Population characteristics of right whales (*Eubalaena glacialis*) observed in Cape Cod and Massachusetts Bays, 1978-1986. Reports of the International Whaling Commission (Special Issue 12):203-208.

Hamilton, P.K., M.K. Marx and S.D. Kraus. 1995. Weaning in North Atlantic right whales. Marine Mammal Science 11:386-390.

Hamilton, P., M. Marx, C. Quinn and A. Knowlton. 1997. Massachusetts' right whale matching and data integration: 1997. Final report to the Massachusetts Environmental Trust by the New England Aquarium, February 1998.

Hamilton, P.K., and S.M. Martin. 1999. A catalog of identified right whales from the western North Atlantic, 1935-1997. New England Aquarium, Boston, MA.

Hamilton, P.K., A.R. Knowlton, S.D. Kraus and E.P. Pike. 2004. Maintenance of the North Atlantic right whale catalog: 1 January – 31 December, 2003. Final report submitted to NOAA/NMFS Northeast Fisheries Science Center, Woods Hole, MA. Contract EA133F-02-CN-0052. July 9, 2004.

Hernández-León S., C. Almeida, M. Gómez, S. Torres, I. Montero, A. Portillo-Hahnefeld. 2001. Zooplankton biomass and indices of feeding and metabolism in island-generated eddies around Gran Canaria. Journal of Marine Systems 30: 51-66

Hooker S. K., H. Whitehead, S. Gowans and R. W. Baird 2002. Fluctuations in distribution and patterns of individual range use of northern bottlenose whales. Marine Ecology Progress Series 225:287-297.

International Whaling Commission (IWC). 2001. Report of the workshop on status and trends of western North Atlantic right whales. Journal of Cetacean Research and Management (Special Issue 2):61-87.

Jaquet N., C. Mayo, O. C. Nichols, M. Bessinger, D. Osterberg, M. K. Marx and C. L. Browning. 2005. Surveillance, Monitoring and Management of North Atlantic Right Whales in Cape Cod Bay and Adjacent Waters - 2005. Final report submitted to the Division of Marine Fisheries, Commonwealth of Massachusetts. October 2005: 157pp.

Jaquet N., C. Mayo, D. Osterberg, O. C. Nichols, M. K. Marx and C. L. Browning. 2006. Surveillance, Monitoring and Management of North Atlantic Right Whales in Cape Cod Bay and Adjacent Waters - 2006. Final report submitted to the Division of Marine Fisheries, Commonwealth of Massachusetts. November 2006: 145pp.

Jaquet N., C. Mayo, D. Osterberg, C. L. Browning, M. K. Marx. 2007. Surveillance, Monitoring and Management of North Atlantic Right Whales in Cape Cod Bay and Adjacent Waters - 2006. Final report submitted to the Division of Marine Fisheries, Commonwealth of Massachusetts. November 2007: 106pp.

Kite-Powell, H., and P. Hoagland. 2002. Economic aspects of right whale ship strike management measures. Final report to the National Marine Fisheries Service, Contract No. 40EMNF100235.

Knowlton, A.R., J. Sigurjonsson, J.N. Ciano and S.D. Kraus. 1992. Long-distance movements of North Atlantic right whales. Marine Mammal Science 8:397-405.

Knowlton, A.R., S.D. Kraus and R.D. Kenney. 1994. Reproduction in North Atlantic right whales (*Eubalaena glacialis)*. Canadian Journal of Zoology 72(7): 1297-1305.

Knowlton A.R. and S.D. Kraus. 2001. Mortality and serious injury of Northern right whales (*Eubalaena glacialis*) in the western North Atlantic. Journal of Cetacean Research and Management (Special Issue 2): 193-208.

Kraus, S.D., K.E. Moore, C.E. Price, M.J. Crone, W.A. Watkins, H.E. Winn and J.H. Prescott. 1986. The use of photographs to identify individual north Atlantic right whales (*Eubalaena glacialis*). Reports of the International Whaling Commission (Special Issue 10):145-151.

Kraus, S.D., M.J. Crone and A.R. Knowlton. 1988. The North Atlantic Right Whale, pp. 684-698, *in* Chandler, W.J., ed., Audubon Wildlife Report 1988/1989. Academic Press, NY, 816 pp.

Kraus, S.D. and R.D. Kenney. 1991. Information on right whales (*Eubalaena glacialis*) in three proposed critical habitats in United States waters of the western North Atlantic Ocean. Final report to the U.S. Marine Mammal Commission, contract numbers T-75133740 and T-75133753. Washington, D.C. 65 pp.

Kraus, S.D., A.R. Knowlton and C.A. Quinn. 1997. A preliminary comparison of methods to detect right whales in Cape Cod Bay. Appendix III *in* Emergency Surveillance, Reporting and Management Program in the Cape Cod Bay Critical Habitat. Final report to the Massachusetts Environmental Trust by the Center for Coastal Studies, September 1997. C.A. Mayo, Principal Investigator.

Kraus, S.D., P.K. Hamilton, R.D. Kenney, A.R. Knowlton and C.K. Slay. 2001. Reproductive parameters of the North Atlantic right whale. Journal of Cetacean Research and Management (Special Issue 2):231-236.

Kraus, S.D. 2002. Birth, Death and Taxis: North Atlantic Right Whales in the Twenty-first Century. Doctoral dissertation, University of New Hampshire, Durham New Hampshire, 162 pp.

Kraus S. D., M.W. Brown, H. Caswell, C.W. Clark, M. Fujiwara, P.K. Hamilton, R.D. Kenney, A.R. Knowlton, S. Landry, C.A. Mayo, W.A. McLellan, M.J. Moore, D.P. Nowacek, D.A. Pabst, A.J. Read and R.M. Rolland. 2005. North Atlantic Right Whales in Crisis. Science 309:561-562.

Kraus S.D. and R.M. Rolland, eds. 2007. The Urban Whale: North Atlantic Right Whales at the Crossroads. Harvard University Press, Cambridge, MA.

Lee P. C. 1994. Social structure and evolution. 266-303 *in*: P. J. B. Slater, Halliday T. R., eds Behaviour and Evolution. Cambridge University Press, Cambridge.

Malik S., M. W. Brown, S. D. Kraus, A. R. Knowlton, P. K. Hamilton and B. N. White. 1999. Assessment of mitochondrial DNA structuring and nursery use in the North Atlantic right whale (*Eubalaena glacialis*). Can J. Zool. 77:1217-1222.

Matthews J. N., S. Brown, D. Gillespie, M.P. Johnson, R. McLanaghan, A. Moscrop, D. P. Nowacek, R. Leaper, T. Lewis and P.L. Tyack. 2001. Vocalisation rates of the North Atlantic right whale (*Eubalaena glacialis*). Journal of Cetacean Research & Management 3:271-282.

Mayo, C.A. and M.K. Marx. 1990. Surface foraging behavior of the North Atlantic right whale, *Eubalaena glacialis*, and associated zooplankton characteristics. Canadian Journal of Zoology 68:2214-2220.

Mayo, C.A. 1997. Emergency Surveillance, Reporting and Management Program in the Cape Cod Bay Critical Habitat. Final report to the Massachusetts Environmental Trust by the Center for Coastal Studies, 1997.

Mayo, C.A. 1998. Interim report to the Massachusetts Environmental Trust by the Center for Coastal Studies, June 15, 1998. 18 pp. + figures.

Mayo, C.A., E.G. Lyman and J. Finzi. 1999. Monitoring the Habitat of the North Atlantic Right Whale in Cape Cod Bay in 1999: An Evaluation of the Influence of Food Resources on Whale Distribution and Occurrence. Final report submitted to the Division of Marine Fisheries, Commonwealth of Massachusetts, Boston, MA. October 1999. Contract No. SCFWE3000-8365027 and to the Massachusetts Environmental Trust.

Mayo, C.A., E.G. Lyman and A. DeLorenzo. 2000. Monitoring the Habitat of the North Atlantic Right Whale in Cape Cod Bay in 2000 and Comparison of Seasonal Caloric Availability in Cape Cod Bay with North Atlantic Right Whale Calving Rates: 1984 – 2000. Final report submitted to the Division of Marine Fisheries, Commonwealth of Massachusetts, Boston, MA. October 2000. Contract No. SCFWE3000-8365027 and to the Massachusetts Environmental Trust.

Mayo, C., M. Brown, A. DeLorenzo and M. Bessinger. 2001a. Using Food Density to Predict Right Whale Occurrence and Movements in Cape Cod Bay: 2001. A final

report to the Massachusetts Environmental Trust and Division of Marine Fisheries, 31 October 2001.

Mayo, C.A., A. DeLorenzo and E. Lyman. 2001b. Monitoring the Habitat of the North Atlantic Right Whale in Cape Cod Bay in 2001. A final report to the Massachusetts Environmental Trust, 31 October 2001.

Mayo, C.A. and M. Bessinger. 2002. Right Whale Occurrence and Habitat Measures in Cape Cod Bay: during a year of change. Chapter two in the final report submitted to the Division of Marine Fisheries, Commonwealth of Massachusetts. Center for Coastal Studies, September 2002.

Mayo, C.A., O.C. Nichols, M.K. Bessinger, M.K. Marx, C.L. Browning and M.W. Brown 2004. Surveillance, Monitoring and Management of North Atlantic Right Whale in Cape Cod Bay and adjacent waters in 2004. Final report submitted to the Division of Marine Fisheries, Commonwealth of Massachusetts, Boston, MA. December 2004.

Mitchell, E.D. and R.R. Reeves. 1983. Catch history, abundance and present status of northwest Atlantic humpback whale. Reports of the International Whaling Commission (Special Issue 5):153-212.

National Marine Fisheries Service (NMFS). 1991. Final recovery plan for the Northern right whale (*Eubalaena glacialis*). NOAA/NMFS, Washington, D.C. 86 pp.

Nichols, O.C. and H.L. Kite-Powell. 2005. Analysis of Risk to North Atlantic Right Whales (*Eubalaena glacialis*) from shipping traffic in Cape Cod Bay. Northeast Fisheries Sciences Center, Final Report, February 2005, 20 pp.

Oleson E. M., J. Calambokidis, W. C. Burgess, M. A . McDonald, C. A. LeDuc and J.A. Hildebrand. 2007. Behavioral context of call production by eastern North Pacific blue whales. Mar Ecol Prog Ser 330:269–284

Parks S.E. 2003. Acoustic Communication in the north Atlantic right whale (*Eubalaena glacialis*). PhD, Woods Hole.

Parks S. E. and P.L. Tyack. 2005. Sound production by North Atlantic right whales (*Eubalaena glacialis*) in surface active groups. J. Acoust. Soc. Am. 117:3297-3306.

Parks S. E. and C. W. Clark. 2007. Acoustic communication: Social sounds and the potential impacts of noise. 310-332 in: S. D. Kraus, Rolland R. M., eds The Urban Whale: North Atlantic Right Whales at the Crossroads. Harvard University Press, Cambridge, MA.

Payne R. and S. McVay. 1971. Songs of humpback whales. Science 173:585-597.

Payne, P.M., D.N. Wiley, S.B. Young, S.Pittman, P.J. Clapham and J.W. Jossi. 1990. Recent fluctuations in the abundance of baleen whales in the southern Gulf of Maine in relation to changes in selected prey. Fishery Bulletin 88:687-696.

Payne, R., O. Brazier, E.M. Dorsey, J.S. Perkins, V.J. Rowntree and A. Titus. 1983. External features in southern right whales (*Eubalaena australis*) and their use in identifying individuals, pp. 371-445 *in* R. Payne (ed.) Communication and Behavior of Whales. AAAS Selected Symposium 76. Westview Press. Boulder, CO.

Pettis, H.M., R. Rolland, P.K. Hamilton, S. Brault, A.R. Knowlton and S.D. Kraus. 2004. Visual health assessment of North Atlantic right whales *(Eubalaena glacialis*) using photographs. Canadian Journal of Zoology 82(1):8-19.

Reeves, R.R., J.M. Breiwick and E.D. Mitchell. 1999. History of whaling and estimated kills of right whales, *Balaena glacialis*, in the northeastern United States, 1620-1924. Marine Fisheries Review 61(3):1-36.

Reeves, R.R., T.D. Smith, R.L. Webb, J. Robbins and P.J. Clapham. 2002. Humpback and fin whaling in the Gulf of Maine from 1800 to 1918. Marine Fisheries Review 64(1):1-12.

Robbins J., J. Kenney, S. Landry, E. Lyman and D.K. Mattila. 2007. Reliability of eyewitness reports of large whale entanglements. IWC, SC/59/BC2.

Schevill, W.E., W.A. Watkins and K.E. Moore. 1986. Status of *Eubalaena glacialis* off Cape Cod. Reports of the International Whaling Commission (Special Issue 10):79-82.

Scott, G.P. and J.R. Gilbert. 1982. Problems and progress in the US BLM-sponsored CETAP surveys. Reports of the International Whaling Commission 32:587-600.

Watkins, W.A. and W.E. Schevill. 1979. Aerial observation of feeding behavior in four baleen whales: *Eubalaena glacialis, Balaenoptera borealis, Megaptera novaeanliae* and *Balaenoptera physalus*. Journal of Mammalogy (60):155-163.

Winn, H.E., C.A. Price and P.W. Sorenson. 1986. The distributional biology of the right whale *Eubalaena glacialis* in the western North Atlantic. Reports of the International Whaling Commission (Special Issue 10):129-138.

Zar J. H. 1996. Biostatistical analysis. Prentice-Hall International, INC.

APPENDIX I: Tables

Table Ia: Aerial survey track line coordinates for CCB & adjacent waters; (b) Tracks east of the Cape.

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	21
2	42° 05.0	-70° 36.3	-70° 15.8 15	15
3	42° 03.5	-70° 36.8	-70° 17.0 15	15
4	42° 02.0	-70° 35.7	-70° 07.7 21	21
5	42° 00.5	-70° 34.2	-70° 07.0 20	20
6	41° 59.0	-70° 34.2	-70° 06.6 21	21
7	41° 57.5	-70° 34.2	-70° 06.6 21	21
8	41° 56.0	-70° 31.6	-70° 06.3 19	19
9	41° 54.5	-70° 30.9	-70° 06.3 18	18
10	41° 53.0	-70° 30.0	-70° 06.1 18	18
11	41° 51.5	-70° 29.5	-70° 06.1 18	18
12	41° 50.0	-70° 30.3	-70° 06.1 18	18
13	41° 48.5	-70° 30.2	-70° 06.1 18	18
14	41° 47.0	-70° 28.3	-70° 06.1 17	17
15	41° 45.5	-70° 26.5	-70° 11.4 11	11
16	41° 40.0	-69° 52.0 35		35
Track line miles in Cape Cod Bay (3-15)				**235**
Track line miles outside Cape Cod Bay (1, 2, 16)				**71**
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 Ib: Aerial survey track lines east of the Cape.

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° 35.0	15
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
9	41° 44.0	-69° 53.0	-69° 35.0	13
10	41° 41.0	-69° 53.0	-69° 35.0	13
11	41° 38.0	-69° 53.0	-69° 35.0	13
12	41° 35.0	-69° 53.0	-69° 35.0	13
Track line miles for East of CCB survey (tracks 1-12)				**184**
Total survey including transit and cross-legs				**~ 252**

Table II: Marine mammal sightings, survey time and track line distance covered for each aerial survey of CCB and adjacent waters in 2008. E indicates track lines east of the Cape. See legend below table for species abbreviations.

Survey#	Date	Eg Sighted	Eg Photo'd	Ba	Bp	Bb	Mn	UNLW	La	Dd	Pp	UNDO	UNSE	Pv	Hg	Hobbs time (h)	Time on watch (h)	Trackline Distance Flown (nm)	Tracks Completed
PCCS454	05-Jan	0	0	0	1	0	0	0	0	0	0	0	1	0	0	3.9	3.6	306	1-15, 16
PCCS455	12-Jan	1	1	0	2	0	3	0	0	0	0	4	0	1	0	5.1	4.7	271	1-12, 16
PCCS456	17-Jan	0	0	3	2	0	18	0	3	0	0	10	0	0	700	3.5	3.2	265	1-13 (E)
PCCS457	26- Jan	0	0	1	0	0	0	0	0	0	0	0	0	0	0	4.3	3.9	306	1-15, 16
PCCS458	03-Feb	2	2	0	0	0	0	0	0	0	0	20	0	0	0	4.2	3.9	306	1-15, 16
PCCS459	21-Feb	1	1	0	0	0	0	0	0	0	0	0	0	0	0	2.0	1.6	82	11-15
PCCS460	24-Feb	0	0	0	3	0	0	0	0	0	0	2	0	0	0	3.9	3.6	306	1-15, 16
PCCS461	25-Feb	11	11	0	2	0	0	0	0	0	0	1	0	0	0	3.4	3.2	184	1-12 (E)
PCCS462	29-Feb	5	5	0	4	0	0	0	0	0	0	2	0	0	0	5.0	4.7	295	1-14, 16
PCCS463	06-Mar	9	9	1	0	0	0	0	0	0	0	0	0	0	0	6.4	6.0	193	1-8, 16
PCCS464	11-Mar	11	11	0	0	0	0	0	0	0	0	0	0	0	0	7.2	6.6	126	8-14
PCCS465	14-Mar	13	12	2	1	0	0	0	0	0	0	2	0	0	0	8.7	8.4	105	1-5
PCCS466	18-Mar	7	7	0	3	0	2	0	0	0	0	0	301	0	0	5.6	5.2	306	1-15, 16
PCCS467	24-Mar	12	12	2	3	0	3	0	0	0	0	40	45	0	0	7.6	6.2	306	1-15, 16
PCCS468	27-Mar	14	14	0	1	0	0	0	0	0	0	0	3	0	0	5.1	4.1	133	8-15
PCCS469	08-Apr	34	34	0	0	0	0	0	0	0	0	0	0	0	0	6.0	3.7	74	11-14
PCCS470	09-Apr	47	45	0	1	0	0	0	0	0	0	1	0	0	0	8.1	7.2	94	11-15
PCCS471	10-Apr	49	47	1	10	0	3	0	0	0	0	150	0	0	0	5.8	4.9	107	1-4, 16
PCCS472	11-Apr	14	14	0	1	0	0	0	0	0	0	2	2	50	0	2.5	1.9	82	11-14
PCCS473	14-Apr	40	39	2	11	0	19	0	150	0	0	85	0	0	0	6.5	5.8	161	1-6, 16
PCCS474	15-Apr	64	59	0	1	0	0	2	0	0	1	0	3	0	0	8.3	7.0	158	7-15
PCCS475	16-Apr	12	12	8	4	0	10	0	0	0	1	140	0	0	0	8.5	7.2	35	16

Survey#	Date	Eg Sighted	Eg Photo'd	Ba	Bp	Bb	Mn	UNLW	La	Dd	Pp	UNDO	UNSE	Pv	Hg	Hobbs time (h)	Time on watch (h)	Trackline Distance Flown (nm)	Tracks Completed
PCCS476	19-Apr	54	54	0	8	0	0	0	0	0	0	25	0	0	0	9.2	8.2	193	6-15
PCCS477	21-Apr	48	48	1	25	0	42	1	0	0	0	0	0	0	0	8.3	7.2	224	3-12
PCCS478	23-Apr	28	25	2	7	0	1	1	0	0	0	0	0	0	0	4.5	4.0	94	10-14
PCCS479	01-May	12	12	4	11	0	21	0	100	0	0	0	0	0	0	7.0	6.3	306	1-15, 16
PCCS480	06-May	0	0	3	14	0	30	0	0	0	0	0	1	0	0	4.3	3.6	306	1-15, 16
PCCS481	15-May	1	1	0	4	0	0	1	0	0	0	0	51	0	0	4.2	3.8	306	1-15, 16
Total All Surveys		**489**	**475**	**30**	**119**	**0**	**152**	**5**	**253**	**0**	**2**	**484**	**407**	**51**	**700**	**159.1**	**139.5**	**5630.00**	

Abbreviation	Common name
Eg	Right whale
Ba	Minke whale
Bp	Fin whale
Bb	Sei whale
Mn	Humpback whale
UNLW	Unidentified large whale
La	Atlantic white-sided dolphin
Dd	Common dolphin
Gm	Pilot whale
Pp	Harbor porpoise
UNDO	Unidentified dolphin/ porpoise
UNSE	Unidentified seal
Pv	Harbor seal
Hg	Grey seal

Table III: Right whale sightings, right whales photographed, survey time and track line distance covered for CCB (tracks 3-15 only).

Survey#	Date	Eg Sighted	Eg Photo'd	Ba	Bp	Bb	Mn	UNLW	La	Dd	Pp	UNDO	UNSE	Pv	Hg	Hours Flown	Distance flown (nm)	Tracks Completed
PCCS454	05-Jan	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2.9	235	3-15
PCCS455	12-Jan	1	1	0	0	0	0	0	0	0	0	4	0	1	0	3.5	189	3-12
PCCS456	17-Jan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0	0
PCCS457	26- Jan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.9	235	3-15
PCCS458	03-Feb	2	2	0	0	0	0	0	0	0	0	20	0	0	0	3.1	235	3-15
PCCS459	21-Feb	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1.6	82	11-15
PCCS460	24-Feb	0	0	0	0	0	0	0	0	0	0	2	0	0	0	2.7	235	3-15
PCCS461	25-Feb	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0	0
PCCS462	29-Feb	5	5	0	0	0	0	0	0	0	0	2	0	0	0	3.6	224	3-14
PCCS463	06-Mar	9	9	0	0	0	0	0	0	0	0	0	0	0	0	5.3	122	3-8
PCCS464	11-Mar	11	11	0	0	0	0	0	0	0	0	0	0	0	0	6.6	126	8-14
PCCS465	14-Mar	13	12	2	1	0	0	0	0	0	0	2	0	0	0	6.7	105	3-5
PCCS466	18-Mar	5	5	0	0	0	0	0	0	0	0	0	301	0	0	4.2	235	3-15
PCCS467	24-Mar	12	12	0	1	0	1	0	0	0	0	40	44	0	0	5.2	235	3-15
PCCS468	27-Mar	14	14	0	1	0	0	0	0	0	0	0	3	0	0	4.1	133	8-15
PCCS469	08-Apr	34	34	0	0	0	0	0	0	0	0	0	0	0	0	3.7	74	11-14
PCCS470	09-Apr	47	45	0	1	0	0	0	0	0	0	1	0	0	0	7.2	94	11-15
PCCS471	10-Apr	41	40	0	5	0	1	0	0	0	0	100	0	0	0	3.4	36	3-4
PCCS472	11-Apr	14	14	0	1	0	0	0	0	0	0	2	2	50	0	1.9	82	11-14
PCCS473	14-Apr	14	14	1	3	0	5	0	0	0	0	8	0	0	0	2.4	90	3-6
PCCS474	15-Apr	64	59	0	1	0	0	2	0	0	1	0	3	0	0	7.0	158	7-15
PCCS475	16-Apr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0	0
PCCS476	19-Apr	54	54	0	8	0	0	0	0	0	0	25	0	0	0	8.2	193	6-15
PCCS477	21-Apr	45	45	1	18	0	25	0	0	0	0	0	0	0	0	6.1	189	3-12
PCCS478	23-Apr	28	25	2	7	0	1	1	0	0	0	0	0	0	0	4.0	94	10-14
PCCS479	01-May	9	9	4	7	0	19	0	0	0	0	0	0	0	0	4.4	235	3-15
PCCS480	06-May	0	0	3	11	0	17	0	0	0	0	0	1	0	0	2.8	235	3-15
PCCS481	15-May	1	1	0	4	0	0	1	0	0	0	0	51	0	0	2.9	235	3-15
Total All Surveys		**425**	**413**	**13**	**69**	**0**	**69**	**4**	**0**	**0**	**1**	**206**	**406**	**51**	**0**	**106.4**	**4106**	

Table IV: Right whale sightings, right whales photographed, survey time and track line distance covered for adjacent waters (tracks 1, 2, 16 and tracks east of the Cape).

Survey#	Date	Eg Sighted	Eg Photo'd	Ba	Bp	Bb	Mn	UNLW	La	Dd	Pp	UNDO	UNSE	Pv	Hg	Hours Flown	Distance Flown (nm)	Tracks Completed
PCCS454	05-Jan	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0.7	71	1-2, 16
PCCS455	12-Jan	0	0	0	2	0	3	0	0	0	0	0	0	0	0	1.2	71	1-2, 16
PCCS456	17-Jan	0	0	3	2	0	18	0	3	0	0	10	0	0	700	3.2	265	1-13 (E)
PCCS457	26-Jan	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1.0	71	1-2, 16
PCCS458	03-Feb	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	71	1-2, 16
PCCS459	21-Feb	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0	-
PCCS460	24-Feb	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0.9	71	1-2, 16
PCCS461	25-Feb	10	10	0	0	0	0	0	0	0	0	1	0	0	0	3.2	184	1-12 (E)
PCCS462	29-Feb	0	0	0	4	0	0	0	0	0	0	0	0	0	0	1.1	71	1-2, 16
PCCS463	06-Mar	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0.7	71	1-2, 16
PCCS464	11-Mar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0	-
PCCS465	14-Mar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.7	0	-
PCCS466	18-Mar	2	2	0	3	0	2	0	0	0	0	0	0	0	0	1.0	71	1-2, 16
PCCS467	24-Mar	0	0	2	2	0	1	0	0	0	0	0	1	0	0	1.0	71	1-2, 16
PCCS468	27-Mar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0	-
PCCS469	08-Apr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0	-
PCCS470	09-Apr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0	-
PCCS471	10-Apr	8	7	1	5	0	2	0	0	0	0	50	0	0	0	1.5	71	1-2, 16
PCCS472	11-Apr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0	-
PCCS473	14-Apr	26	25	1	8	0	14	0	150	0	0	77	0	0	0	3.4	71	1-2, 16
PCCS474	15-Apr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0	-
PCCS475	16-Apr	12	12	8	4	0	10	0	0	0	1	140	0	0	0	7.2	35	16
PCCS476	19-Apr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0	-
PCCS477	21-Apr	3	3	0	7	0	17	1	0	0	0	0	0	0	0	1.1	35	-
PCCS478	23-Apr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0	-
PCCS479	01-May	3	3	0	4	0	2	0	100	0	0	0	0	0	0	1.9	71	1-2, 16
PCCS480	06-May	0	0	0	3	0	23	0	0	0	0	0	0	0	0	0.8	71	1-2, 16
PCCS481	15-May	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.9	71	1-2, 16
Total All Surveys		**64**	**62**	**17**	**48**	**0**	**92**	**1**	**253**	**0**	**1**	**278**	**1**	**0**	**700**	**33.0**	**1513.00**	

Table V: Opportunistic marine mammal sightings and survey time for all vessel-based habitat sampling cruises of CCB in 2008. Species abbreviations as for Table II.

Cruise	Date 2008	Eg Sighted	Eg Photo'd	Ba	Bp	Bb	Mn	UNLW	La	Dd	Pp	UNDO	UNSE	Pv	Hg	Hours At Sea
SW679	12 Jan	1	0	0	0	0	0	0	0	0	0	0	0	0	0	5.5
SW681	17 Jan	0	0	0	0	0	0	0	0	0	0	3	0	0	0	7.3
SW682	24 Jan	0	0	0	0	0	1	1	0	0	7	48	4	7	3	6.5
SW683	04 Feb	2	2	0	0	0	0	0	0	0	0	3	2	4	2	6.8
SW684	22 Feb	1	0	0	0	0	0	0	0	0	0	0	0	0	0	6.5
SW687	07 Mar	11	8	0	0	0	0	0	0	0	0	2	0	0	0	7.1
SW688	11 Mar	6	3	0	0	0	0	0	0	0	0	0	0	0	0	2.6
SW689	14 Mar	10	8	0	0	0	0	0	0	0	0	0	1	1	0	8.3
SW690	24 Mar	6	6	0	1	0	1	0	0	0	4	0	1	1	0	8.7
SW691	27 Mar	12	9	0	0	0	2	1	0	0	3	0	1	2	0	7.2
SW692	09 Apr	15	6	0	4	0	0	2	0	0	17	0	0	2	0	5.4
SW693	10 Apr	18	9	0	1	0	1	0	75	0	1	0	0	2	0	5.8
SW694	11 Apr	15	1	0	0	0	1	0	0	0	0	0	0	0	0	7.7
SW695	15 Apr	23	23	0	1	0	0	0	0	0	13	0	0	2	0	9.4
SW696	21 Apr	19	16	0	1	0	2	0	0	0	0	0	0	0	0	4.3
SW697	23 Apr	15	12	0	5	0	1	1	200	0	0	0	0	0	0	6.9
SW698	25 Apr	5	3	0	21	0	21	1	0	0	3	0	0	3	0	7.4
SW699	3 May	0	0	0	6	0	10	0	0	0	0	0	0	0	0	5.3
SW700	5 May	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.9
Total for all cruises	**19**	**159**	**106**	**0**	**40**	**0**	**40**	**1**	**0**	**0**	**48**	**56**	**9**	**24**	**5**	**123.2**

Table VI: Number of survey days, demographic composition and number of right whales identified in (a) all areas, (b) CCB and (c) adjacent waters, from aerial survey data, in two-week periods from January to late May, 2008. The values in these tables represent the minimum number of whales, as photo-analysis has not been finalized. (The total column is lower than the sum of each row, as many individual whales were sighted during multiple fortnightly periods. The shaded areas highlight fortnights when right whales were seen.)

(a) All areas

Two week intervals	1Jan-14Jan	15Jan-28Jan	29Jan-11Feb	12Feb-25Feb	26Feb-11Mar	12Mar-25Mar	26Mar-8Apr	9Apr-22Apr	23Apr-6May	7May-20May	Total
Number of aerial surveys	2	2	1	3	3	3	2	8	3	1	28
Number of individuals identified	1	0	2	11	19	26	36	120	21	1	237
Number of new individuals	1	0	2	11	15	18	24	73	4	0	148
Demographics											
Male	0	0	0	8	7	10	22	66	9	0	122
Female	1	0	1	1	9	11	10	29	5	1	68
Unknown Sex	0	0	1	2	3	5	4	25	7	0	47
Calf	0	0	0	0	0	0	0	3	1	0	4
Juvenile	0	0	1	0	3	4	3	16	3	0	30
Adult	1	0	1	9	16	21	31	94	15	1	189
Unknown Age	0	0	0	2	0	1	2	7	2	0	14

(b) Cape Cod Bay

Two week intervals	1Jan-14Jan	15Jan-28Jan	29Jan-11Feb	12Feb-25Feb	26Feb-11Mar	12Mar-25Mar	26Mar-8Apr	9Apr-22Apr	23Apr-6May	7May-20May	Total
Number of aerial surveys	2	2	1	2	3	3	2	7	3	1	26
Number of individuals identified	1	0	1	2	19	24	36	112	19	1	215
Number of new individuals	1	0	1	2	16	17	24	72	4	0	137
Demographics											
Male	0	0	0	0	7	10	22	62	8	0	109
Female	1	0	1	1	9	9	10	26	5	1	63
Unknown Sex	0	0	0	1	3	5	4	24	6	0	43
Calf	0	0	0	0	0	0	0	3	1	0	4
Juvenile	0	0	0	0	3	4	3	15	3	0	28
Adult	1	0	1	2	16	19	31	85	13	1	169
Unknown Age	0	0	0	0	0	1	2	9	2	0	14

(c) Adjacent waters

Two week intervals	1Jan-14Jan	15Jan-28Jan	29Jan-11Feb	12Feb-25Feb	26Feb-11Mar	12Mar-25Mar	26Mar-8Apr	9Apr-22Apr	23Apr-6May	7May-20May	Total
Number of aerial surveys	2	0	0	2	2	3	1	4	2	1	17
Number of individuals identified	0	0	0	9	0	2	0	30	2	0	43
Number of new individuals	0	0	0	9	0	2	0	30	2	0	43
Demographics							0				
Male	0	0	0	6	0	0	0	15	1	0	22
Female	0	0	0	0	0	2	0	11	0	0	13
Unknown Sex	0	0	0	3	0	0	0	4	1	0	8
Calf	0	0	0	0	0	0	0	0	0	0	0
Juvenile	0	0	0	0	0	0	0	5	0	0	5
Adult	0	0	0	7	0	2	0	25	2	0	36
Unknown Age	0	0	0	2	0	0	0	0	0	0	2

Table VII: Sightings records of identified right whales seen in CCB and adjacent waters during aerial surveys, January 12 to May 15, 2008. F: female, M: male, J: juvenile, C: calf, U: unknown. B: sighting in CCB (tracks 3-15), N: sighting on tracks 1-2, E: sighting on track 16 or eastern track lines. Incomplete surveys of the bay are color-coded: yellow columns indicate dates of disentanglement support; blue indicates deteriorating weather conditions and green indicates surveys limited by daylight hours.

Whale ID	Sex	Age category	5-Jan-08	12-Jan-08	17-Jan-08	26-Jan-08	3-Feb-08	21-Feb-08	24-Feb-08	25-Feb-08	29-Feb-08	6-Mar-08	11-Mar-08	14-Mar-08	18-Mar-08	24-Mar-08	27-Mar-08	8-Apr-08	9-Apr-08	10-Apr-08	11-Apr-08	14-Apr-08	15-Apr-08	16-Apr-08	19-Apr-08	21-Apr-08	23-Apr-08	1-May-08	6-May-08	15-May-08		# of days sighted	Time span first - last sighting +1 (days)
2645	F	A		B									B				B	B	B	B											6	31
2007calfof 2460	U	J					B																								1	1
1968	F	A					B															E									2	72
1503	F	A						B			B	B																			3	15
2720	U	A								B		B		B									B					E			5	67
2740	M	A								E																					1	1
3421	M	A								E																					1	1
2640	M	A								E																					1	1
3110	M	A								E																					1	1
3140	M	A								E											B	B									3	50
Intermatch C8YG	U	A								E																					1	1
3423	U	U								E																					1	1
2304	M	A								E			B	B	B		B								B						6	55
3193	U	U								E																					1	1
2530	M	A									B																				1	1
2614	F	A									B		B	B																	3	16
2430	F	A									B									B			B								3	48
1301	F	A									B	B		B						N											4	42
2303	M	A										B					B	B		N		B	B				B				7	49
1507	M	A										B						B	B		B										4	37
2006calfof 2123	U	J										B	B	B									B		B						5	45
2370	U	A										B	B			B	B			B											5	36

Whale ID	Sex	Age category	5-Jan-08	12-Jan-08	17-Jan-08	26-Jan-08	3-Feb-08	21-Feb-08	24-Feb-08	25-Feb-08	29-Feb-08	6-Mar-08	11-Mar-08	14-Mar-08	18-Mar-08	24-Mar-08	27-Mar-08	8-Apr-08	9-Apr-08	10-Apr-08	11-Apr-08	14-Apr-08	15-Apr-08	16-Apr-08	19-Apr-08	21-Apr-08	23-Apr-08	1-May-08	6-May-08	15-May-08		# of days sighted	Time span first - last sighting +1 (days)
1140	F	A										B	B	B																	3	9
2123	F	A											B						B	B											3	31
1820	M	A											B								B										2	32
2006calfof 2029	M	J											B						B						B						3	40
1716	M	A											B																		1	1
1911	F	A											B	B				B		B		E			B	B					7	42
3520	F	J											B				B		B		B				B	B		B			7	52
1310	F	A												B																	1	1
3314	F	A												B	B				B			N			B						5	37
1980	M	A												B										N							2	34
2540	M	A													B		B		B			N									4	28
1706	F	A													B					N			B								3	29
2320	F	A													B																1	1
1970	F	A													E																1	1
SE07BK08	U	U														B															1	1
2770	M	A														B				B		N									3	22
3510	M	J														B		B		B		B									4	22
2681	M	A														B	B	B													3	16
2310	M	A														B				N											2	18
2006calfof 1946	U	J														B								B							2	27
3302	M	J														B					B	N									3	22
2340	M	A														B															1	1
3208	M	A														B		B	B				B								4	23
1249	M	A															B	B		B			B			B					5	26
2027	M	A															B	B													2	13
1327	M	A															B		B			E			B						4	24
3530	M	U															B		B	B			B		B						5	24

Whale ID	Sex	Age category	5-Jan-08	12-Jan-08	17-Jan-08	26-Jan-08	3-Feb-08	21-Feb-08	24-Feb-08	25-Feb-08	29-Feb-08	6-Mar-08	11-Mar-08	14-Mar-08	18-Mar-08	24-Mar-08	27-Mar-08	8-Apr-08	9-Apr-08	10-Apr-08	11-Apr-08	14-Apr-08	15-Apr-08	16-Apr-08	19-Apr-08	21-Apr-08	23-Apr-08	1-May-08	6-May-08	15-May-08		# of days sighted	Time span first - last sighting +1 (days)
2140	M	A															B		B				B								3	20
2710	F	A												B				B	B											B		4	63
1122	M	A															B	B														2	13
3460	U	U																B	B							B						3	14
3380	M	A																B	B	B			B									4	8
2007calfof 1710	U	J																B	B		B		B									4	8
2830	M	A																B	B						B							3	12
1409	M	A																B					B		B	B						4	14
3405	F	A																B														1	1
2705	M	A																B				E										2	7
BK56	U	A																B	B				B		B							4	12
1609	M	A																B														1	1
3279	M	A																B	B						B		B					4	16
2440	M	A																B	B							B						3	14
3329	F	A																B		B				N								3	9
3440	F	A																B					B		B							3	12
3040	M	A																B	B	B												3	3
3390	F	A																B		B					B							3	12
2940	M	A																B							B							2	12
3503	F	A																B					B		B							3	12
3301	M	A																	B	B						B							3	13
CT50	U	U																	B				B										2	7
2427	M	A																	B			B					B						3	15
1317	M	A																	B			E		N									3	8
3411	F	A																	B	B		E			B								4	11
3360	F	A																	B			B	B										3	7
2010	M	A																	B														1	1

Whale ID	Sex	Age category	5-Jan-08	12-Jan-08	17-Jan-08	26-Jan-08	3-Feb-08	21-Feb-08	24-Feb-08	25-Feb-08	29-Feb-08	6-Mar-08	11-Mar-08	14-Mar-08	18-Mar-08	24-Mar-08	27-Mar-08	8-Apr-08	9-Apr-08	10-Apr-08	11-Apr-08	14-Apr-08	15-Apr-08	16-Apr-08	19-Apr-08	21-Apr-08	23-Apr-08	1-May-08	6-May-08	15-May-08		# of days sighted	Time span first - last sighting +1 (days)
1934	F	A																	B	B											2	2
2743	M	A																	B		B					B	B				4	15
1712	M	A																	B		B	N	B								4	7
2006calfof 2791	U	U																	B												1	1
1036	U	A																	B												1	1
1032	M	A																	B				B		B	B		E			5	23
3546	U	U																	B							B					2	13
3541	M	J																	B												1	1
1103	M	A																	B												1	1
3442	M	A																	B		B		B				B				4	15
1207	M	A																	B												1	1
2135	M	A																	B			N									2	6
1607	U	U																	B							N					2	13
BK39	U	U																	B	B			B								3	7
3192	U	A																	B	B			B								3	7
2007calfof 2430	U	U																		N	B		B				B				4	14
1209	F	A																		N											1	1
2215	M	A																		N		E									2	5
3260	F	A																		B											1	1
2006calfof 2660	U	U																		B		E									2	5
2790	F	A																		B	B		B		B	B					5	12
2008calfof 2790	U	C																		B	B		B		B	B					5	12
2601	F	A																		B		B		N							3	7
3323	M	A																		B			B			B					3	12
1971	M	A																B		B											2	3
3308	M	A																		B											1	1
1817	F	A																		B											1	1

Whale ID	Sex	Age category	5-Jan-08	12-Jan-08	17-Jan-08	26-Jan-08	3-Feb-08	21-Feb-08	24-Feb-08	25-Feb-08	29-Feb-08	6-Mar-08	11-Mar-08	14-Mar-08	18-Mar-08	24-Mar-08	27-Mar-08	8-Apr-08	9-Apr-08	10-Apr-08	11-Apr-08	14-Apr-08	15-Apr-08	16-Apr-08	19-Apr-08	21-Apr-08	23-Apr-08	1-May-08	6-May-08	15-May-08		# of days sighted	Time span first - last sighting +1 (days)
1429	M	A																		B		B	B								3	6
1821	M	A																		B			B				B	B			4	14
3343	U	U																		B		B				B					3	12
1428	M	A																		B			B								2	6
2006calfof 2503	U	J																		B				N		B		B			4	22
BK52	U	U																			B		B		B						3	9
1218	M	A																				E			B	B					3	8
2920	U	A																				N	B		B	B	B				5	10
3180	F	A																				B									1	1
1245	F	A																				B			B	B	B				4	10
2008calfof 1245	U	C																				B			B	B	B				4	10
3050	U	A																				B									1	1
3230	F	A																				B									1	1
2410	M	A																				B	B		B						3	6
3120	M	A																				B	B		B						3	6
3346	M	A																					B								1	1
3610	U	U																					B					B			2	17
1802	F	A																					B		B	B					3	7
2008calfof 1802	U	C																							B	B					2	3
1328	M	A																					B								1	1
1150	M	A																					B			B	B				3	9
1250	M	A																					B				B				2	9
1720	U	A																					B		B						2	5
2406	M	A																					B								1	1
1332	M	A																					B			B					2	7
1427	M	A																						N	B						2	4
3420	F	J																						N	B						2	4

Whale ID	Sex	Age category	5-Jan-08	12-Jan-08	17-Jan-08	26-Jan-08	3-Feb-08	21-Feb-08	24-Feb-08	25-Feb-08	29-Feb-08	6-Mar-08	11-Mar-08	14-Mar-08	18-Mar-08	24-Mar-08	27-Mar-08	8-Apr-08	9-Apr-08	10-Apr-08	11-Apr-08	14-Apr-08	15-Apr-08	16-Apr-08	19-Apr-08	21-Apr-08	23-Apr-08	1-May-08	6-May-08	15-May-08		# of days sighted	Time span first - last sighting +1 (days)
1019	M	A																						B	B						2	3
2750	M	A																						B							1	1
1167	M	A																						B							1	1
2910	M	A																						B							1	1
3466	M	J																							B						1	1
2608	M	A																							B						1	1
1271	M	A																							B						1	1
1511	M	A																							B						1	1
1625	M	A																							B						1	1
1804	M	A																							B						1	1
3240	F	A																								B					1	1
3103	F	A																								B					1	1
2042	F	A																								B					1	1
2145	F	A												B	E																2	5
2460	F	A																	B												1	1
CT42	U	U																								B					1	1
3108	F	A																		N											1	1
3414	M	J																							B						1	1

Section 2 Appendices

Appendices I-IV Right Whale Habitat Studies
2008

Appendix I

Spatial and Temporal Plots of Cape Cod Bay Surface and Water Column Zooplankton
2008

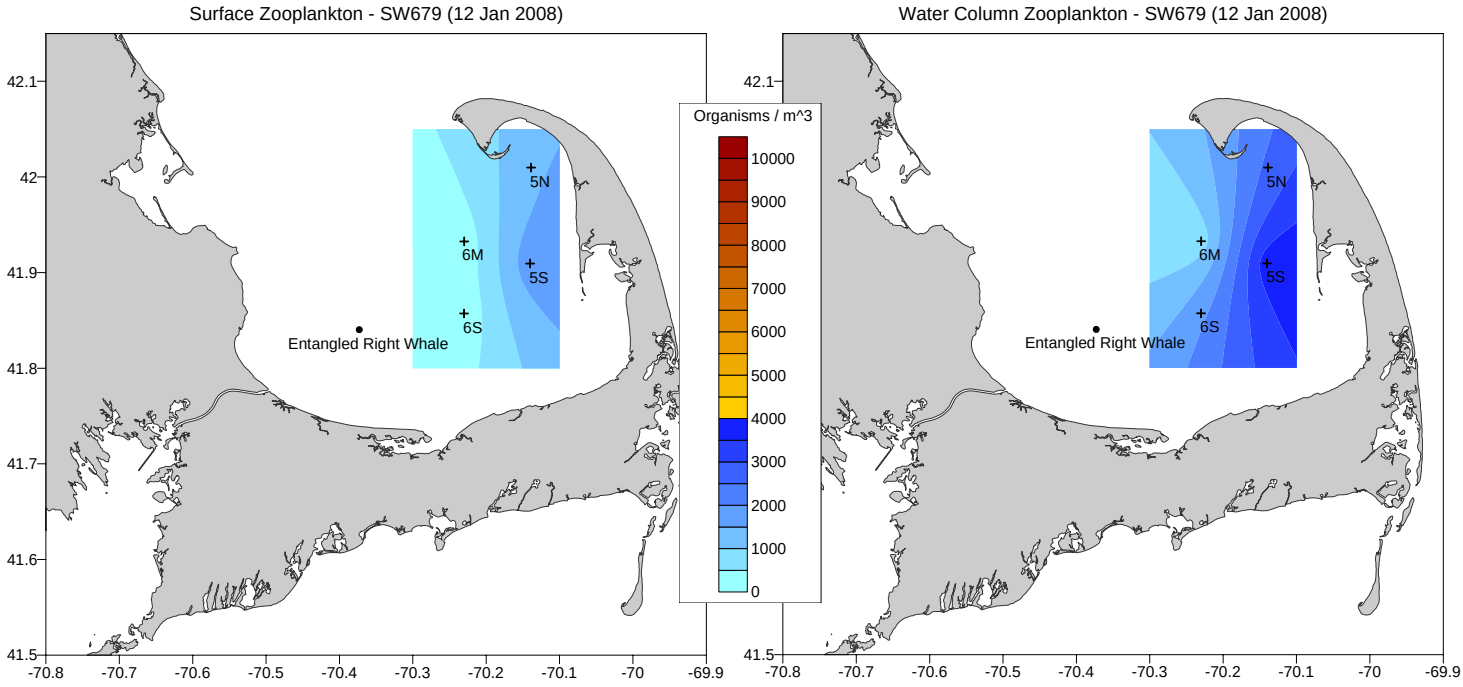


Figure A1. Zooplankton density distribution in Cape Cod Bay on 12 January 2008 from surface (left) and water column (right) collections. Sampling station locations are indicated with a "+" symbol. Approximate right whale locations are labeled with a "•" symbol and the number of individuals sighted, generally within a 2nm area. Densities were calculated from enumeration of regular station samples only, though special stations that were sampled are shown.

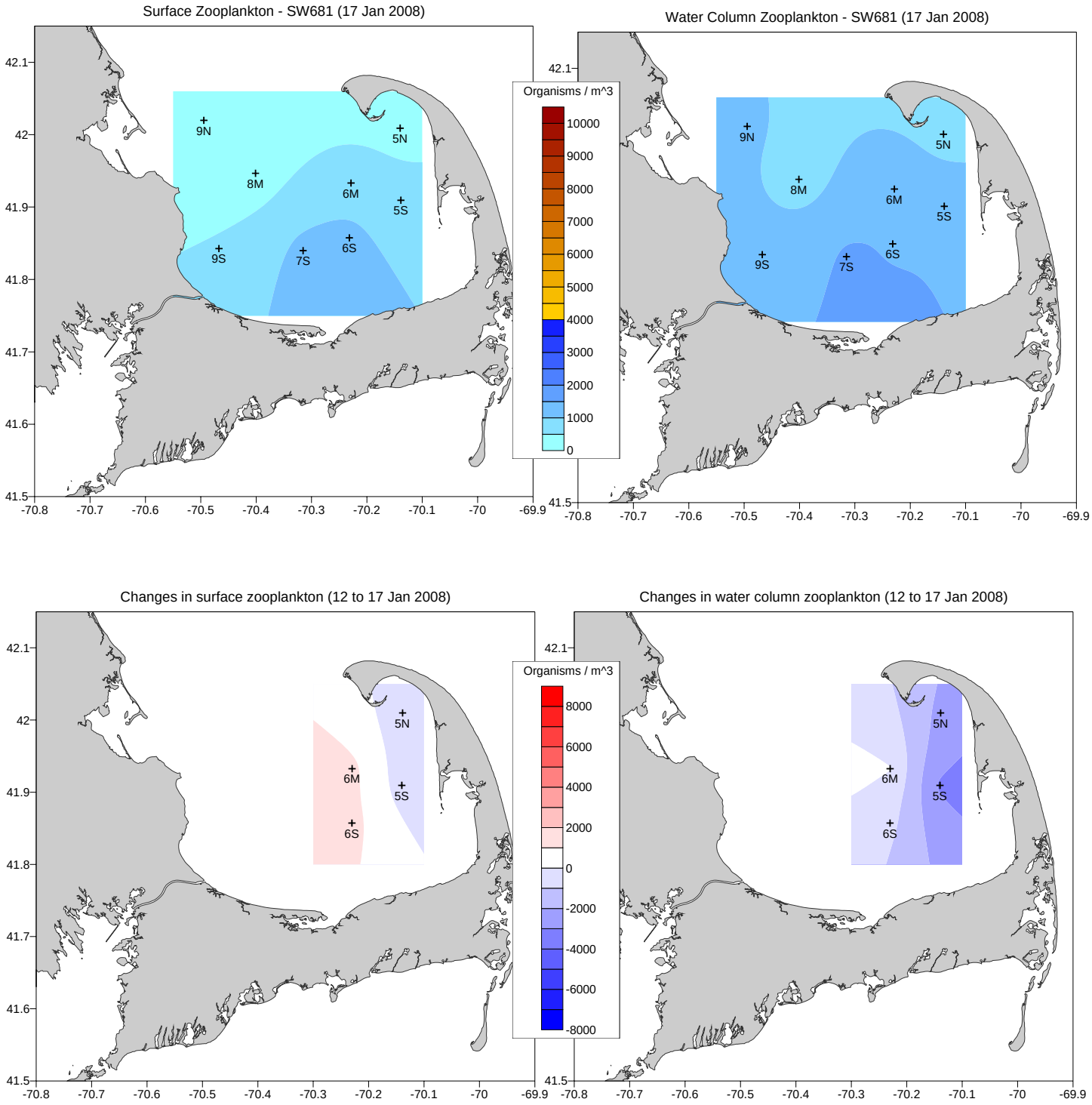


Figure A2. *Upper plots*: **Zooplankton density distribution** in Cape Cod Bay on 17 January 2008 from surface (left) and water column (right) collections. *Lower plots*: Spatial distribution of **zooplankton density changes** between 12 and 17 January 2008, with surface density changes displayed at left and water column density changes presented at right. Sampling station locations are indicated with a "+" symbol. Densities were calculated from enumeration of regular station samples only, though special stations that were sampled are shown.

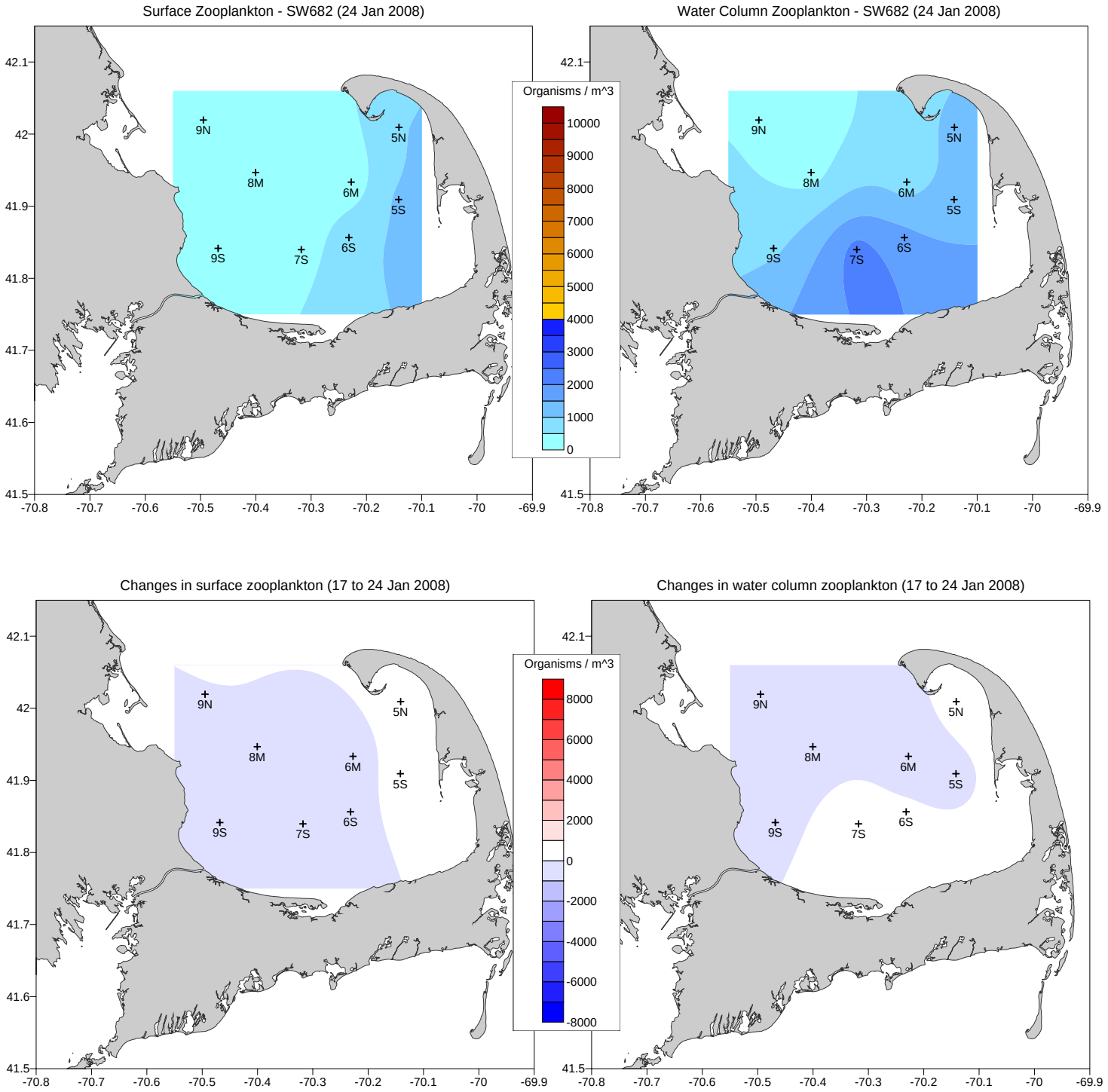


Figure A3. *Upper plots*: **Zooplankton density distribution** in Cape Cod Bay on 24 January 2008 from surface (left) and water column (right) collections. *Lower plots*: Spatial distribution of **zooplankton density changes** between 17 and 24 January 2008, with surface density changes displayed at left and water column density changes presented at right. Sampling station locations are indicated with a "+" symbol. Densities were calculated from enumeration of regular station samples only, though special stations that were sampled are shown.

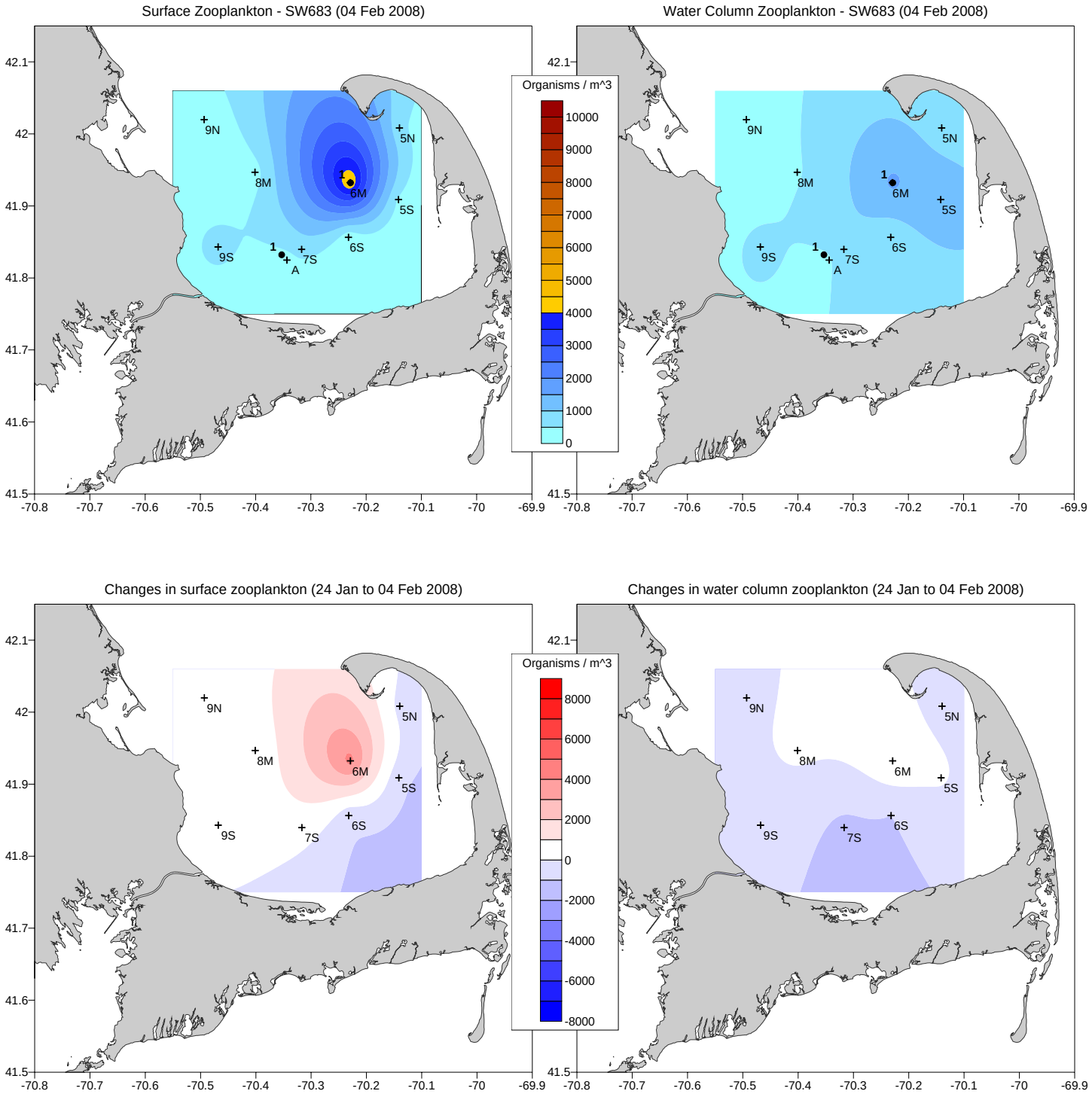


Figure A4. *Upper plots*: **Zooplankton density distribution** in Cape Cod Bay on 04 February 2008 from surface (left) and water column (right) collections. *Lower plots*: Spatial distribution of **zooplankton density changes** between 24 January and 04 February 2008, with surface density changes displayed at left and water column density changes presented at right. Sampling station locations are indicated with a "+" symbol. Approximate right whale locations are labeled with a "•" symbol and the number of individuals sighted, generally within a 2nm area. Densities were calculated from enumeration of regular station samples only, though special stations that were sampled are shown.

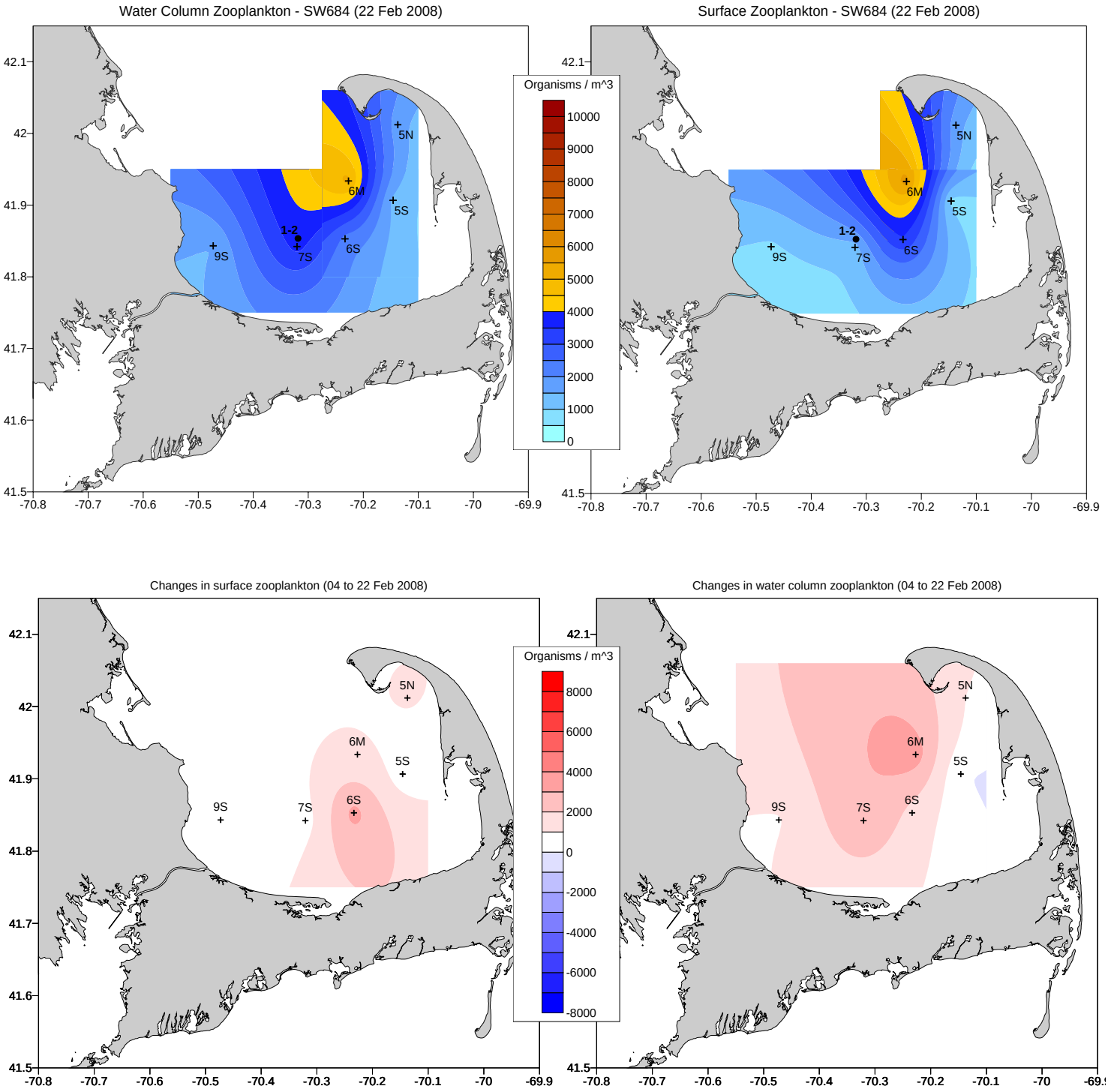


Figure A5. *Upper plots*: **Zooplankton density distribution** in Cape Cod Bay on 22 February 2008 from surface (left) and water column (right) collections. *Lower plots*: Spatial distribution of **zooplankton density changes** between 04 and 22 February 2008, with surface density changes displayed at left and water column density changes presented at right. Sampling station locations are indicated with a "+" symbol. Approximate right whale locations are labeled with a "•" symbol and the number of individuals sighted, generally within a 2nm area. Densities were calculated from enumeration of regular station samples only, though special stations that were sampled are shown.

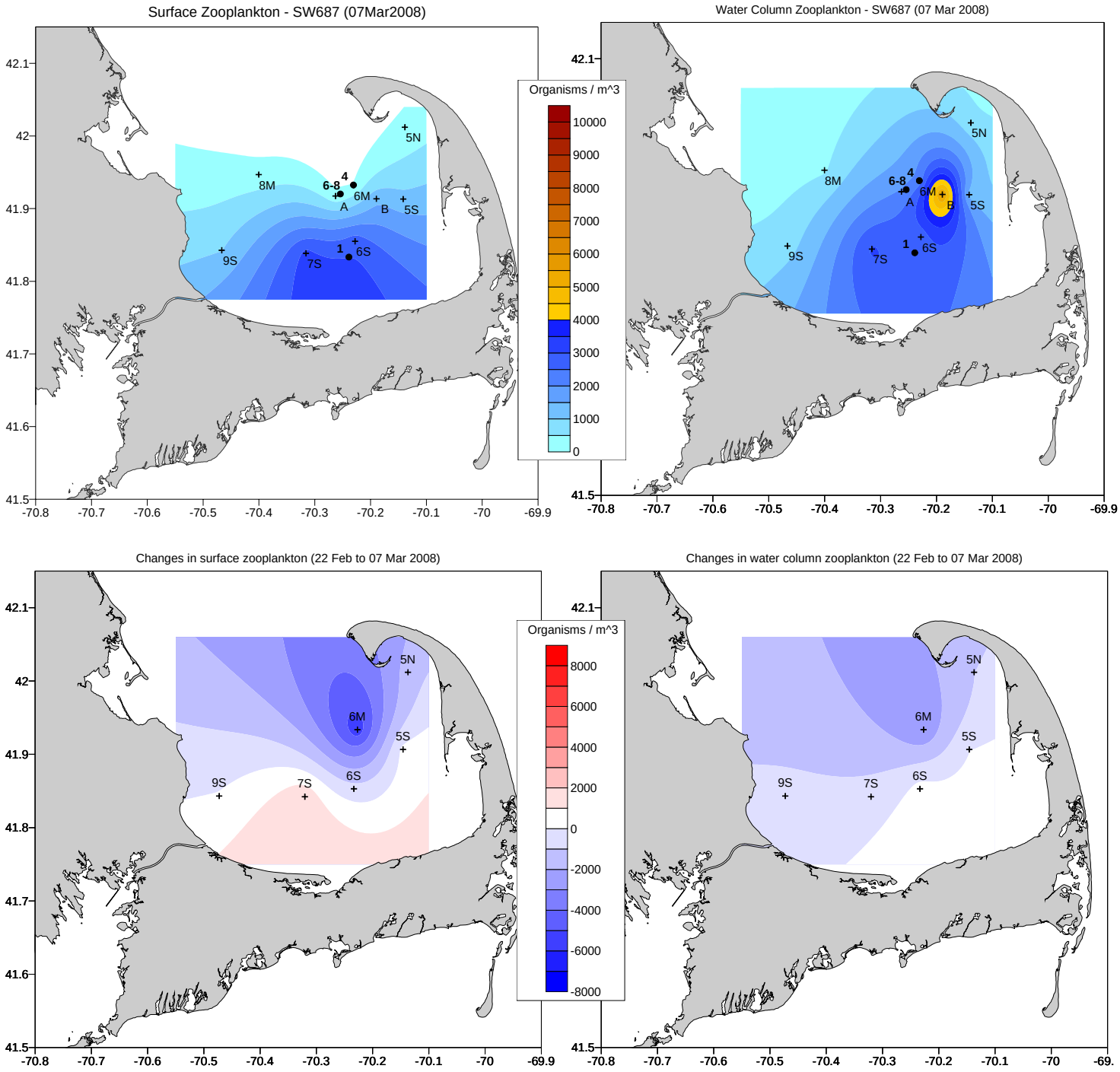


Figure A6. *Upper plots*: **Zooplankton density distribution** in Cape Cod Bay on 07 March 2008 from surface (left) and water column (right) collections. *Lower plots*: Spatial distribution of **zooplankton density changes** between 22 February and 07 March 2008, with surface density changes displayed at left and water column density changes presented at right. Sampling station locations are indicated with a "+" symbol. Approximate right whale locations are labeled with a "•" symbol and the number of individuals sighted, generally within a 2nm area. Densities were calculated from enumeration of regular station samples only, though special stations that were sampled are shown.

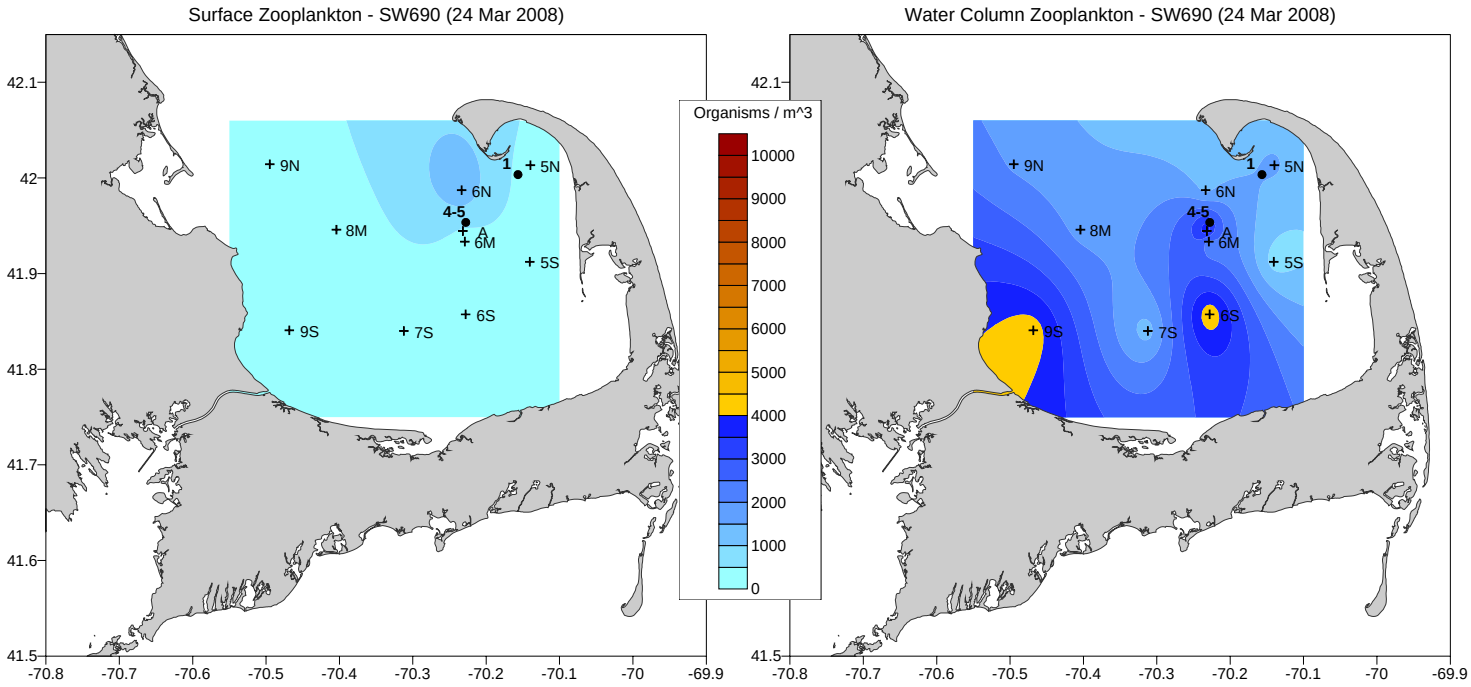


Figure A7. Zooplankton density distribution in Cape Cod Bay on 24 March 2008 from surface (left) and water column (right) collections. Sampling station locations are indicated with a "+" symbol. Approximate right whale locations are labeled with a "•" symbol and the number of individuals sighted, generally within a 2nm area. Densities were calculated from enumeration of regular station samples only, though special stations that were sampled are shown.

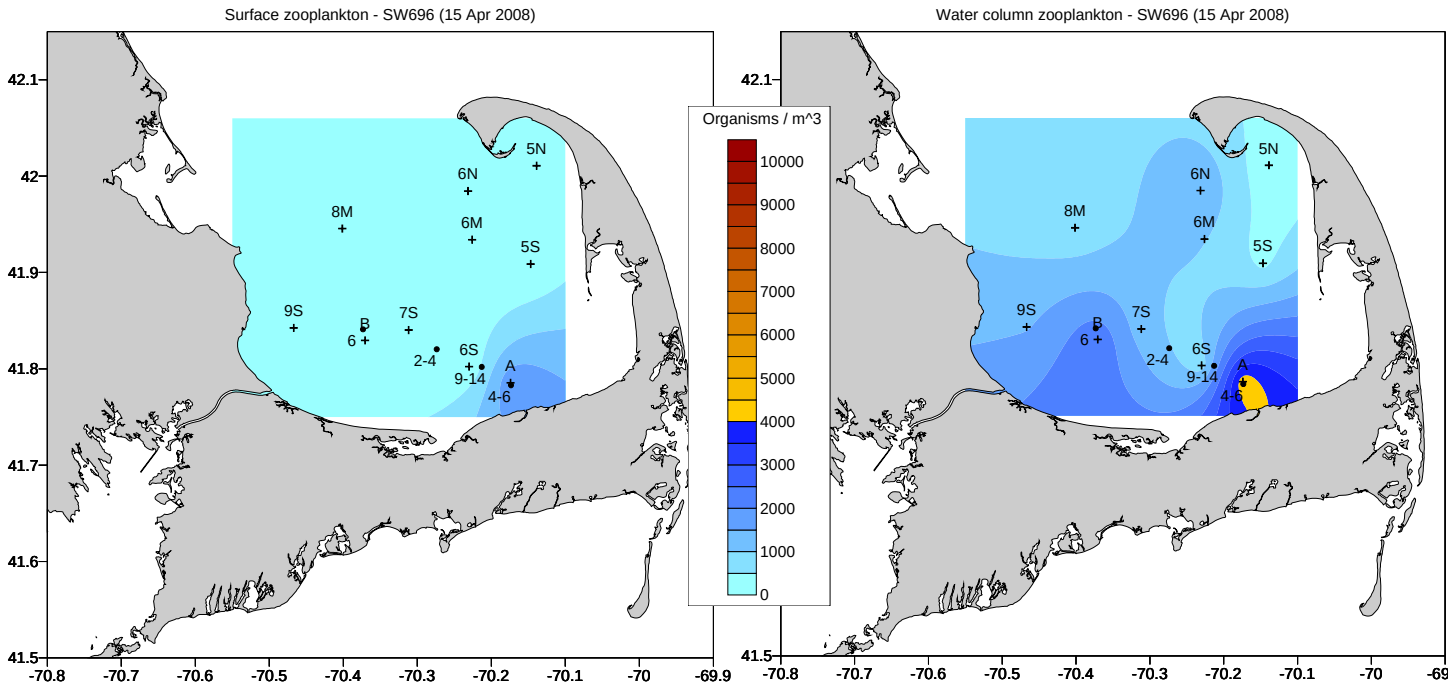


Figure A8. Zooplankton density distribution in Cape Cod Bay on 15 April 2008 from surface (left) and water column (right) collections. Sampling station locations are indicated with a "+" symbol. Approximate right whale locations are labeled with a "•" symbol and the number of individuals sighted, generally within a 2nm area. Densities were calculated from enumeration of regular station samples only, though special stations that were sampled are shown.

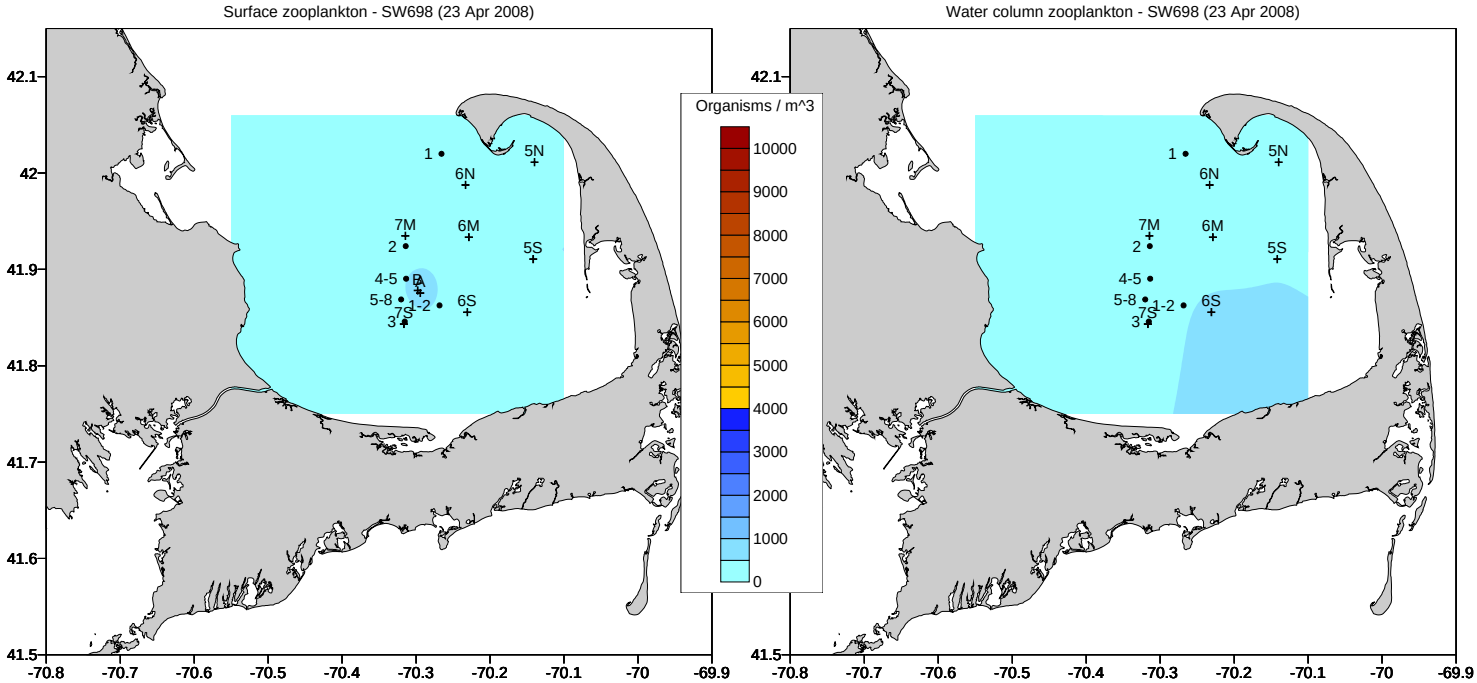


Figure A9. Zooplankton density distribution in Cape Cod Bay on 23 April 2008 from surface (left) and water column (right) collections. Sampling station locations are indicated with a "+" symbol. Approximate right whale locations are labeled with a "•" symbol and the number of individuals sighted, generally within a 2nm area. Densities were calculated from enumeration of regular station samples only, though special stations that were sampled are shown.

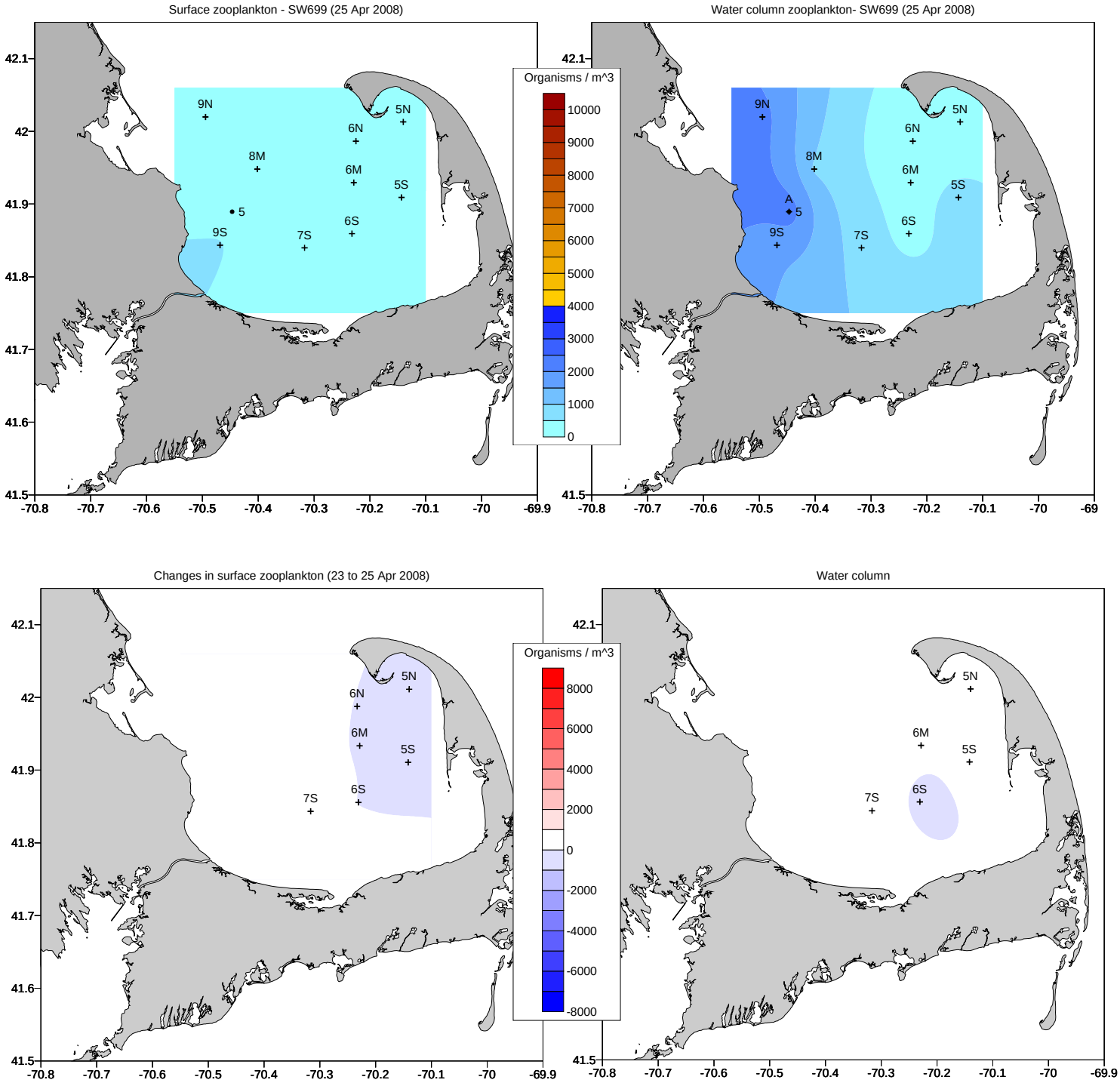


Figure A10. *Upper plots*: **Zooplankton density distribution** in Cape Cod Bay on 25 April 2008 from surface (left) and water column (right) collections. *Lower plots*: Spatial distribution of **zooplankton density changes** between 23 April and 25 April 2008, with surface density changes displayed at left and water column density changes presented at right. Sampling station locations are indicated with a "+" symbol. Approximate right whale locations are labeled with a "•" symbol and the number of individuals sighted, generally within a 2nm area. Densities were calculated from enumeration of regular station samples only, though special stations that were sampled are shown.

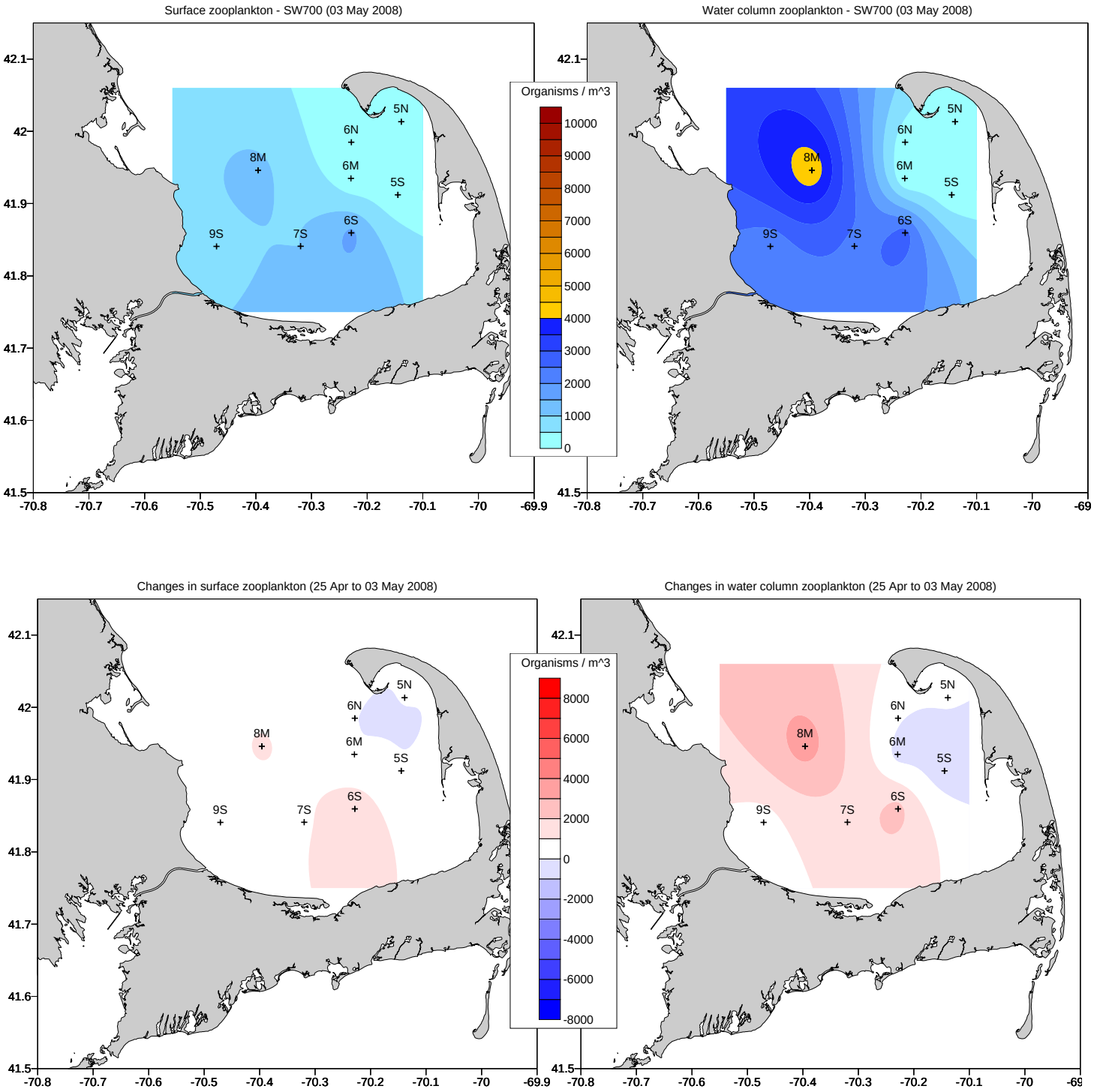


Figure A11. *Upper plots*: **Zooplankton density distribution** in Cape Cod Bay on 03 May 2008 from surface (left) and water column (right) collections. *Lower plots*: Spatial distribution of **zooplankton density changes** between 25 April and 03 May 2008, with surface density changes displayed at left and water column density changes presented at right. Sampling station locations are indicated with a "+" symbol. Densities were calculated from enumeration of regular station samples only, though special stations that were sampled are shown.

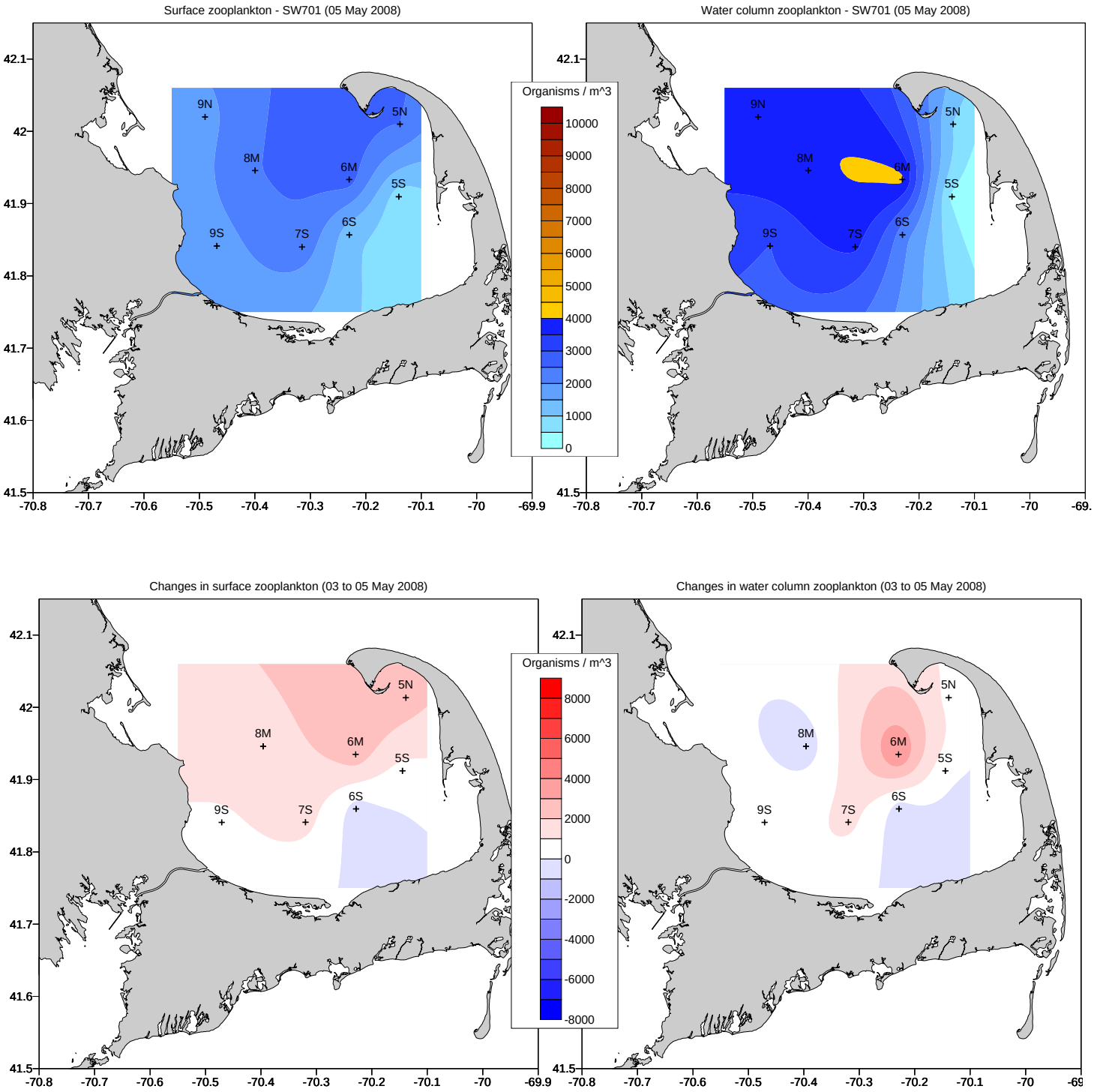


Figure A12. *Upper plots*: **Zooplankton density distribution** in Cape Cod Bay on 05 May 2008 from surface (left) and water column (right) collections. *Lower plots*: Spatial distribution of **zooplankton density changes** between 03 and 05 May 2008, with surface density changes displayed at left and water column density changes presented at right. Sampling station locations are indicated with a "+" symbol. Densities were calculated from enumeration of regular station samples only, though special stations that were sampled are shown. Densities were calculated from enumeration of regular station samples only, though special stations that were sampled are shown.

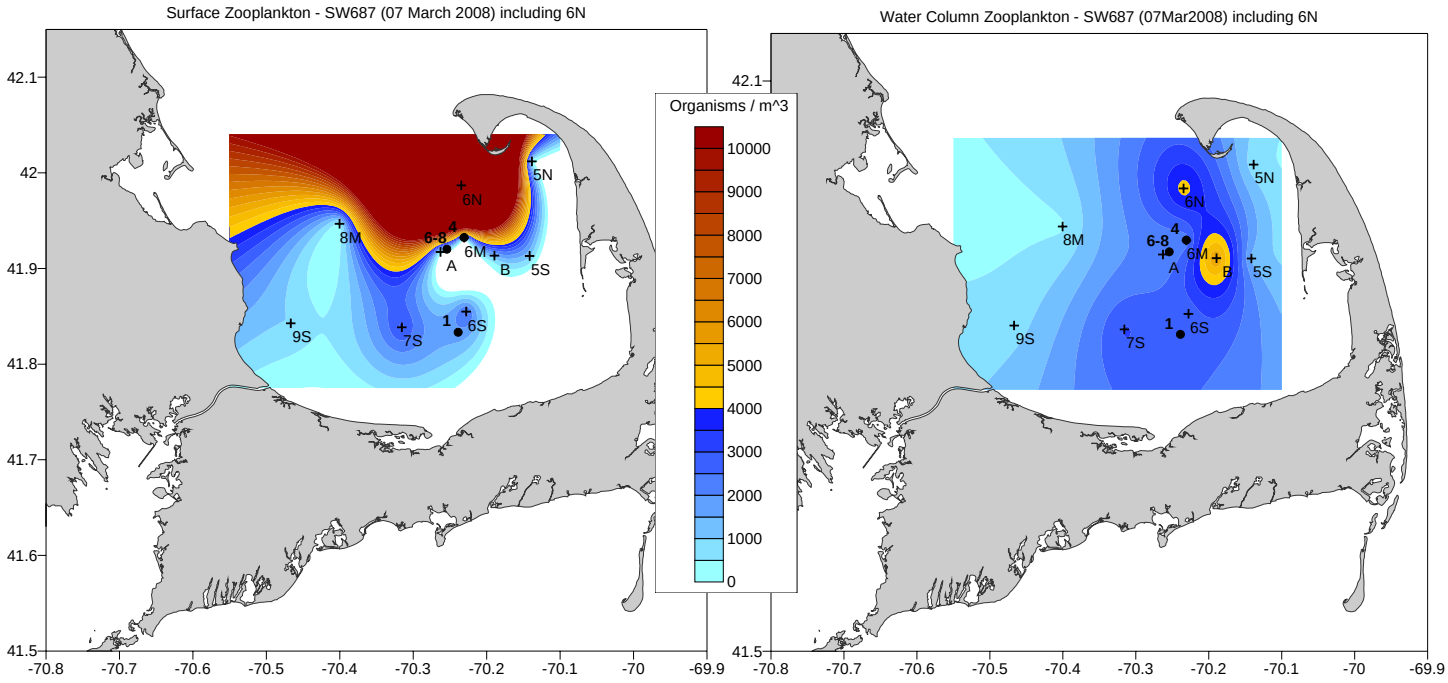
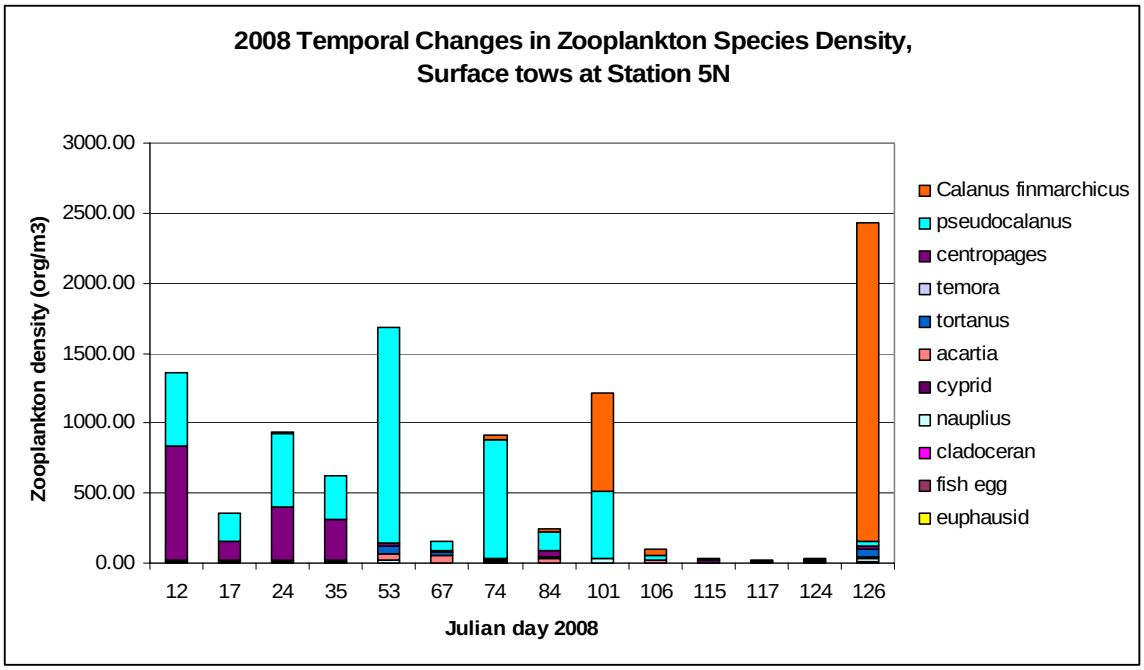


Figure A13. Zooplankton density distribution in Cape Cod Bay on 07 March 2008 from surface (left) and water column (right) collections. Sampling station locations are indicated with a "+" symbol. Approximate right whale locations are labeled with a "•" symbol and the number of individuals sighted, generally within a 2nm area. While not a regular station in the beginning of the season, 6N was sampled during the SW687 cruise, revealing an extraordinarily rich zooplankton patch, dominated by *Pseudocalanus spp*. It is shown here to demonstrate the sensitivity of the results to the spatial scale of the sampling.



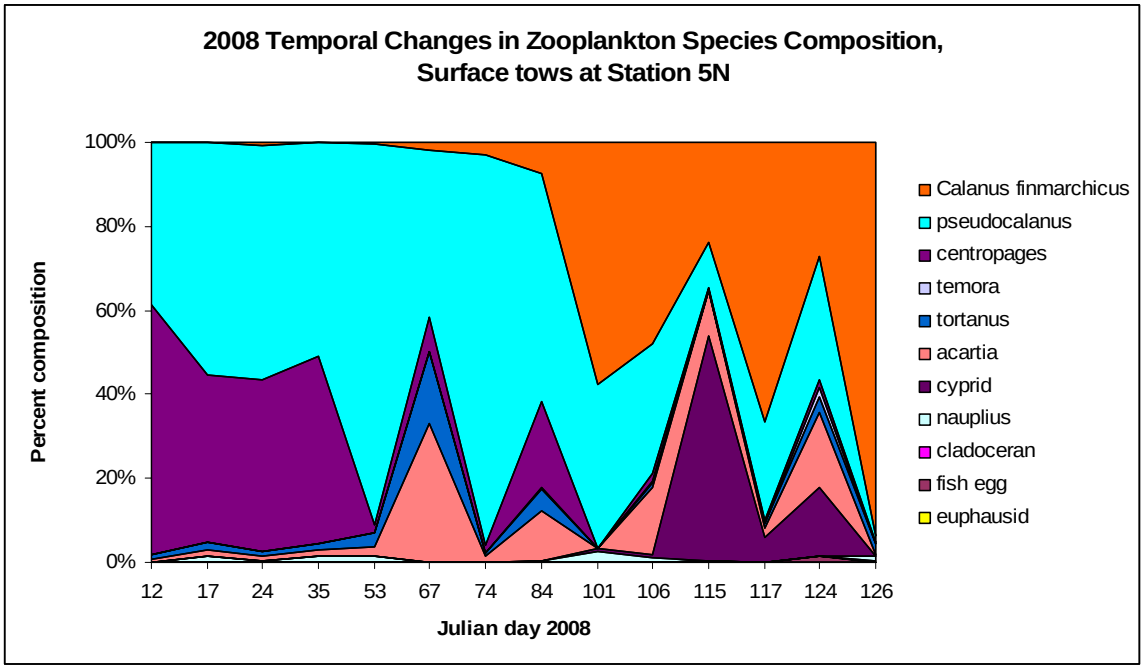
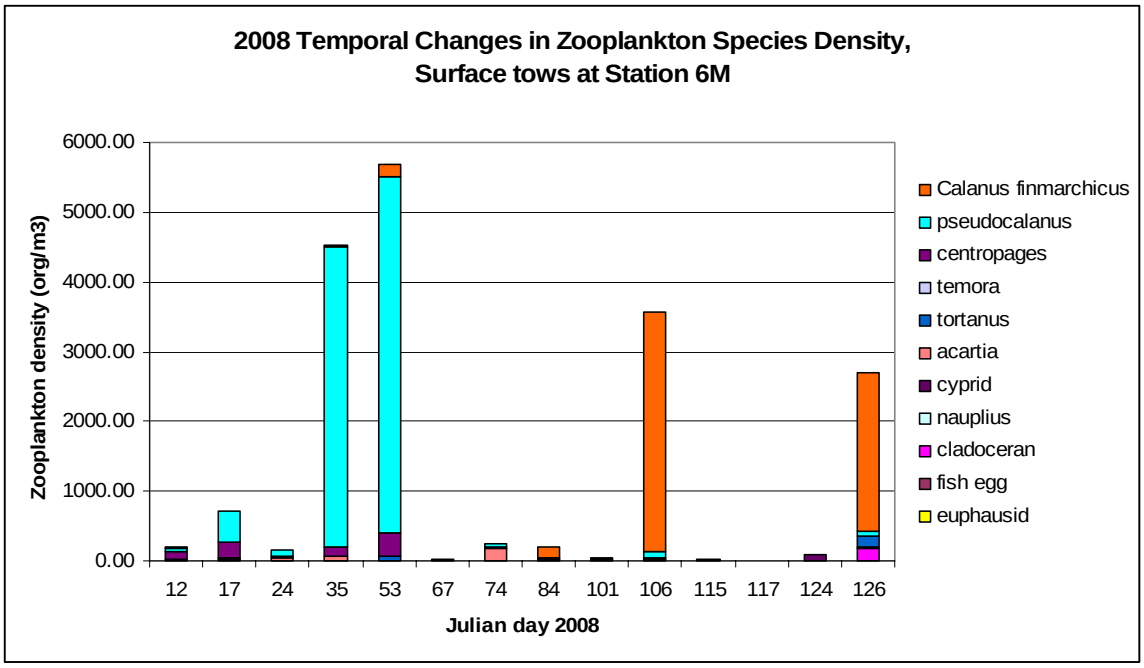


Figure A14. Temporal progression of <u>surface</u> zooplankton species at Station 5N in 2008
Panel A (top) – Zooplankton species density through time
Panel B (bottom) – Zooplankton species composition through time



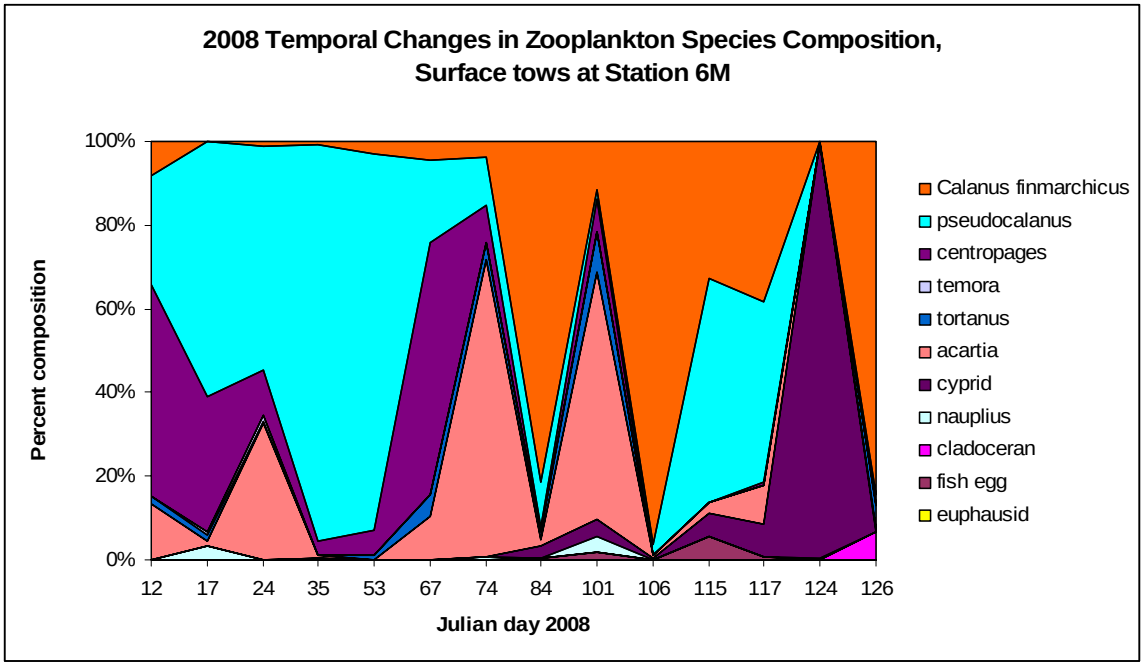
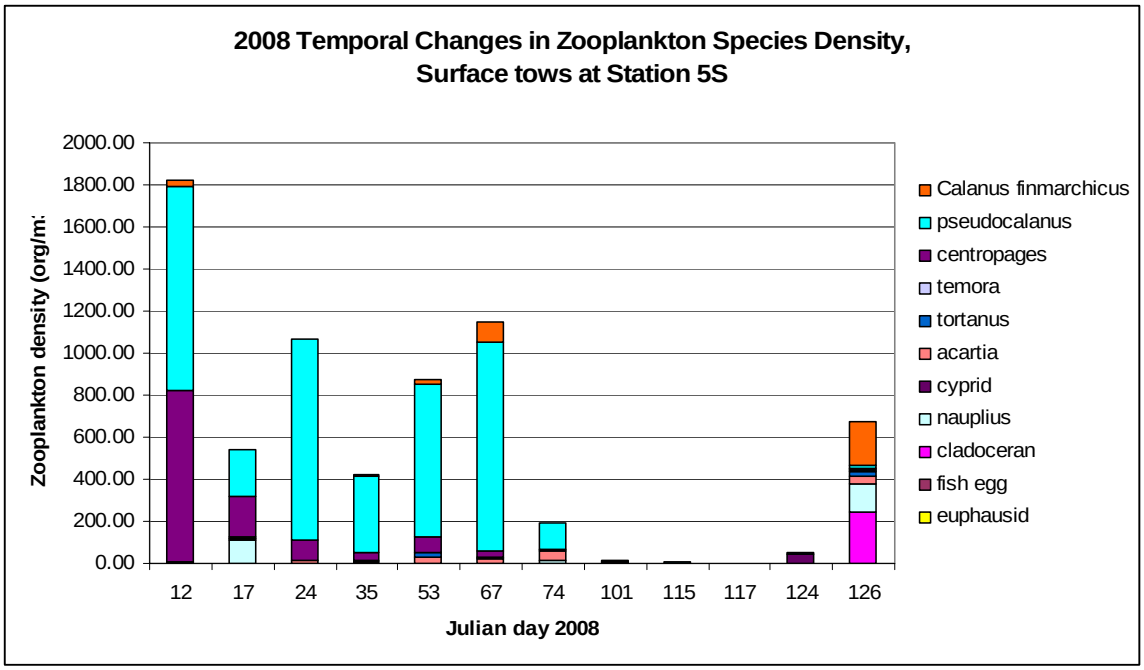


Figure A15. Temporal progression of <u>surface</u> zooplankton species at Station 6M in 2008
Panel A (top) – Zooplankton species density through time
Panel B (bottom) – Zooplankton species composition through time



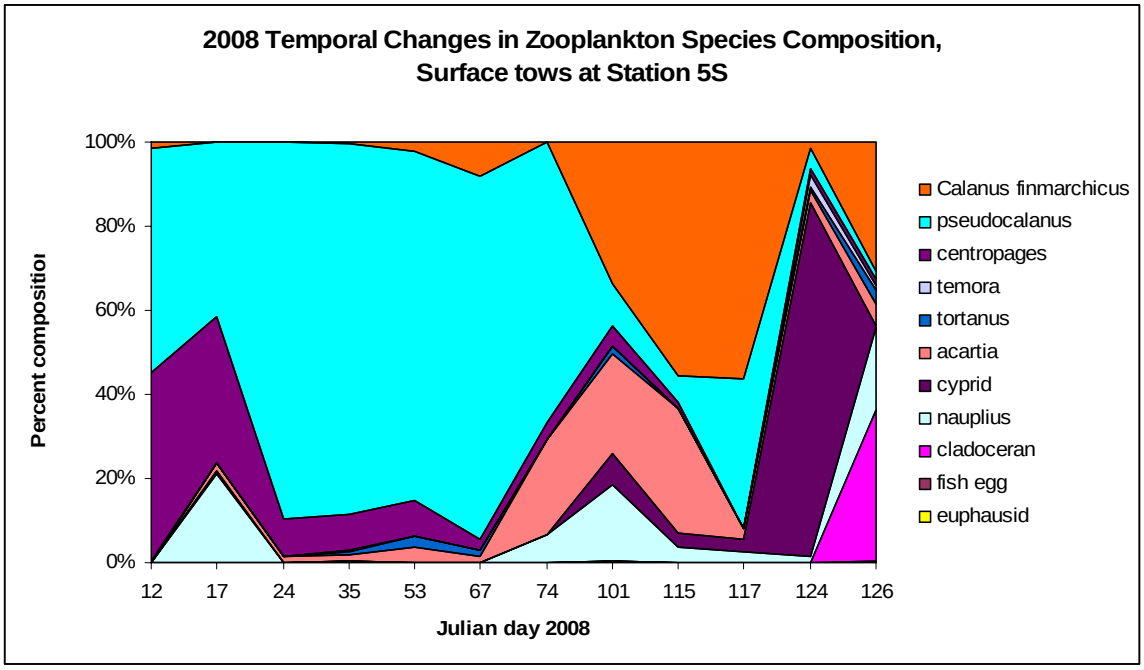
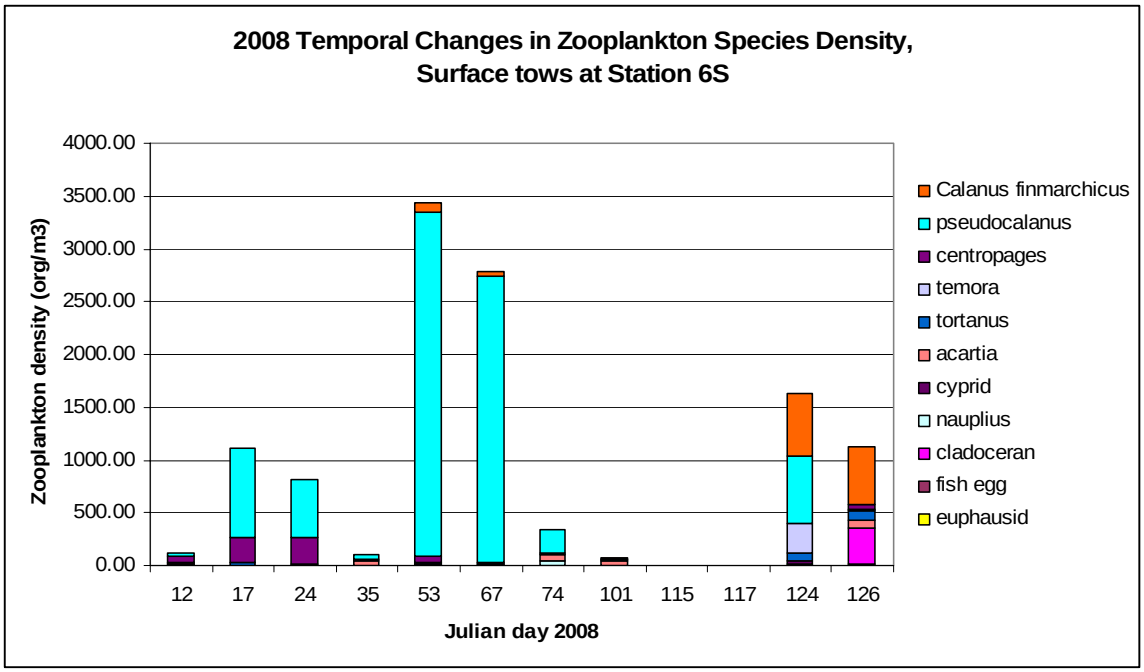


Figure A16. Temporal progression of <u>surface</u> zooplankton species at Station 5S in 2008
Panel A (top) – Zooplankton species density through time
Panel B (bottom) – Zooplankton species composition through time



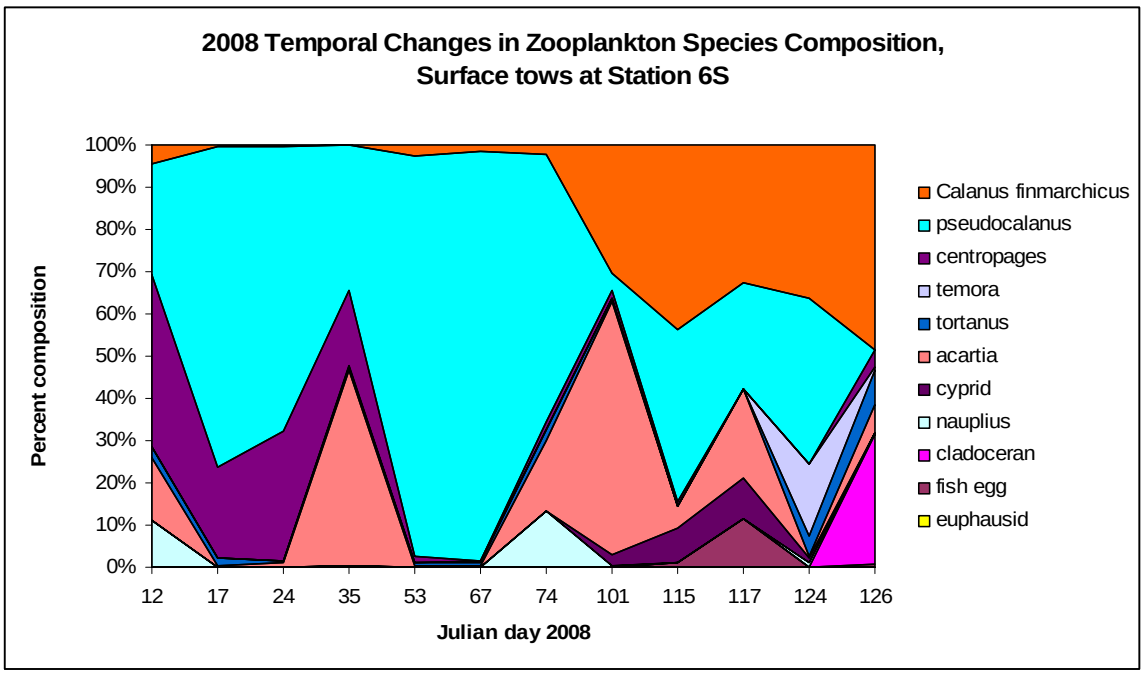
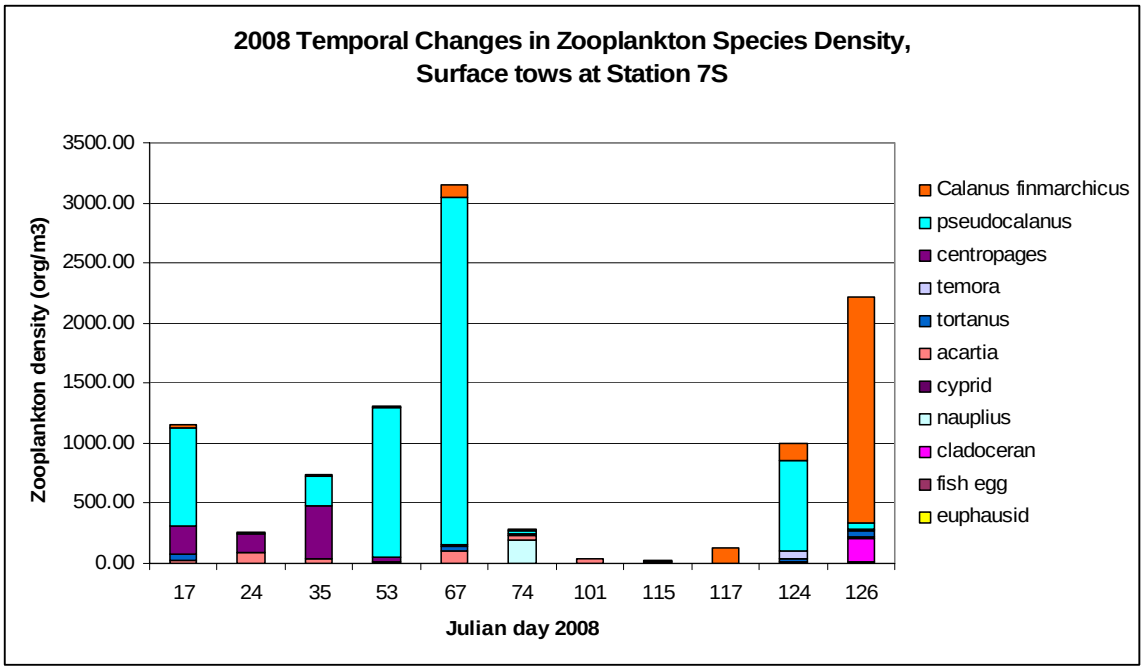


Figure A17. Temporal progression of <u>surface</u> zooplankton species at Station 6S in 2008
Panel A (top) – Zooplankton species density through time
Panel B (bottom) – Zooplankton species composition through time



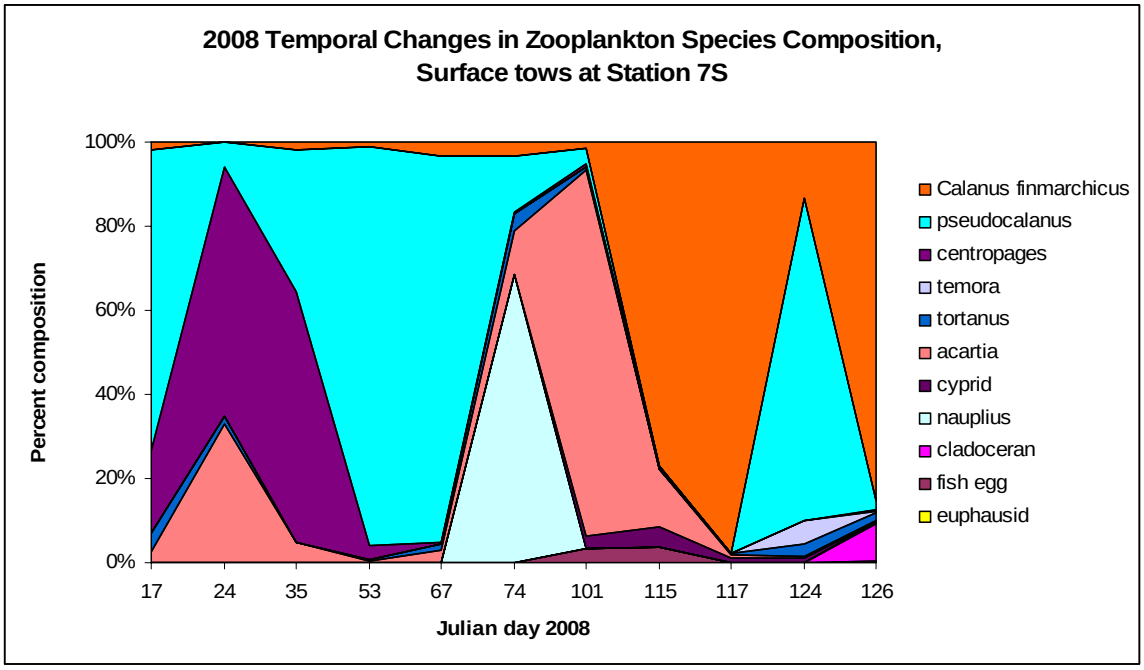
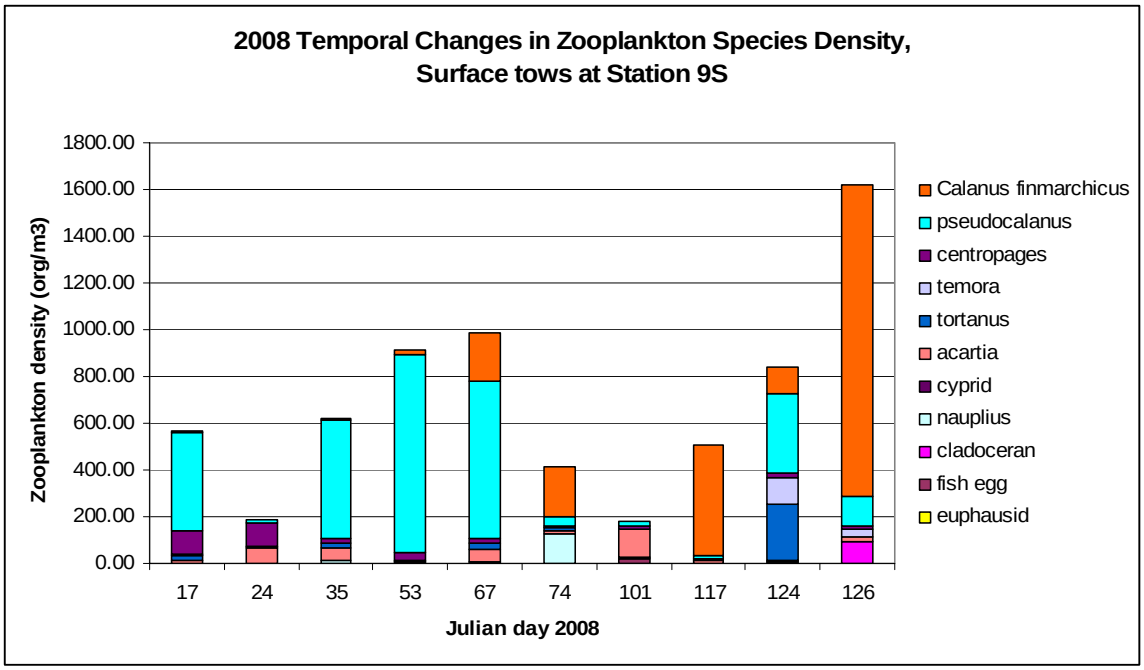


Figure A18. Temporal progression of <u>surface</u> zooplankton species at Station 7S in 2008
Panel A (top) – Zooplankton species density through time
Panel B (bottom) – Zooplankton species composition through time



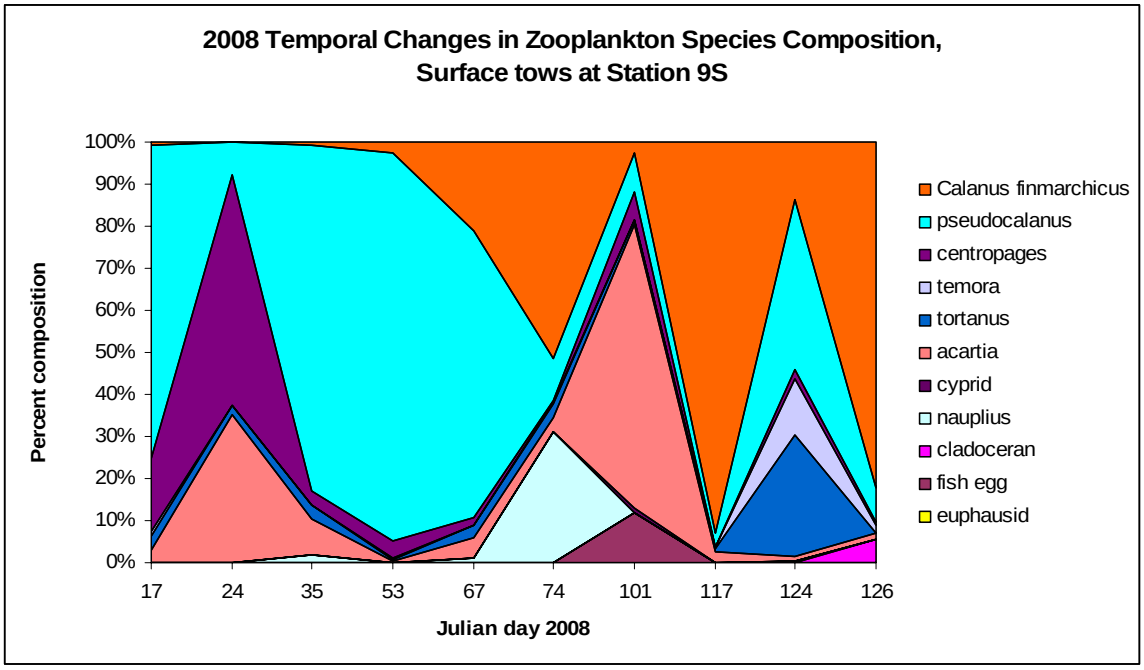
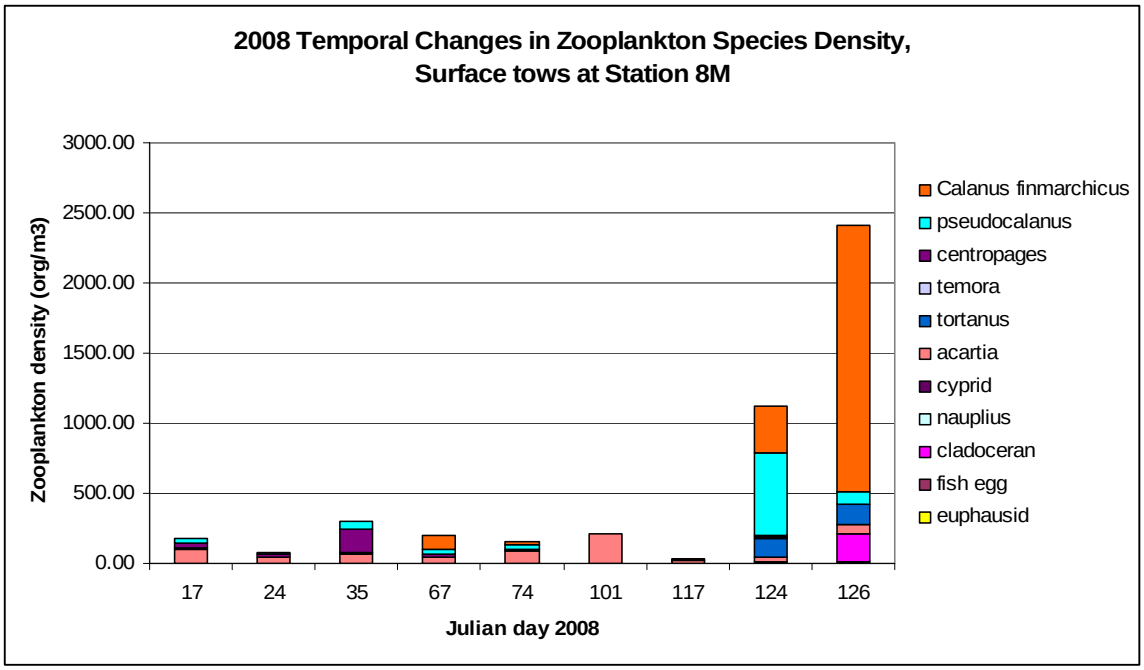


Figure A19. Temporal progression of <u>surface</u> zooplankton species at Station 9S in 2008
Panel A (top) – Zooplankton species density through time
Panel B (bottom) – Zooplankton species composition through time



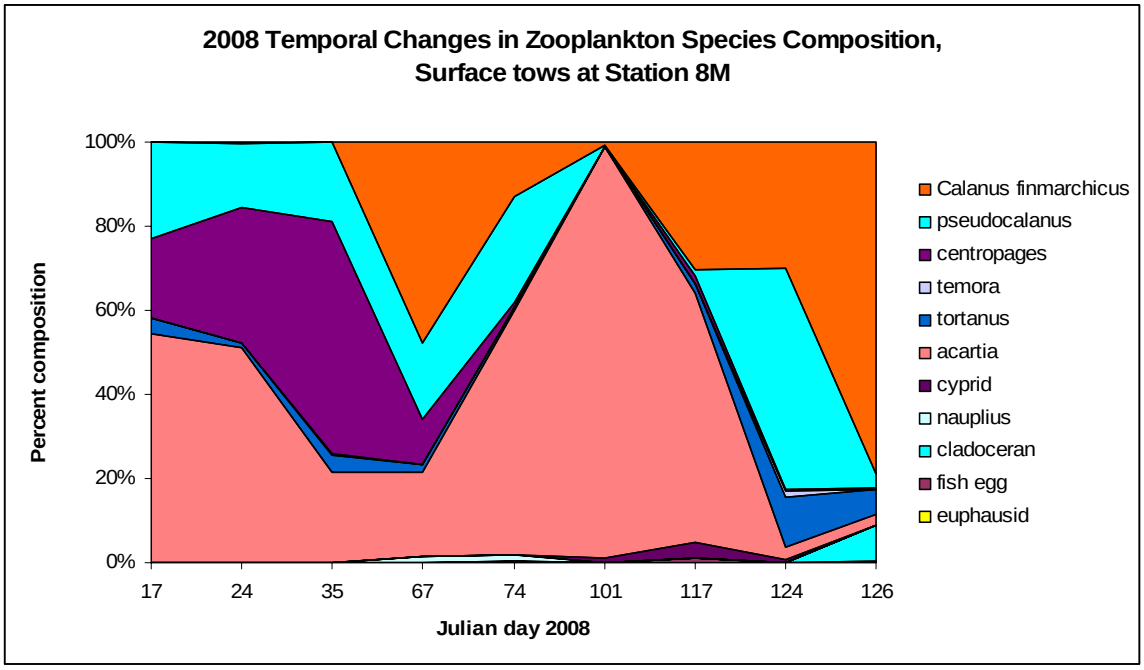
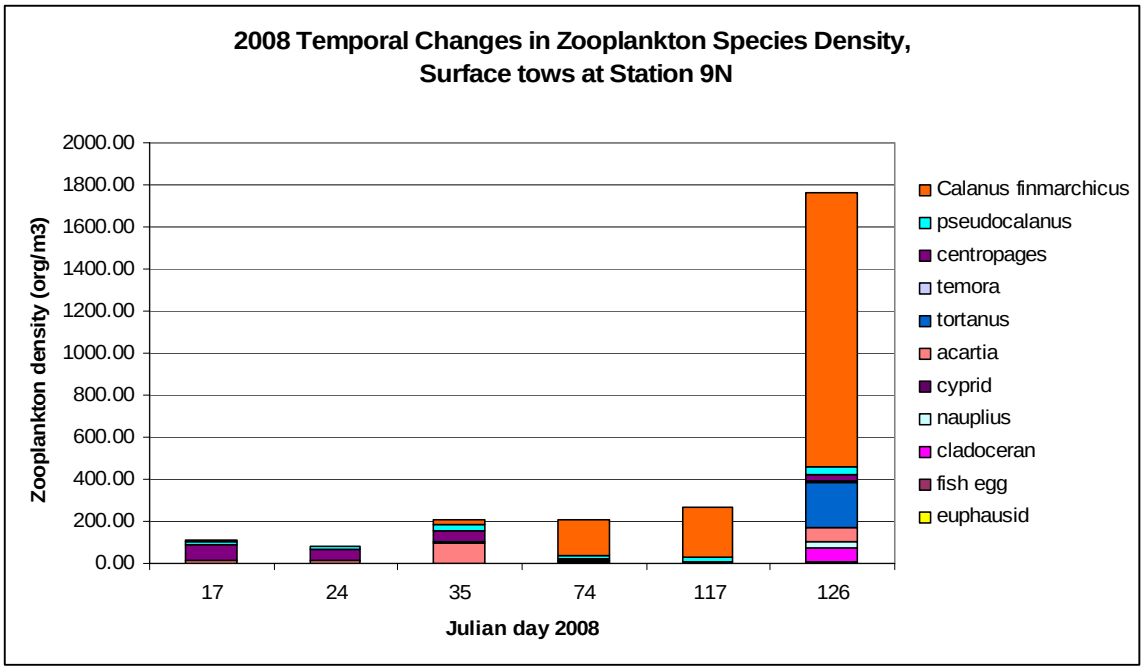


Figure A20. Temporal progression of <u>surface</u> zooplankton species at Station 8M in 2008
Panel A (top) – Zooplankton species density through time
Panel B (bottom) – Zooplankton species composition through time



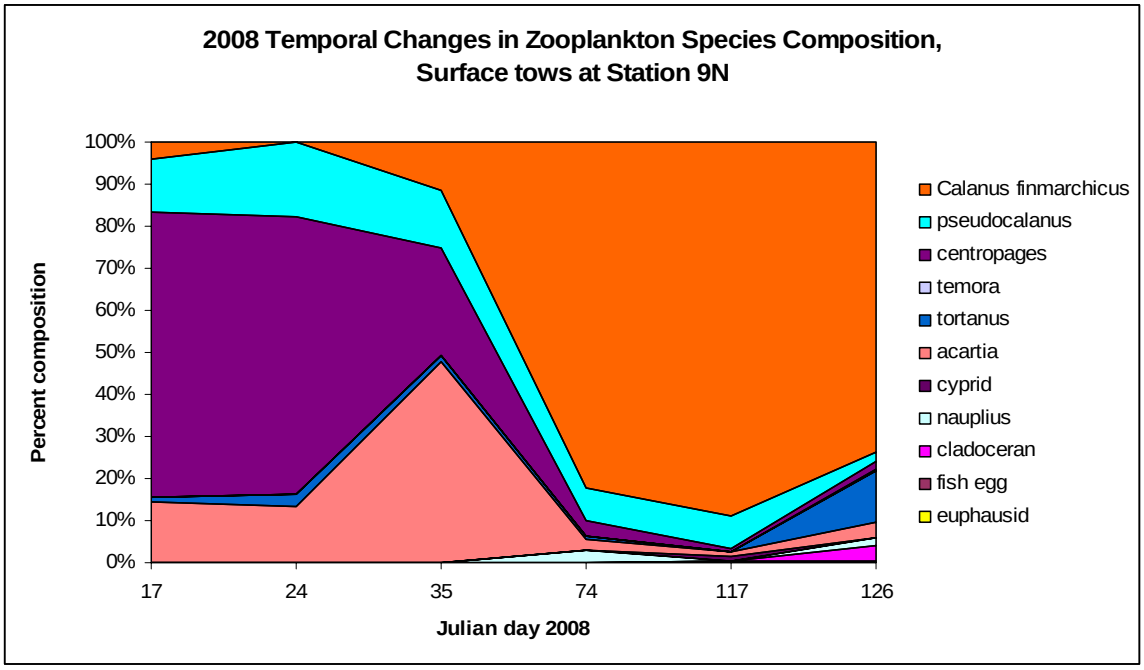
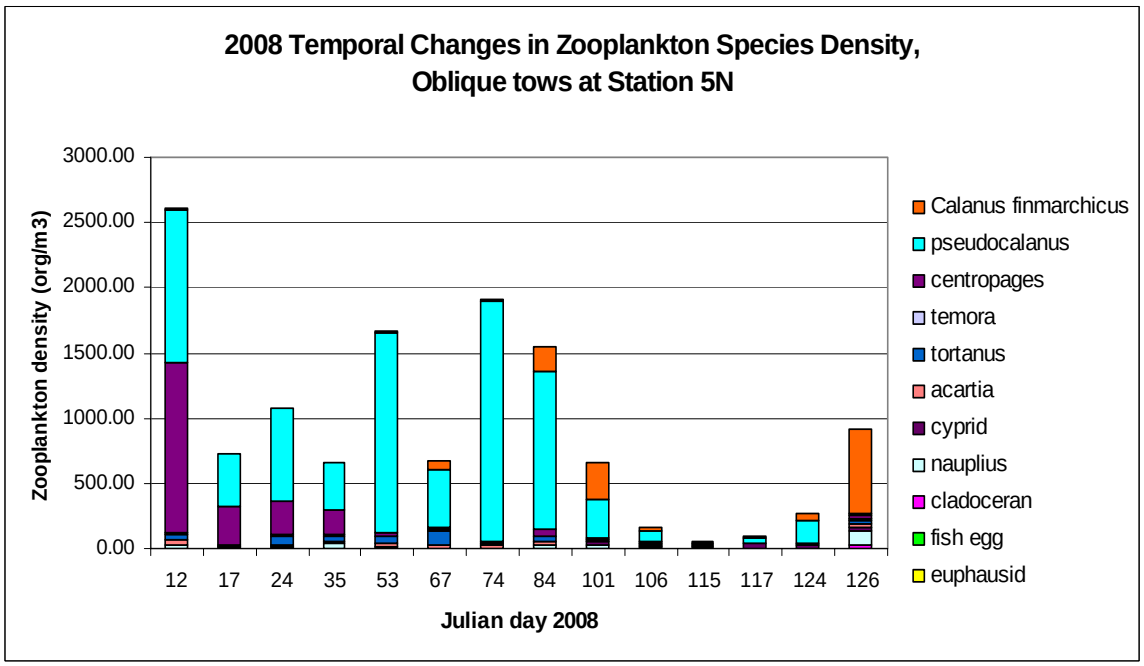


Figure A21. Temporal progression of <u>surface</u> zooplankton species at Station 9N in 2008
Panel A (top) – Zooplankton species density through time
Panel B (bottom) – Zooplankton species composition through time



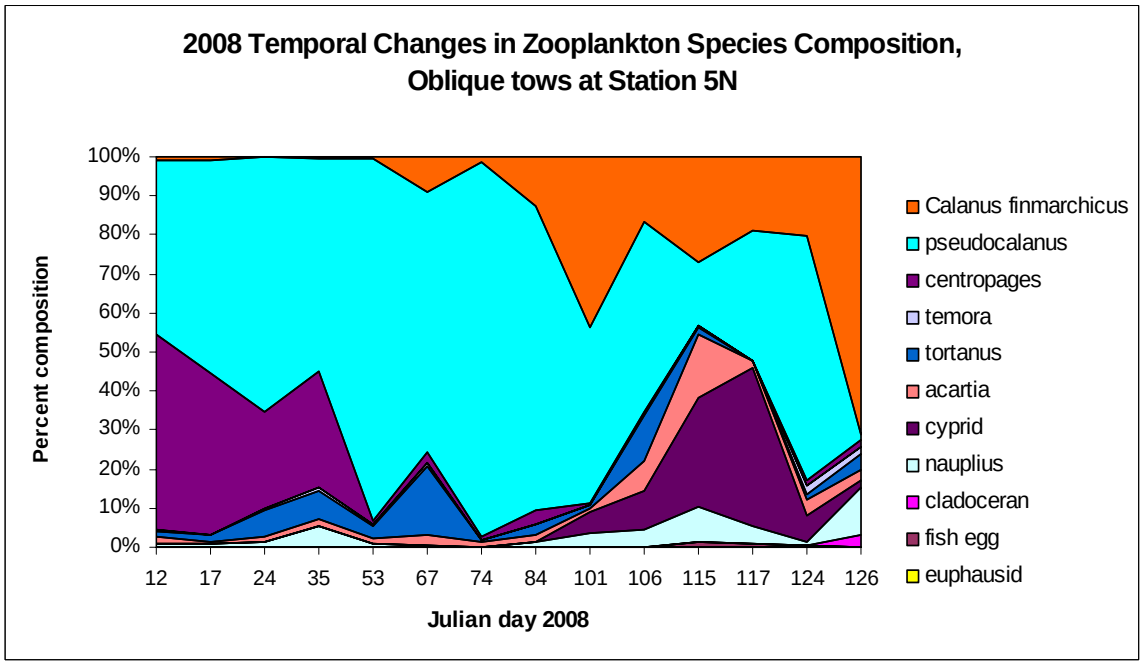
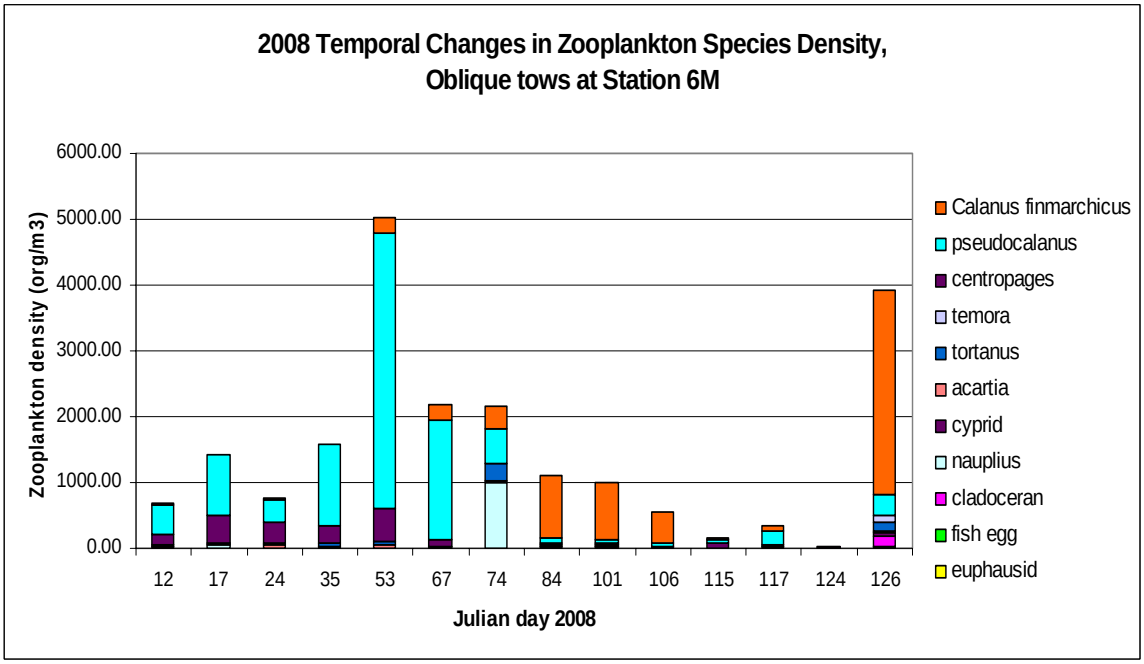


Figure A22. Temporal progression of <u>water column</u> zooplankton species at Station 5N in 2008
Panel A (top) – Zooplankton species density through time
Panel B (bottom) – Zooplankton species composition through time



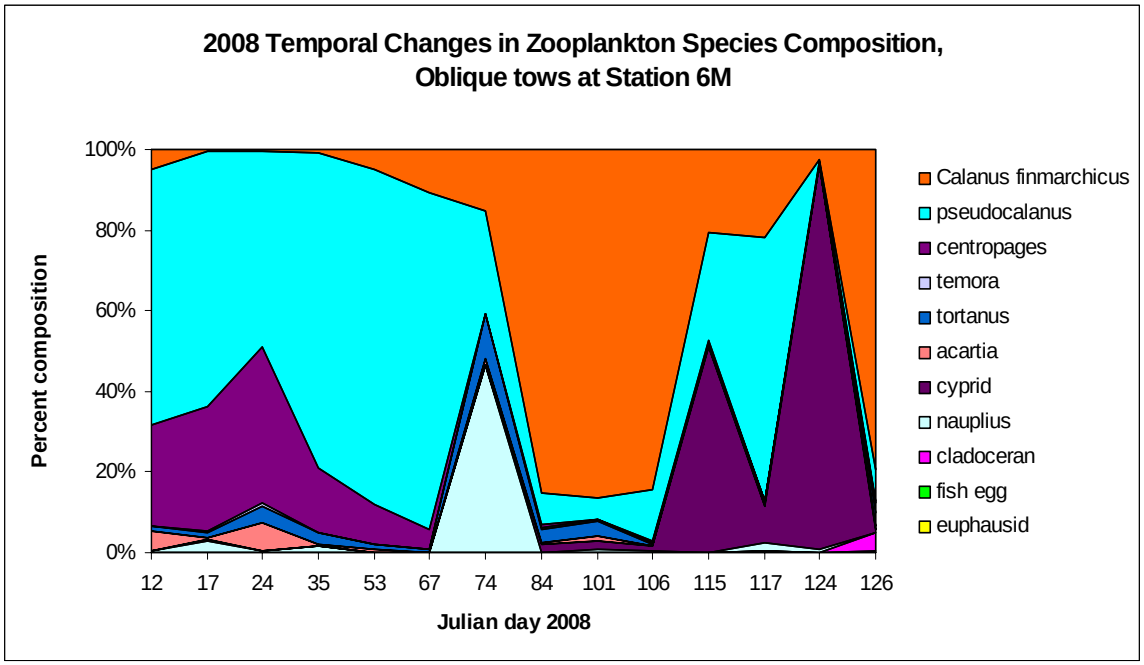
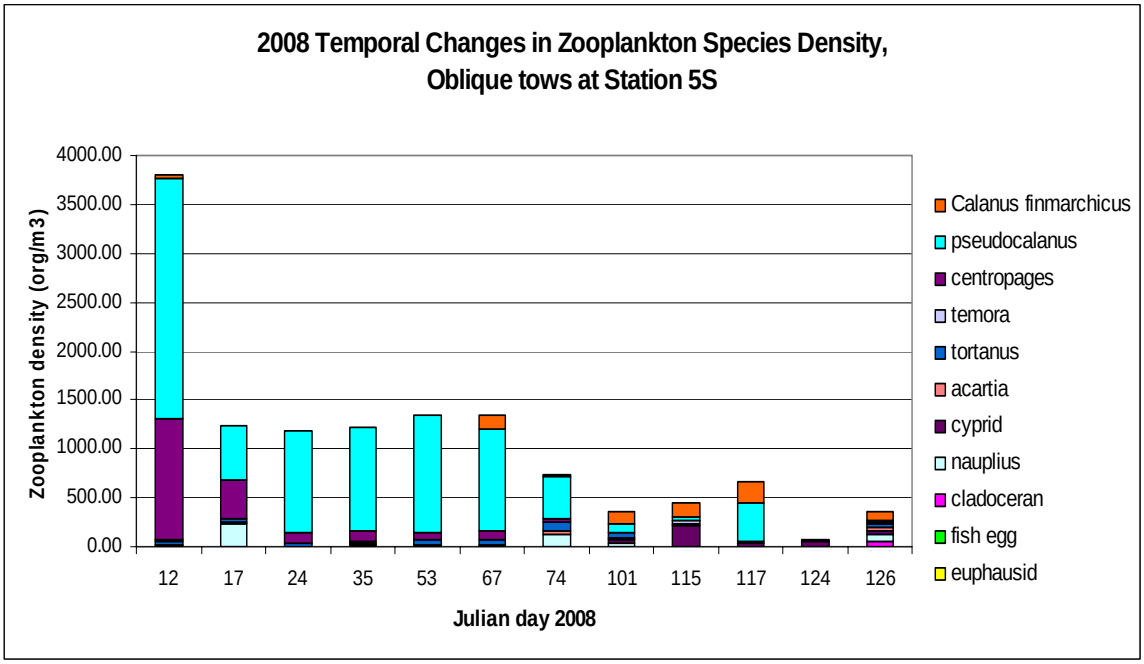


Figure A23. Temporal progression of <u>water column</u> zooplankton species at Station 6M in 2008
Panel A (top) – Zooplankton species density through time
Panel B (bottom) – Zooplankton species composition through time



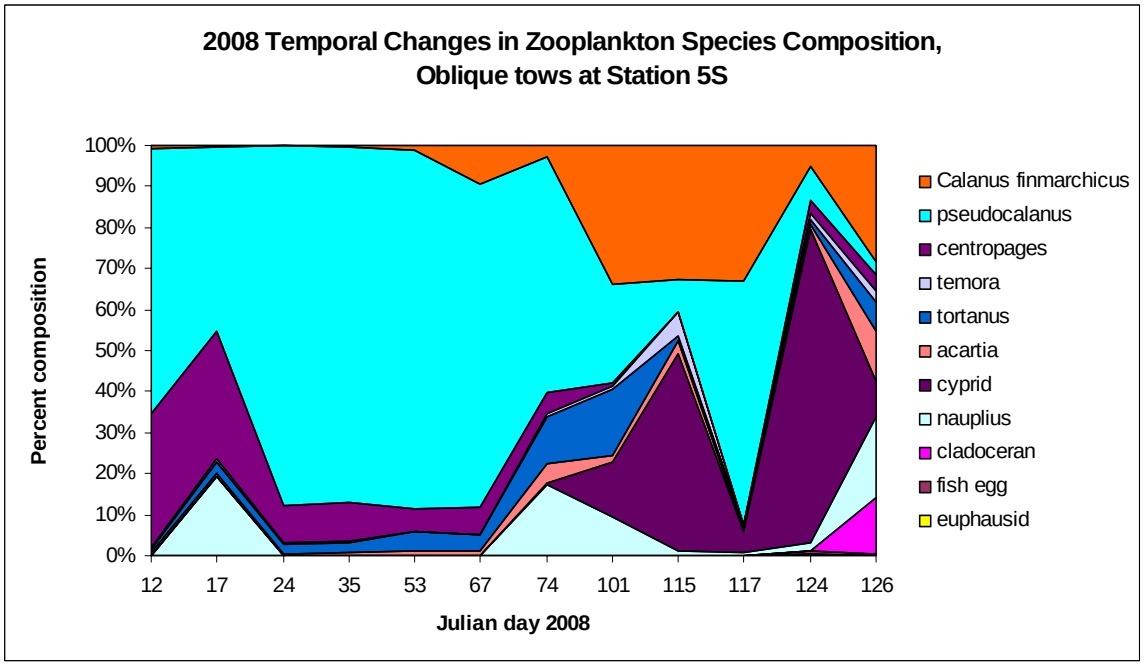
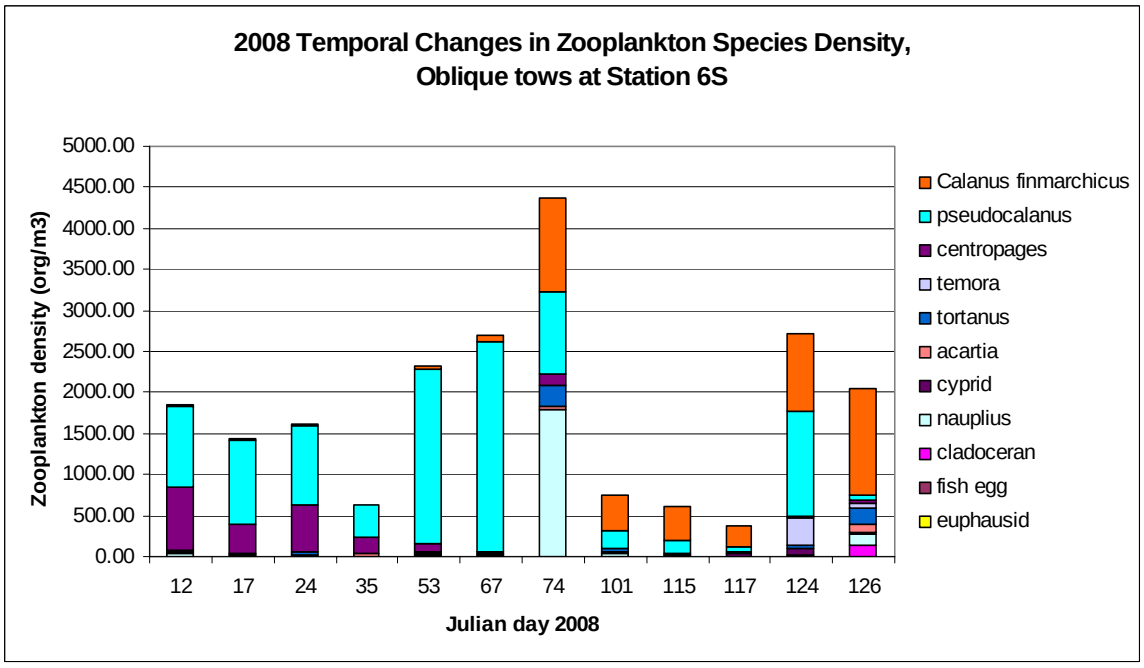


Figure A24. Temporal progression of <u>water column</u> zooplankton species at Station 5S in 2008
Panel A (top) – Zooplankton species density through time
Panel B (bottom) – Zooplankton species composition through time



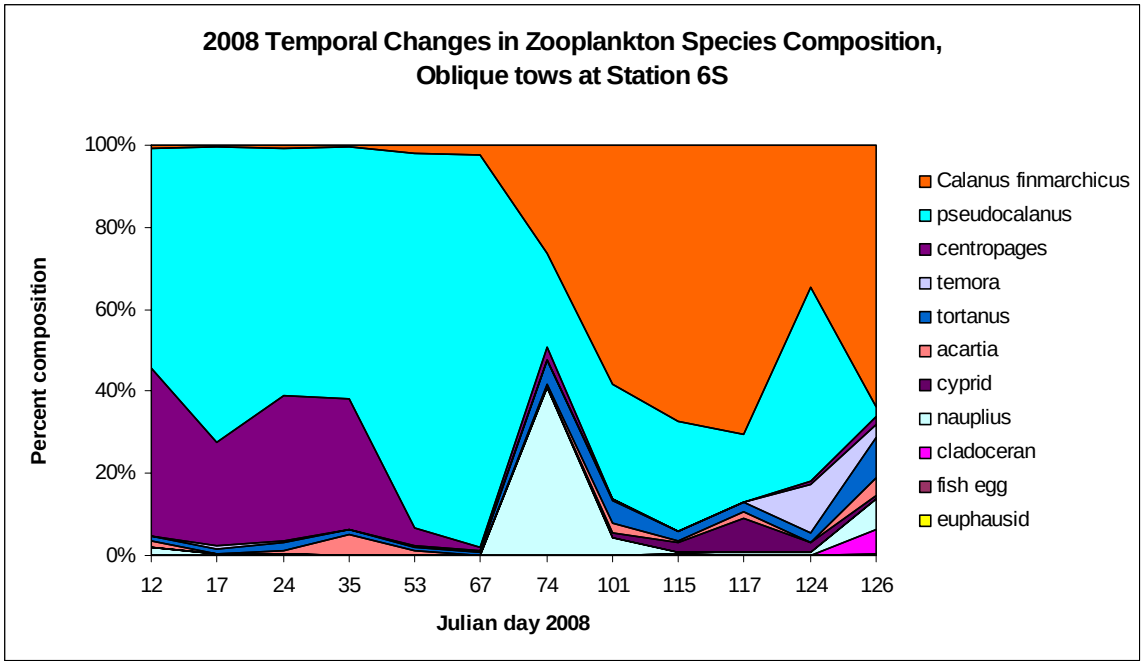
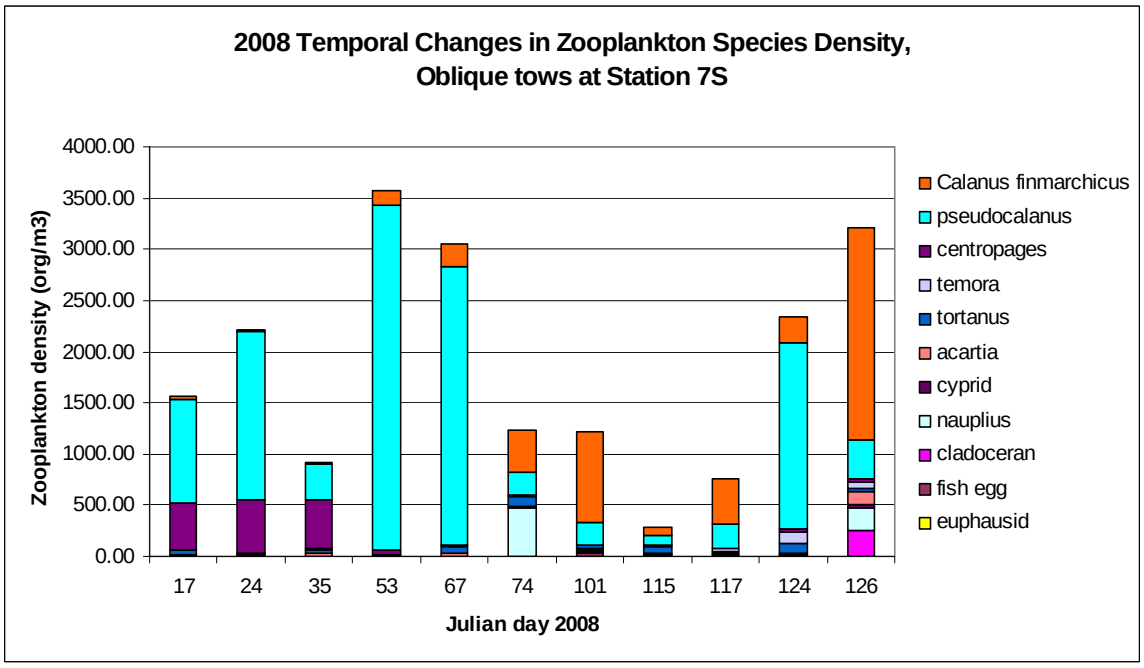


Figure A25. Temporal progression of <u>water column</u> zooplankton species at Station 6S in 2008
Panel A (top) – Zooplankton species density through time
Panel B (bottom) – Zooplankton species composition through time



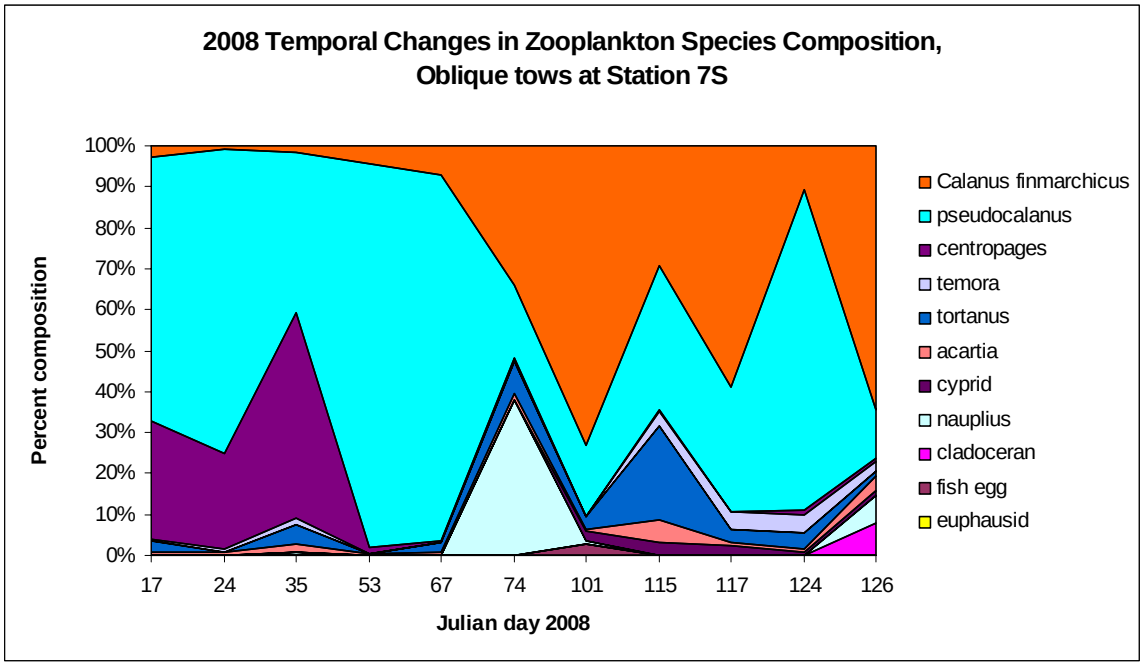
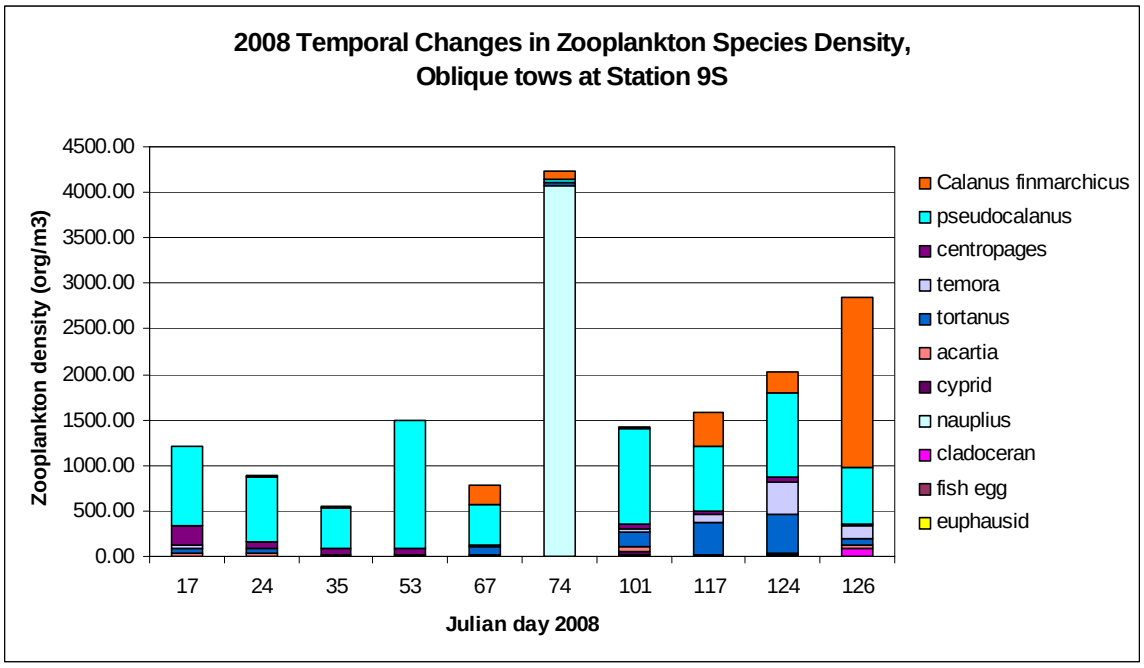


Figure A26. Temporal progression of <u>water column</u> zooplankton species at Station 7S in 2008
Panel A (top) – Zooplankton species density through time
Panel B (bottom) – Zooplankton species composition through time



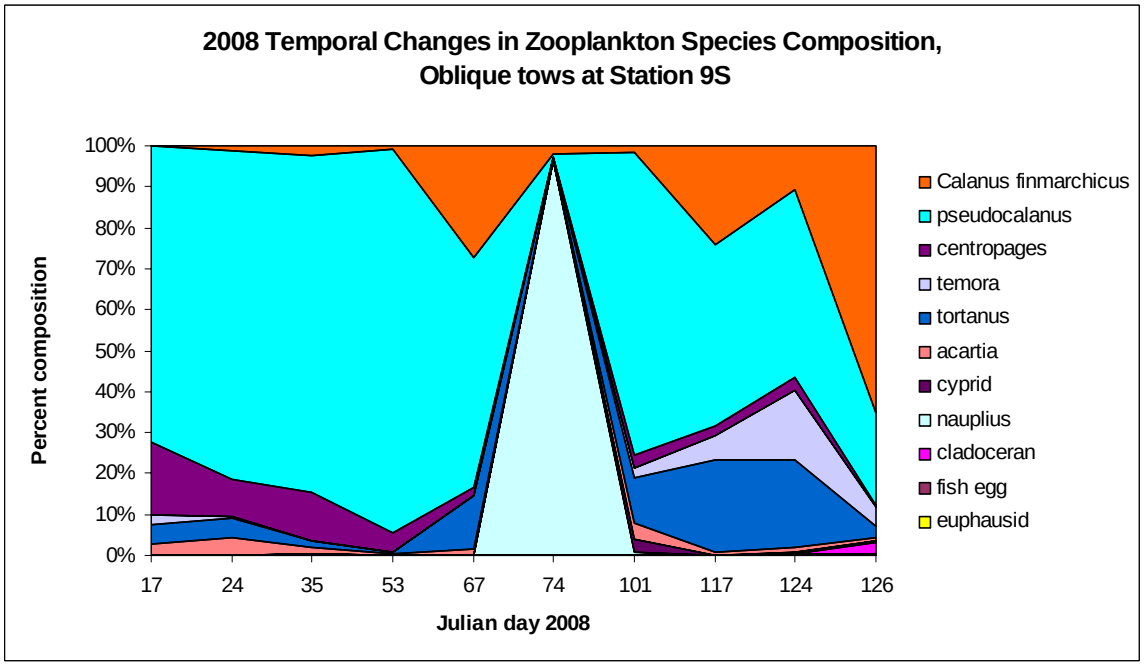
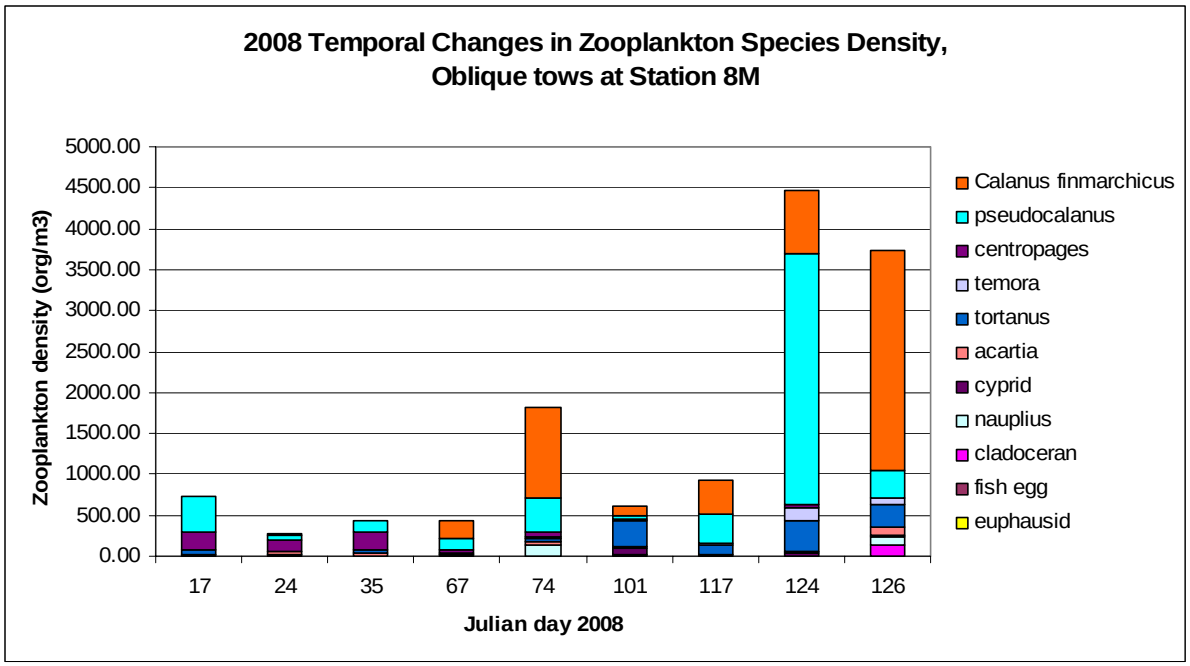


Figure A27. Temporal progression of <u>water column</u> zooplankton species at Station 9S in 2008
Panel A (top) – Zooplankton species density through time
Panel B (bottom) – Zooplankton species composition through time



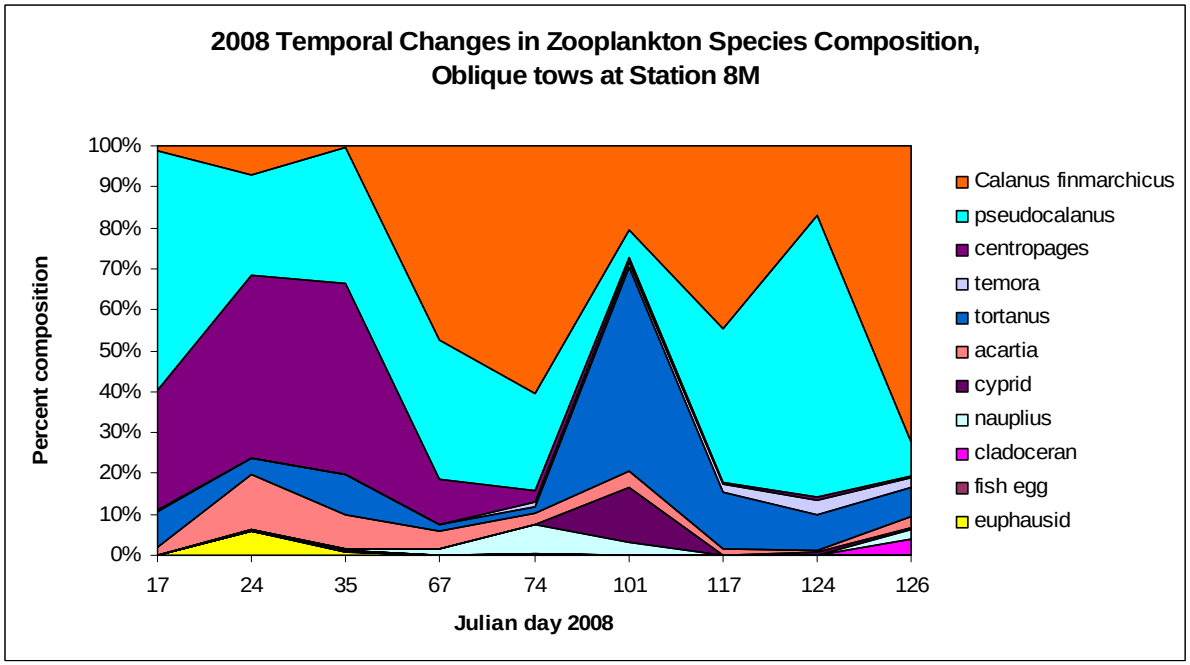
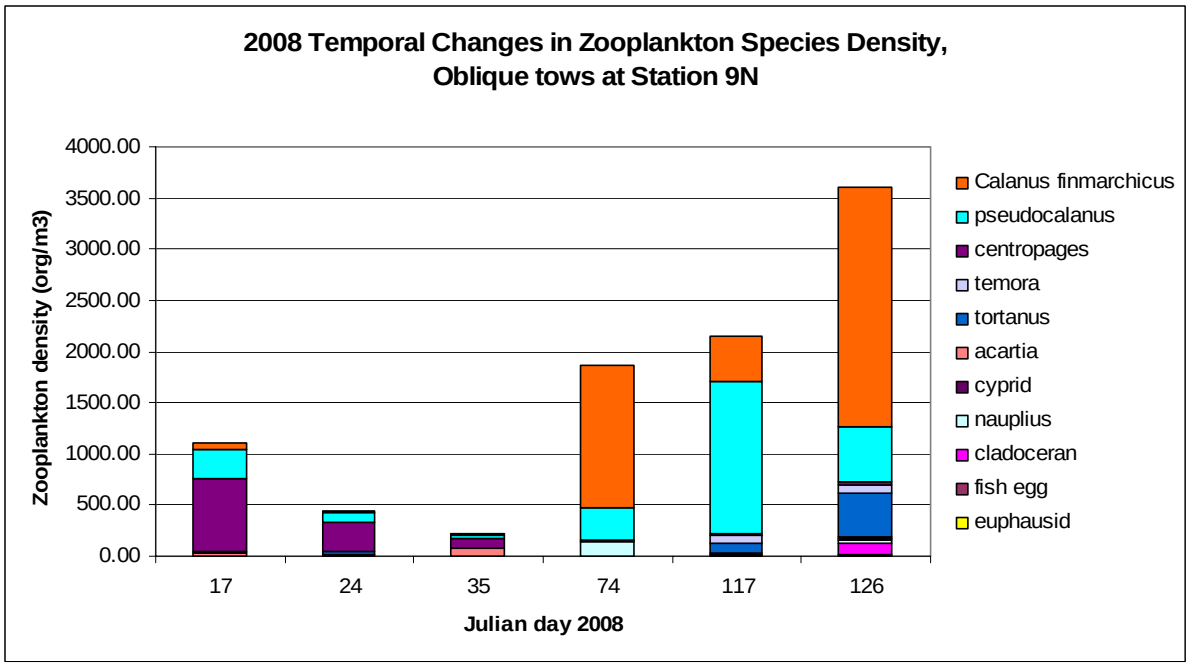


Figure A28. Temporal progression of <u>water column</u> zooplankton species at Station 8M in 2008
Panel A (top) – Zooplankton species density through time
Panel B (bottom) – Zooplankton species composition through time



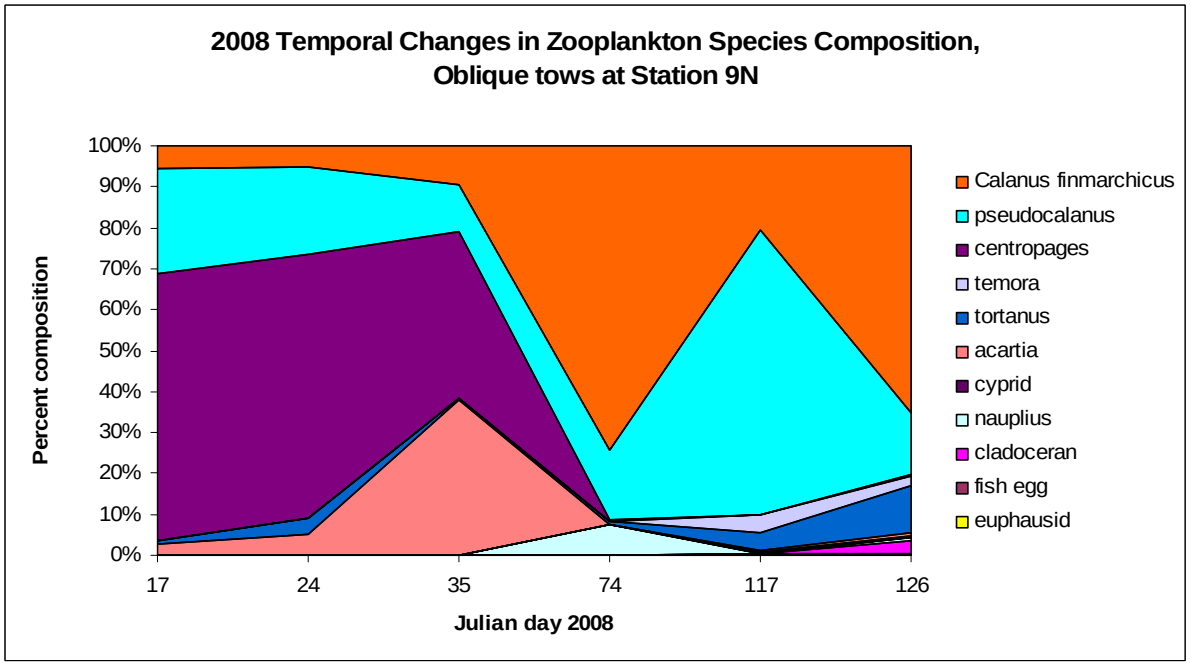


Figure A29. Temporal progression of <u>water column</u> zooplankton species at Station 9N in 2008
Panel A (top) – Zooplankton species density through time
Panel B (bottom) – Zooplankton species composition through time

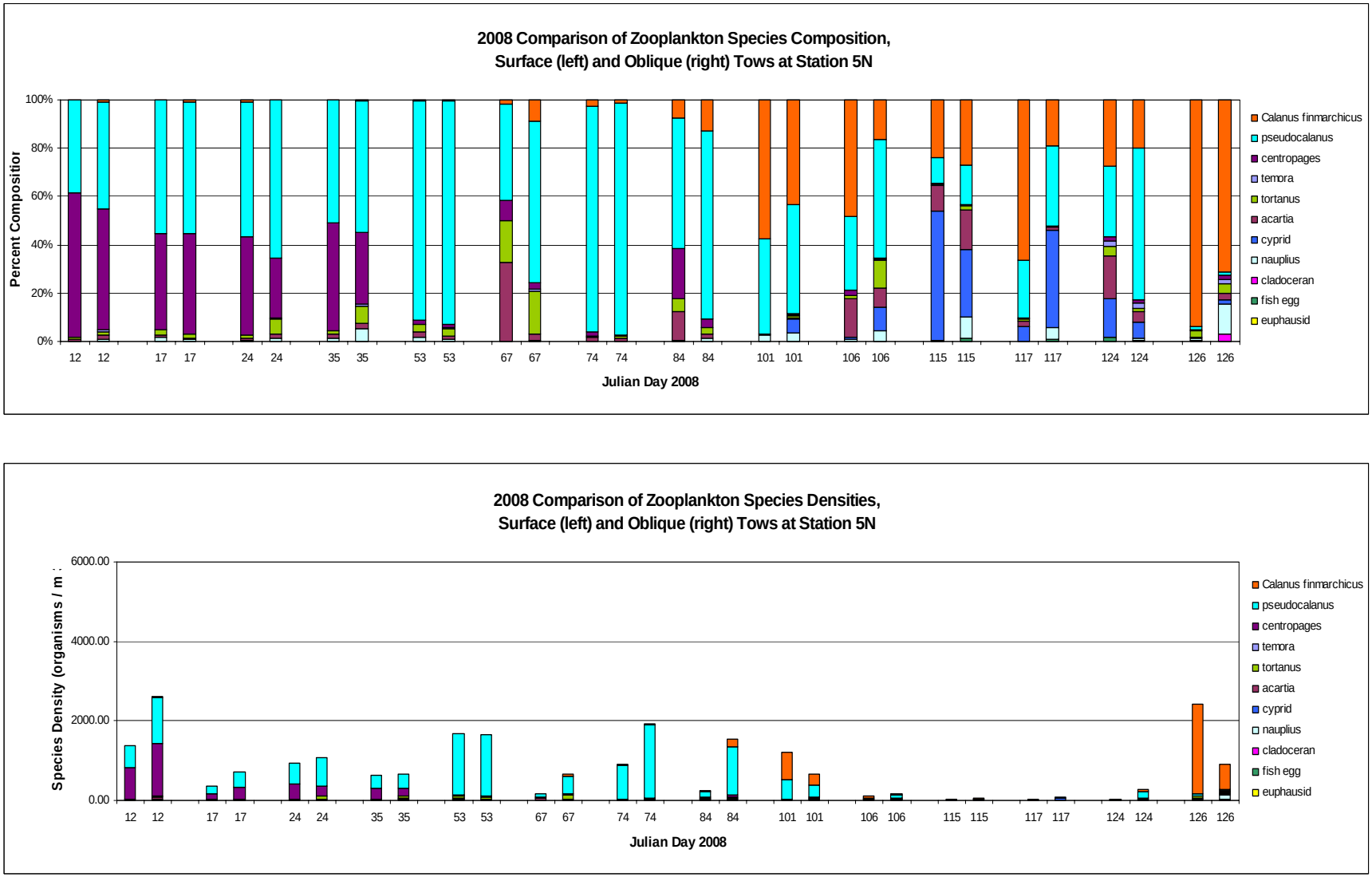
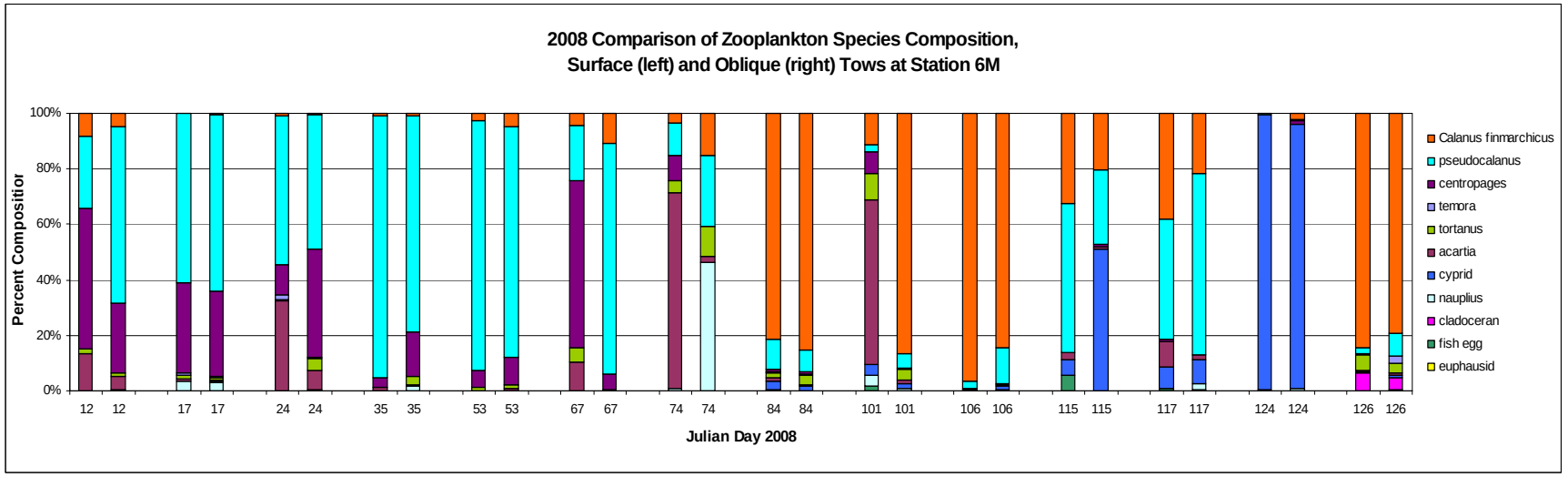


Figure A30. Comparison of surface and oblique zooplankton collections at Station 5N in 2008:
Panel A (top) – Zooplankton species composition through time
Panel B (bottom) – Zooplankton species densities through time



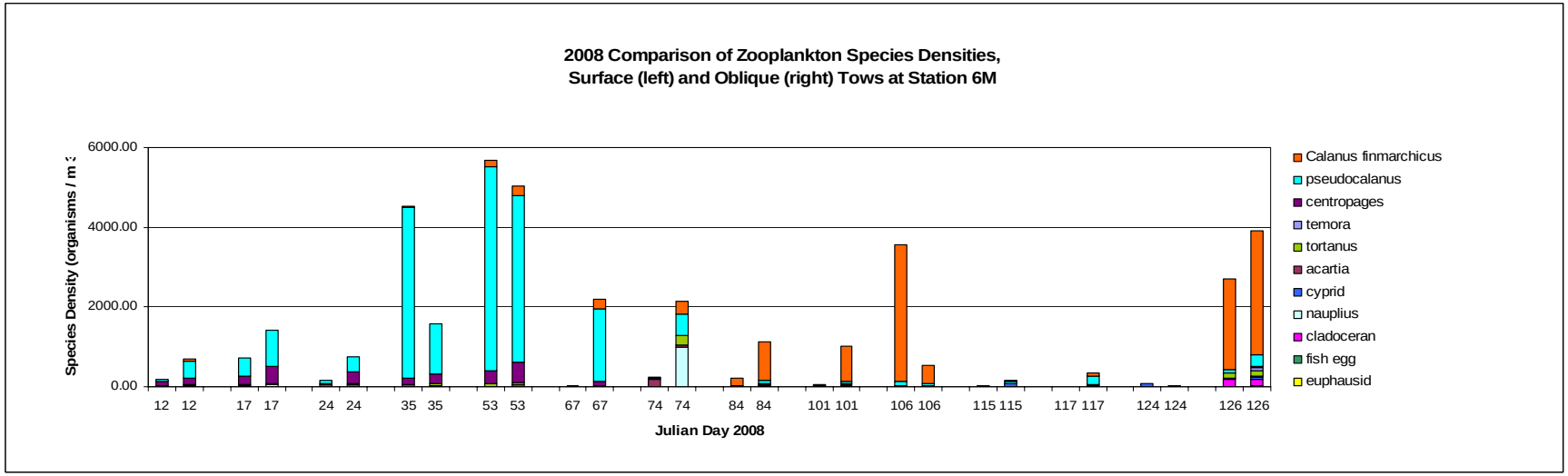


Figure A31. Comparison of surface and oblique zooplankton collections at Station 6M in 2008:
Panel A (top) – Zooplankton species composition through time
Panel B (bottom) – Zooplankton species densities through time

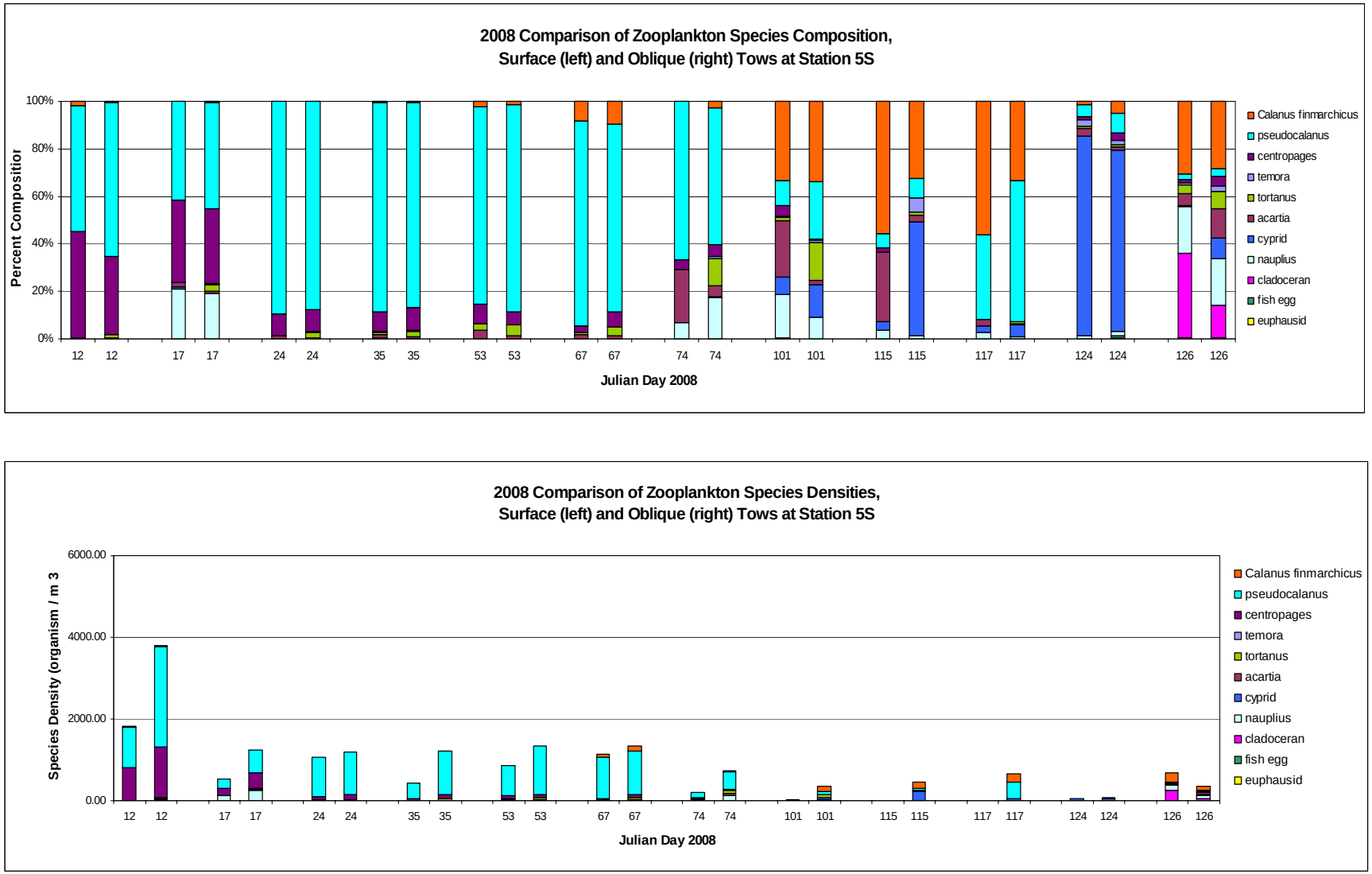


Figure A32. Comparison of surface and oblique zooplankton collections at Station 5S in 2008:
Panel A (top) – Zooplankton species composition through time
Panel B (bottom) – Zooplankton species densities through time

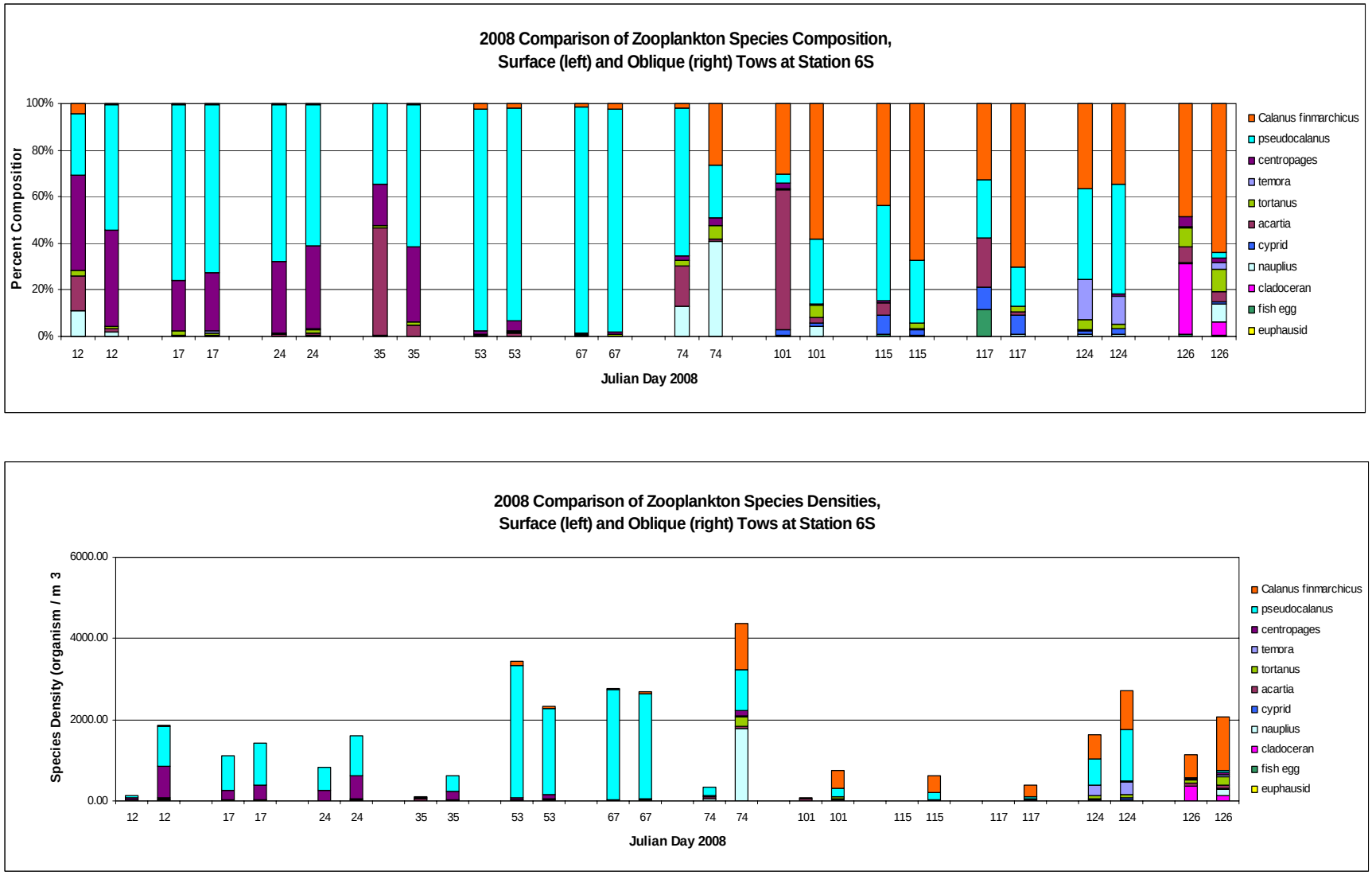


Figure A33. Comparison of surface and oblique zooplankton collections at Station 6S in 2008:
Panel A (top) – Zooplankton species composition through time
Panel B (bottom) – Zooplankton species densities through time

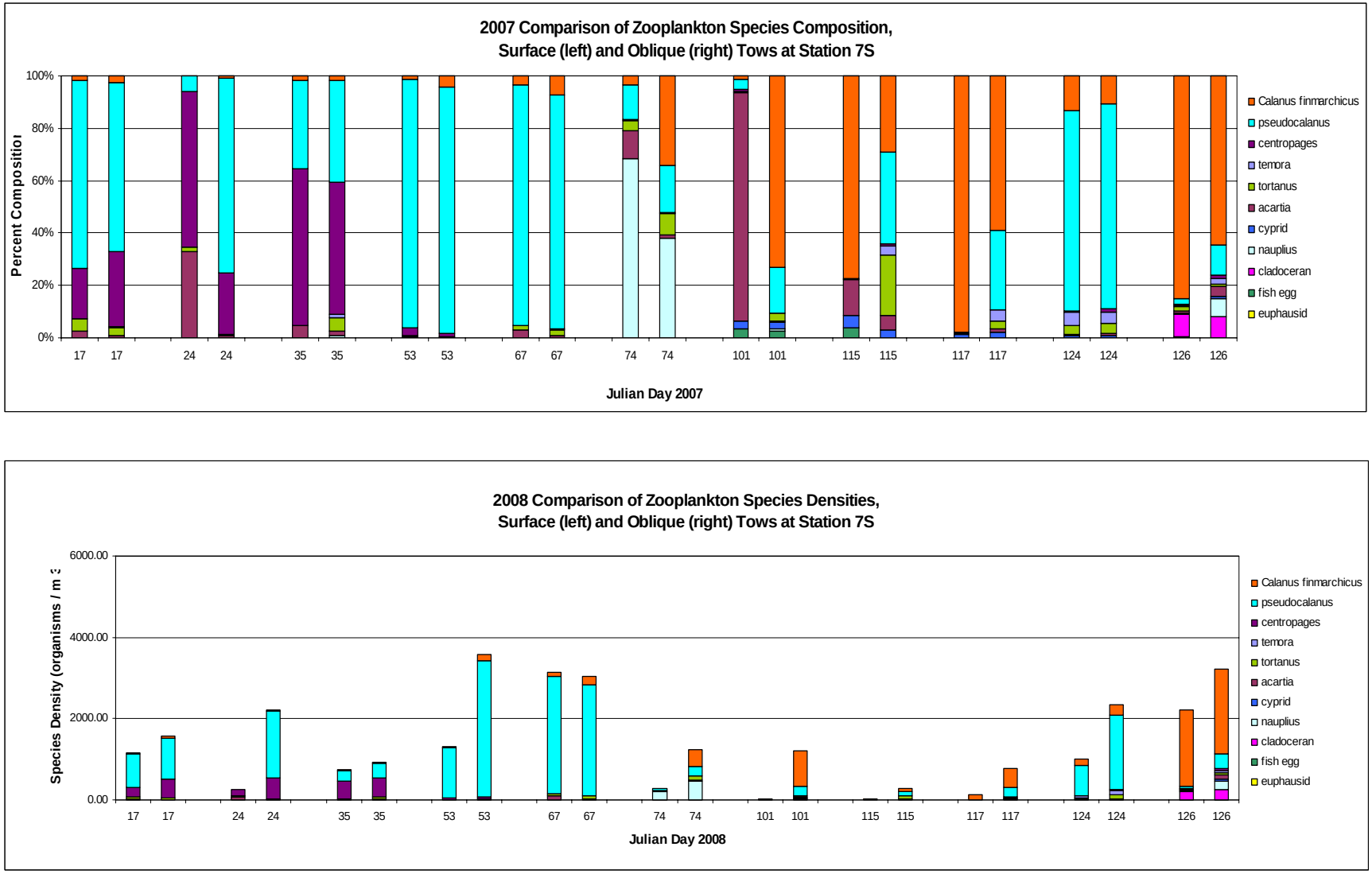


Figure A34. Comparison of surface and oblique zooplankton collections at Station 7S in 2008:
Panel A (top) – Zooplankton species composition through time
Panel B (bottom) – Zooplankton species densities through time

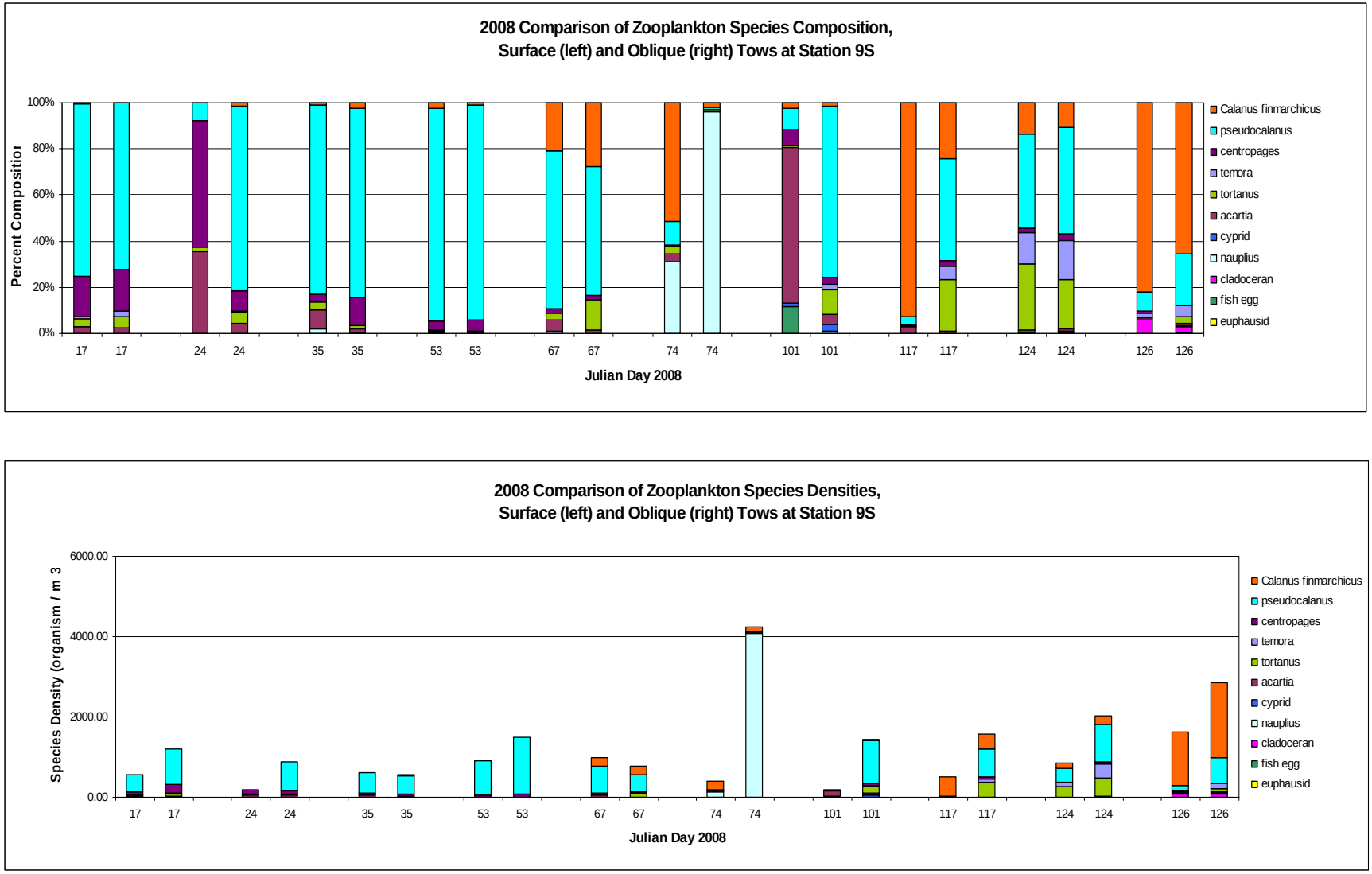
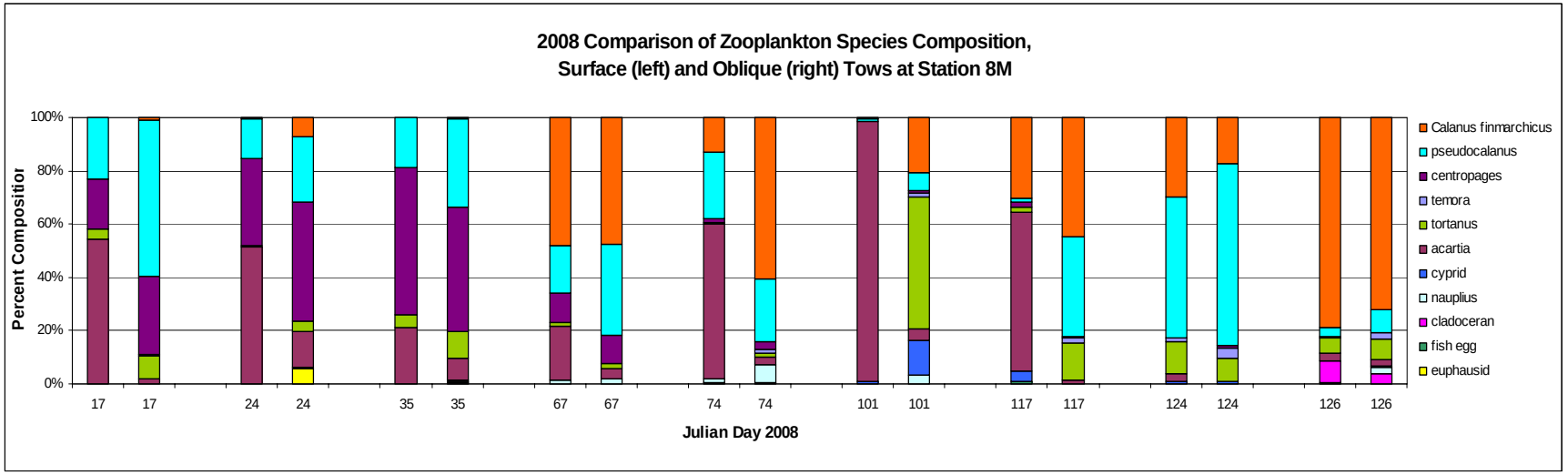


Figure A35. Comparison of surface and oblique zooplankton collections at Station 9S in 2008:
Panel A (top) – Zooplankton species composition through time
Panel B (bottom) – Zooplankton species densities through time



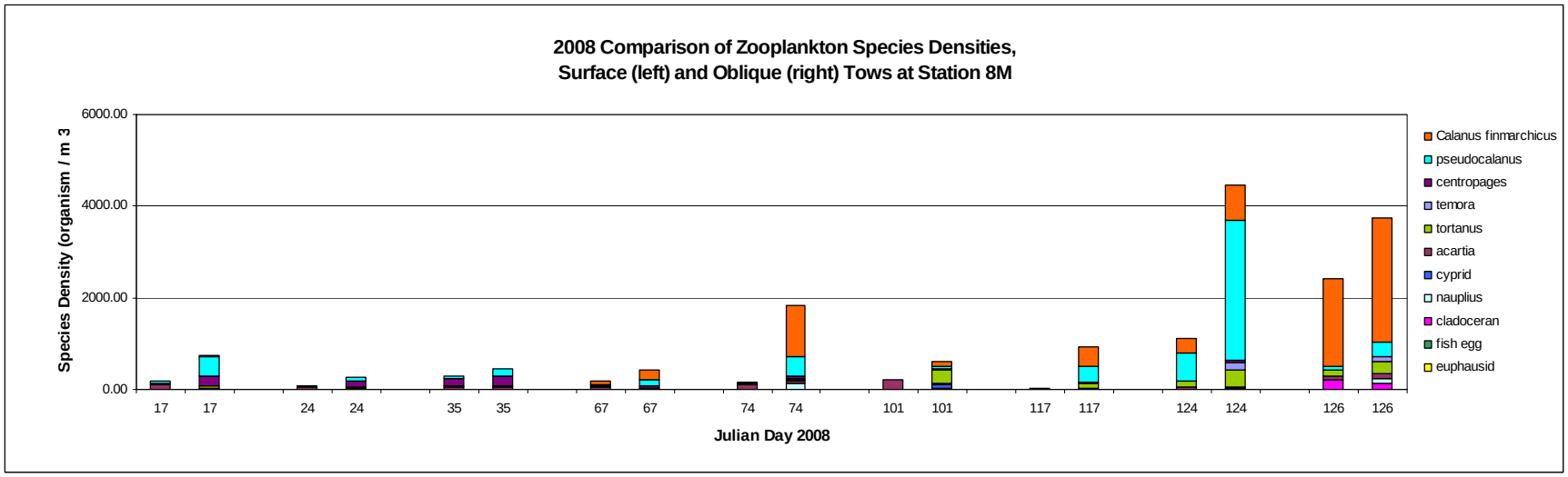
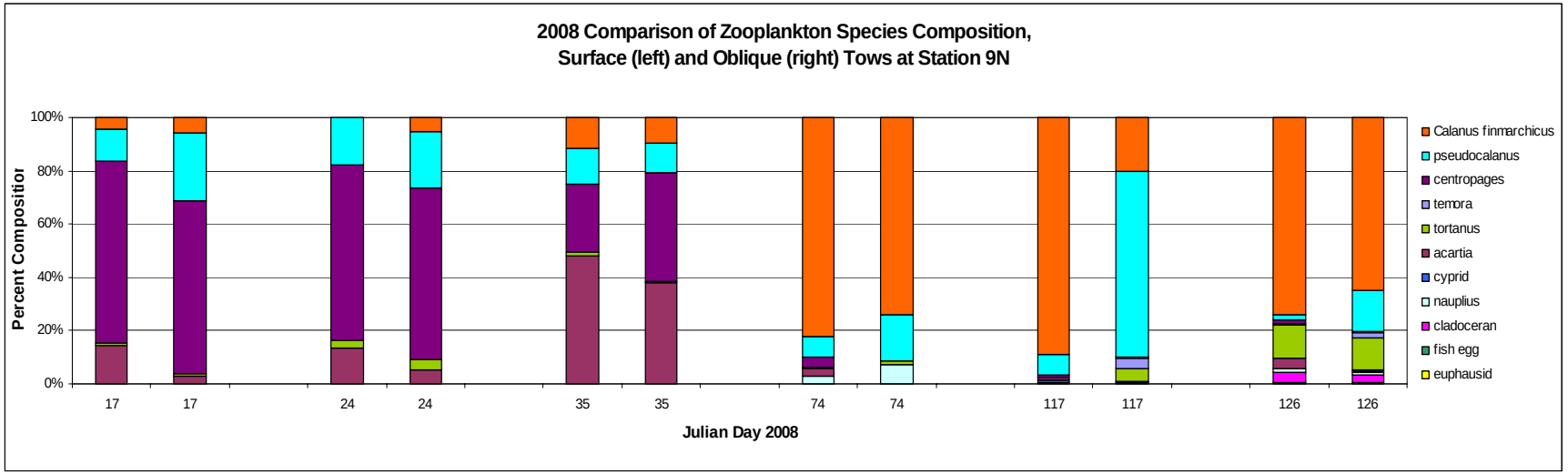


Figure A36. Comparison of surface and oblique zooplankton collections at Station 8M in 2008:
Panel A (top) – Zooplankton species composition through time
Panel B (bottom) – Zooplankton species densities through time



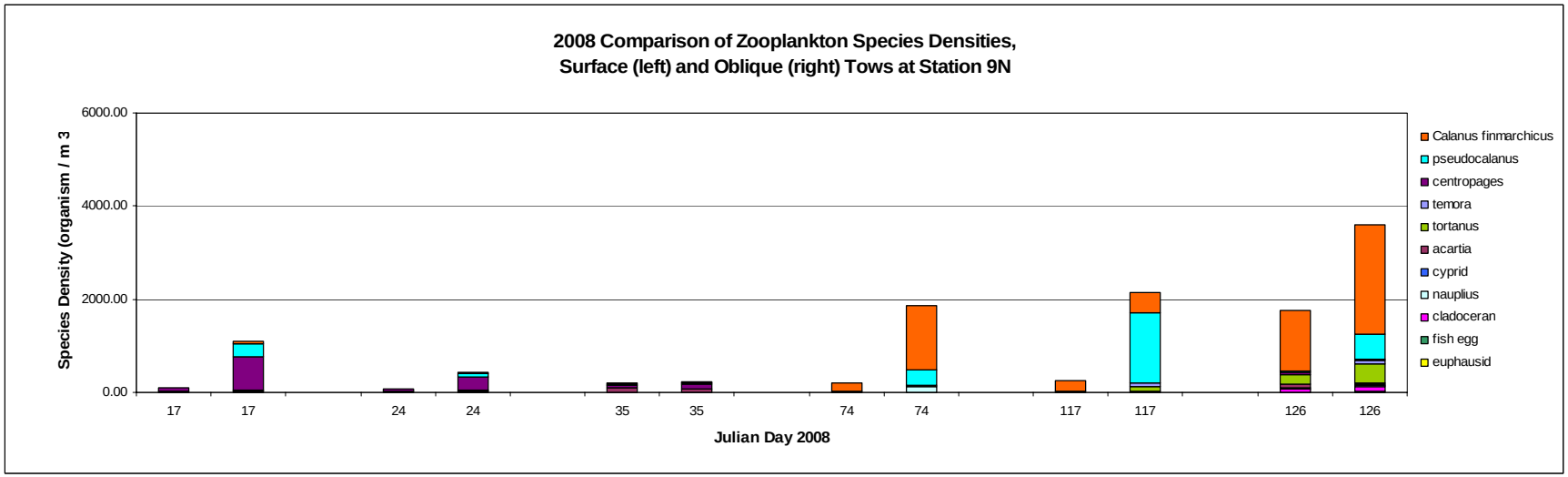


Figure A37. Comparison of surface and oblique zooplankton collections at Station 9N in 2008:
Panel A (top) – Zooplankton species composition through time
Panel B (bottom) – Zooplankton species densities through time

Appendix II

Habitat Assessment and Prediction Documents
2008

Cape Cod Bay Right Whale Habitat
Preliminary Assessment Report: Cruise SW679
12 January 2008

SW679, the first right whale habitat cruise of 2008, was conducted in clear, sunny conditions with moderate temperatures and a light northwest wind. Sea state and sighting conditions were excellent throughout. Intensive zooplankton sampling of the eastern and southeastern portions of Cape Cod Bay included surface and water column collections, designed to establish baseline resource conditions during the period preceding right whale residency within the Bay. The DMF/PCCS aircraft flew the eastern outer shore and nearly completed a full Cape Cod Bay survey before sighting an entangled right whale in the southwestern Bay, at which time further survey activity was aborted and the team stood by the animal. A brief disentanglement response was mounted at dusk by the crew aboard the R/V *Shearwater*, but the team was unable to approach the whale closely before darkness forced the aircraft and the vessel to abandon the disentanglement effort.

The food resource in the eastern quadrants of Cape Cod Bay was dominated by the calanoid copepods *Centropages* spp. and *Pseudocalanus* spp. at concentrations estimated to range between 1000 and 2000 organisms/m^3 both at the surface and in the water column, typical of resource conditions early in the winter. These concentrations and the resulting available caloric density are below the estimated feeding threshold for right whales and no aggregation or residency within the area is forecast.

The observed conditions suggest that the food resources of Cape Cod Bay will track the typical seasonal pattern of winter and spring enrichment. We anticipate a reduction in the standing stock of copepods at all depths for the next several weeks as *Centropages* spp. goes through its normal pattern of decline. Until the anticipated enrichment of the system by *Pseudocalanus* spp. as early as mid-February, the concentration of the influential food above feeding threshold levels is not expected.

These observations are considered preliminary pending detailed analysis and final assessment reporting.

The assessment and prediction reports are a product of the Right Whale Surveillance Program at the Provincetown Center for Coastal Studies – a management study supported by the Division of Marine Fisheries of the Commonwealth of Massachusetts and funded by the National Marine Fisheries Service, NOAA, Department of Commerce. (study conducted under NMFS research permit #633-1483-06)

Cape Cod Bay Right Whale Habitat
Preliminary Assessment Report: Cruise SW681
17 January 2008

Cruise SW681 was the second Cape Cod Bay habitat cruise of 2008. Zooplankton samples were collected at all 8 of the regular stations, with surface and oblique (to 19 meters depth) net tows conducted at each. Conditions were overcast and sea state ranged from Beaufort 1 to 3, but visibility was nonetheless excellent throughout the day. While no right whales were sighted from either the vessel or from the companion DMF/PCCS air survey, vessel-based marine mammal sightings did include three unidentified dolphins. Auxiliary sampling during SW681included CTD casts and nutrient sampling at all stations.

The food resource of Cape Cod Bay continues to be dominated by the copepod *Centropages* spp. in moderate concentration. As on the preceding cruise, SW679, the subdominant copepod is the small mid-winter taxon *Pseudocalanus* spp. Preliminarily we estimate that the total zooplankton concentration ranges between 1500 and 2500 organisms/m^3 in both mid-water and surface samples. As is often typical of the early winter zooplankton resource during the period of mixed water column, the resource of the Bay continues to be characterized as uniformly distributed and of modest quality, below the density that elicits either right whale feeding or aggregation and residency. These mid-winter conditions are typical of the last decade and may be expected to evolve as the *Pseudocalanus* resource, presently dominated by early life stages, matures and increases in density during early February. Also typical of the early- and mid-winter period, *Calanus finmarchicus*, the dominant contributor to the food resource in Cape Cod Bay during the late winter and early spring, was sparse or not present in the collections.

The observations of SW681 suggest that few right whales will enter the Bay in the near future, given the prevailing low zooplankton biomass, and that any whales found will neither remain nor aggregate. These January conditions continue to follow the pattern of the last decade during which early season feeding and residency were rarely observed.

These observations are considered preliminary pending detailed analysis and final assessment reporting.

The assessment and prediction reports are a product of the Right Whale Surveillance Program at the Provincetown Center for Coastal Studies – a management study supported by the Division of Marine Fisheries of the Commonwealth of Massachusetts and funded by the National Marine Fisheries Service, NOAA, Department of Commerce. (study conducted under NMFS research permit #633-1483-06)

Cape Cod Bay Right Whale Habitat
Preliminary Assessment Report: Cruise SW682
24 January 2008

Weather conditions during cruise SW682 were excellent with sea state of beaufort 1 under light winds. Sky conditions were increasingly overcast and visibility was greater than 10 km during the cruise. Water temperatures over the study area ranged between 3.8 and 4.3^{o}C, more than 2 degrees warmer than expected during mid-winter.

The surface and water column were sampled using standard techniques at all 8 stations regular throughout Cape Cod Bay. Routinely collected data on the location of fixed fishing gear, gear marking, and ship/vessel traffic were recorded and reported to DMF. Excellent conditions permitted the sighting of several pods of delphinids, harbor and grey seals, one humpback whale, and one unidentified additional large whale. No confirmed right whale sightings were made. The DMF/PCCS survey aircraft did not fly.

The zooplankton resource at all sample depths throughout the Bay remains uniformly distributed and moderate to low in total biomass. Although zooplankton densities did not approach the estimated threshold for right whale feeding at any sampling location, elevated concentrations of calanoid copepods were observed in the mid-water samples collected at station 7S located in the southern portion of the central Bay, as well as in the southeastern Bay. A preliminary review of the zooplankton collections indicates that the resource continues to be dominated by a mixture of *Centropages* and *Pseudocalanus* with an increase in the latter.

Given the present conditions across the entire range of Cape Cod Bay it is unlikely that right whales will aggregate, feed, or become resident in the Bay during the next week or more. Only with a very significant enrichment in the principal mid-winter food for right whales, the calanoid *Pseudocalanus* spp., which is not anticipated earlier than mid February, will right whales begin to aggregate and feed in the Bay.

These observations are considered preliminary pending detailed analysis and final assessment reporting.

The assessment and prediction reports are a product of the Right Whale Surveillance Program at the Provincetown Center for Coastal Studies – a management study supported by the Division of Marine Fisheries of the Commonwealth of Massachusetts and funded by the National Marine Fisheries Service, NOAA, Department of Commerce. (study conducted under NMFS research permit #633-1483-06)

Cape Cod Bay Right Whale Habitat
Preliminary Assessment Report: Cruise SW683
4 February 2008

Weather conditions during cruise SW683 were moderate with a sea state of less than Beaufort 2 and a northerly swell. While the sky was overcast, visibility during the entire cruise was greater than 10 km. The zooplankton resource at the surface and in the water column was sampled using standard techniques at all 8 stations in Cape Cod Bay, and the location of fixed fishing gear and of vessel traffic were recorded for reporting to DMF. Two right whales, one each in the southwest and northeast quadrants, were sighted by vessel-based observers. Marine mammal sightings also included several unidentified dolphins and gray and harbor seals. The DMF/PCCS survey aircraft did not fly on this day, but during their survey on the previous day (3 Feb) two right whales were sighted in locations similar to today's vessel-based sightings.

The right whales' zooplanktonic food resource in Cape Cod Bay remains low at all depths sampled, with the exception of one collection in the vicinity of a deep diving right whale from the surface collection at station 6M in the central eastern portion of the Bay. With the exception of the collection at station 6M, the densities of all of the other 17 zooplankton samples were estimated to be substantially below the density of the right whales' feeding threshold. In all parts of the Bay the food resource is dominated by the calanoid *Pseudocalanus*, a complex of a number of small species of copepods, the principal food of right whale feeding in Cape Cod Bay during the late winter. It is the enrichment of this taxon that often heralds the beginning of the feeding season of the right whales. Nevertheless, at present the zooplankton resource in the Bay remains uniformly poor and right whale feeding is not predicted.

Given the present conditions we do not forecast aggregation or long-term residency by right whales in the near future. As reported previously, only with a strong enrichment of the zooplankton resource will we anticipate the aggregation and residency by right whales. The suggestion of an increase in the surface resource at mid-bay station 6M encourages the idea that some usable food resources may develop within the next week or more.

The absence of an indication of feeding by either of the two whales sighted during the cruise and their deep diving behavior hint at the possibility of near-bottom foraging activities may be occurring. In order to explore the possibility of feeding on a bottom layer of zooplankton we will commence directed discreet depth vertical pump sampling on the next cruises.

These observations are considered preliminary pending detailed analysis and final assessment reporting.

The assessment and prediction reports are a product of the Right Whale Surveillance Program at the Provincetown Center for Coastal Studies – a management study supported by the Division of Marine Fisheries of the Commonwealth of Massachusetts and funded by the National Marine Fisheries Service, NOAA, Department of Commerce. (study conducted under NMFS research permit #633-1483-06)

Cape Cod Bay Right Whale Habitat
Preliminary Assessment Report: Cruise SW687
7 March 2008

Cruise SW687 was conducted one day after a DMF/PCCS aerial survey observed nine right whales in the central portion of eastern Cape Cod Bay (including one entangled right whale). While the aircraft did not fly due to a persistent low ceiling, vessel-based observers sighted at least as many right whales (an estimated 6-10) in the same area during cruise SW687; unfortunately, the entangled animal was not re-sighted. All right whales were observed taking long fluking dives, typically of durations exceeding 12 minutes. Seven of the eight regular zooplankton sampling stations were visited during SW687, with surface and oblique (to 19 meters depth) net collections made at each. Additional zooplankton net sampling was conducted in the eastern Bay to better characterize the quality and spatial extent of the resource in relation to the distribution of whales.

During the past two weeks the zooplankton at all depths throughout eastern Cape Cod Bay has increased significantly in both richness and taxonomic diversity, with two areas of particularly high abundance found in the central portion of the eastern Bay and in a broad central region along the southern edge of the Bay. Zooplankton concentrations in both of these areas, the former in the water column, the latter at all depths, approached or exceeded the right whale feeding threshold. The behavior of the whales, located between these two areas, suggests active feeding at the bottom in an engybenthic layer of *Pseudocalanus* spp. that often develops during early March. The goal of SW687 was to document the extent of the increasing food resource throughout the Bay, hence bottom-layer samplers were not used; however, all indications are that a rich resource capable of releasing bottom feeding activities was concentrated low in the water column. The surface concentration of zooplankton in the vicinity of the whale aggregation was below the estimated threshold and no indication of surface feeding was observed, further supporting the view that a bottom layer had formed.

The taxonomic composition of the collections has begun to change several weeks earlier than usual, with a significant contribution by *Calanus finmarchicus* (primarily early stage copepodites) to the available zooplanktonic food resources now dominated by *Pseudocalanus* spp. The early arrival of *Calanus*, the increased midwater biomass, the suggestion of bottom feeding by whales on a strong *Pseudocalanus* layer, and the widespread distribution of midwater resources, suggest the likelihood of a protracted period of whale presence and feeding in Cape Cod Bay. In the short term, the movement of the whales throughout the eastern quadrants of the bay is likely. Increased food densities in both the central portion of the eastern Bay and along the western edge of the southeastern quadrant further suggests that movement into those areas, several miles removed from the whale's present location is likely. Given the late winter patterns of water circulation it is likely that the whales, probably increasing in numbers, will favor a move to areas south of the present location, several miles west of Billingsgate Shoals. Since such forecasts are dependant upon moderate weather, strong easterly storms could substantially change the pattern of behavior and occurrence.

In summary, a rich and diverse food resource is presently influencing the distribution of whales and will likely result in increasing aggregation and increasing potential for near-surface or surface feeding in areas of the eastern bay for the foreseeable future. Weather permitting, a special cruise to assess the quality of the bottom resource will be mounted in the next several days.

These observations are considered preliminary pending detailed analysis and final assessment reporting.

The assessment and prediction reports are a product of the Right Whale Surveillance Program at the Provincetown Center for Coastal Studies – a management study supported by the Division of Marine Fisheries of the Commonwealth of Massachusetts and funded by the National Marine Fisheries Service, NOAA, Department of Commerce. (study conducted under NMFS research permit #633-1483-06)

Cape Cod Bay Right Whale Habitat
Preliminary Assessment Report: Cruise SW688
11 March 2008

With at least nine right whales aggregated in the central portion of eastern Cape Cod Bay on 7 March, a directed cruise was mounted on 11 March to better characterize the quality and spatial extent of the resource and to document changes in the distribution of whales. The previous behavior of nearly all the whales in the Bay – fluking dives typically exceeding 12 minutes – along with high zooplankton densities in nearby water column collections suggested feeding at depth; by sampling at discrete depths with a pump sampler we planned to assess the depth and composition of the near-bottom ("engybenthic") resource. However, persistent northwest winds kept the sea state above Beaufort 4, preventing the use of vertical sampling gear.

During the shortened cruise, two net tows (one surface and one through the water column to 19 meters depth) were conducted in an area several miles to the north of the previously documented aggregation. Samples collected at this location on 7 March had revealed an extremely rich zooplankton resource that was strongly dominated by *Pseudocalanus* spp., with high densities in the water column and extremely high densities (well in excess of the "threshold" thought to release right whale feeding) found in the surface sample. While no right whales had yet been observed in that area on 7 March, at least six right whales were sighted there during cruise SW688, many of which appeared to be near-surface feeding (strong serial fluke prints and tight turns observed). A horizontal net tow taken in the near-surface waters revealed an extremely high-density resource with continued dominance by *Pseudocalanus* spp.

The persistence of a *Pseudocalanus* resource capable of supporting right whale feeding and aggregation in the central region of eastern Cape Cod Bay, and now in areas to the north of this location, continues to suggest the likelihood of a protracted period of whale presence and feeding in Cape Cod Bay. In particular, the richness of the near-surface resource in the northern area will result in increasing potential for near-surface and surface feeding for the foreseeable future. Weather permitting, further directed sampling in areas of whale aggregation will be conducted in the coming days to better assess both the horizontal and vertical distribution of the zooplankton resource presently influencing whale distribution.

These observations are considered preliminary pending detailed analysis and final assessment reporting.

The assessment and prediction reports are a product of the Right Whale Surveillance Program at the Provincetown Center for Coastal Studies – a management study supported by the Division of Marine Fisheries of the Commonwealth of Massachusetts and funded by the National Marine Fisheries Service, NOAA, Department of Commerce. (study conducted under NMFS research permit #633-1483-06)

Cape Cod Bay Right Whale Habitat
Preliminary Assessment Report: Cruise SW689
14 March 2008

Calm conditions during cruise SW689 permitted zooplankton resource sampling directed at the vertical structure of the resource combined with right whale behavior. In excess of 23 right whale sightings were recorded during the cruise (some of which were duplicates that photo documentation will resolve) in an area of about 20 km^2 centered approximately 10 km west of Wood End Light, Provincetown. The DMF/PCCS air survey team will issue a report on survey numbers and locations later today.

A total of 72 zooplankton samples were collected, with 4 pump profiles sampled in the vicinity of whales apparently responding to diel migration of the zooplankton layer. Samples were collected next to whales on long-diving patterns, likely feeding on a resource close to the bottom, in the early morning and at mid-day, and vertical profiles were also collected during the mid- and late-afternoon when skim feeding behavior was widespread. Because of the importance of such collections to our evolving understanding of the influence of the diel vertical migration (DVM) of zooplankton layers on management of both ship strike and fishing practices we will be providing analysis and interpretation of the results of the vertical profiling/DVM studies in the coming week, exploring in detail the patterns of vertical food resource distribution and the coincident behavior of the whales.

A preliminary review of the collections indicates the presence of a rich bottom layer concentrated within 1 meter of the bottom and composed of a nearly pure adult *Pseudocalanus* ssp. resource present throughout the day. Late afternoon profiling demonstrated a splitting of the resource, with a surface layer formed from adult *Pseudocalanus* ssp. with modest additional contribution by *Calanus finmarchicus* adults. The forthcoming analysis of the samples should provide a detailed perspective on the characteristics and influence of the resource eliciting bottom and skim feeding behaviors identified as particularly risky to right whales.

The focused studies conducted on SW689 do not allow the usual forecasting of the movement of whales within the Cape Cod Bay system, however today's observations do suggest that a very rich zooplankton resource is at least spread over an area in the north-central and northeast portion of the Bay. This resource apparently is vertically mobile and the characteristics of whale behavior will be coupled to the DVM. All of the whale behaviors identified as risky may be expected within the next week, <u>at a minimum</u> in an area bounded by:

42° 03 70° 16'
41° 58' 70° 10'
42° 00' 70° 22'
42° 05' 70° 23'

These observations are considered preliminary pending detailed analysis and final assessment reporting.

The assessment and prediction reports are a product of the Right Whale Surveillance Program at the Provincetown Center for Coastal Studies – a management study supported by the Division of Marine Fisheries of the Commonwealth of Massachusetts and funded by the National Marine Fisheries Service, NOAA, Department of Commerce. (study conducted under NMFS research permit #633-1483-06)

Cape Cod Bay Right Whale Habitat
Preliminary Assessment Report: Cruise SW690
24 March 2008

Cruise SW690 was conducted in excellent sea and visibility conditions, with zooplankton samples collected from the surface and water column at all 8 regular and 2 special stations. Information on fixed fishing gear and location of vessels was also recorded for transmission to DMF. An estimated 5-6 right whales were sighted during the cruise, all located in the northeastern quadrant of Cape Cod Bay over a broad area from 6 miles west to 4 miles south of Wood End Light, Provincetown. Additional ship-board sightings included 1 humpback whale, 1 probable fin whale, harbor porpoises and seals, all recorded with location and behavior. The DMF/PCCS aerial team will report separately the results of today's survey.

The zooplankton resource available to right whales appears to have declined in the last 10 days, with significant decreases in densities of the dominant prey copepod, *Pseudocalanus* spp. The surface zooplankton concentration at all stations throughout the Bay is well below that estimated to release right whale feeding behavior. Water-column sampling suggests localized areas of mid-water richness in the vicinity of the aggregation of whales in the northern portion of the NE quadrant, along the southern edge the SE quadrant, and along the far western edge of the Right Whale Critical habitat. Concentrations in all mid-water collections throughout the Bay, however, are estimated to be below the feeding threshold.

We anticipate and are observing typical changes in zooplankton in early spring: a decline in *Pseudocalanus*, a rise in larval forms of cirripedes (taxa and life stages known from past observations to release feeding behavior) and a rise in various stages of *Calanus finmarchicus*. A modest increase in the concentration of *Calanus* in the western portion of the Bay is evident, a possible harbinger of the spring increases that support mid- to late-spring feeding by right whales.

Zooplankton at the bottom of the water column was not sampled due to rough sea conditions, therefore a complete assessment of the influence of the food resource on whales distribution within the Bay cannot be made. Nevertheless, using the mid- and upper-water column data from SW690 we anticipate that whales may begin to move out of the Bay in the near future because of the observed decline in the *Pseudocalanus* resource and the yet-to-be documented strong increase in *Calanus* concentration and patch formation. Only with a rapid enrichment of the *Calanus* resource (not yet indicated by sampling) within the next week will the potential for right whale aggregation and feeding be anticipated. Given this scenario and the SW690 observations, surface feeding and aggregation, while not anticipated, are most likely in the central and northeastern portions of Cape Cod Bay.

These observations are considered preliminary pending detailed analysis and final assessment reporting.

The assessment and prediction reports are a product of the Right Whale Surveillance Program at the Provincetown Center for Coastal Studies – a management study supported by the Division of Marine Fisheries of the Commonwealth of Massachusetts and funded by the National Marine Fisheries Service, NOAA, Department of Commerce. (study conducted under NMFS research permit #633-1483-06)

Cape Cod Bay Right Whale Habitat
Preliminary Assessment Report: Cruise SW691
27 March 2008

Cruise SW691 was focused on the distribution of zooplankton in layers throughout the water column, using discrete-depth vertical sampling techniques identical to those reported for cruise SW689 on 14 March. The objective was to develop a better understanding of the influence of the diel vertical distribution of zooplankton in relation to observed right whale behavior.

SW691 started in calm weather and ended with threatening conditions and an increasing wind from the south-southwest. Visibility throughout the cruise was excellent. The DMF/PCCS air survey team flew tracks in Cape Cod Bay and located numbers of whales in the northwest quadrant and a maximum of 14 right whales were sighted from R/V *Shearwater*. The results of the air survey of Cape Cod Bay will be reported separately.

Collections were directed at (1) re-sampling the water column at the station profiled on 14 March where both long-diving and skim feeding whales had been observed, and (2) conducting surface and water column net tows and acquiring vertical profiles of the zooplankton resource in the near-vicinity of an aggregation of whales seen in the northwestern quadrant, 5-6 miles east of the Manomet cliffs. A total of sixty-four zooplankton samples were collected both in the vicinity of fluking whales and at the previously sampled station.

Although sampling was not directed at a bay-wide assessment of the available food resources, a potentially influential change in the zooplankton conditions was observed in the SW691 collections: a marked increase in the abundance of *Calanus finmarchicus* was associated with the aforementioned aggregation of whales. The zooplankton resource appears to be in transition between a community dominated by *Pseudocalanus* spp. to one of mixed taxonomic character with a strengthening signal from late stage *Calanus*. In the area of whale aggregation the zooplankton resource appeared to be split between a rich deep layer at the bottom (41 meters) and a near-surface layer between 1 and 6 meters. The behavior of the whales consistently suggested that feeding was focused on the deep layer. The concentration of zooplankton in both layers exceeded the feeding threshold. Particularly notable was the density and thickness of the bottom layer suggesting that the zooplankton biomass in the 36 sq km area of feeding whales was very high and, with the evolution of an increasingly rich of the *Calanus* resource, may be expected to increase. These conditions point to the increasing possibility of surface and near surface feeding in western Cape Cod Bay and the further development of aggregations of whales, likely moving slowly south. It is possible that the resource will also drift west of the present location, although that situation is not now predicted, impinging on the Boston – Cape Cod Canal shipping lanes. With conditions favoring increasing near-surface feeding and the southward movement of whales we will be endeavoring to survey the resource in the next week in order to forecast any potential vessel-strike risk to the whales.

These observations are considered preliminary pending detailed analysis and final assessment reporting.

The assessment and prediction reports are a product of the Right Whale Surveillance Program at the Provincetown Center for Coastal Studies – a management study supported by the Division of Marine Fisheries of the Commonwealth of Massachusetts and funded by the National Marine Fisheries Service, NOAA, Department of Commerce. (study conducted under NMFS research permit #633-1483-06)

Cape Cod Bay Right Whale Habitat
High Risk Alert and Preliminary Habitat Assessment: Cruises SW692&SW693
9-10 April 2008

Cruises SW692 and SW693 (both ½ day) were directed at the collection of resource information in the vicinity of high concentrations of feeding right whales distributed over much of Cape Cod Bay. Using discrete-depth sampling through the water column, regular station net sampling, and net collections in the feeding path of whales, conditions within Cape Cod Bay were assessed with respect to potential risks to right whales (see below). SW692 was conducted on 9 April in calm conditions and excellent visibility; unusually high concentrations of right whales (in excess of 50 individuals) were located by the DMF/PCCS aerial survey team throughout the southwestern quadrant of the Bay, with most animals subsurface- and skim-feeding. Coincident vessel-based sightings of more than 25 right whales included at least 15 non-duplicates, suggesting that more than 70 whales may have been present in the Bay on 9 April. Sighting conditions on 10 April were limited, with visibility for the morning below 200 meters and sea conditions moderate; vessel-based observations indicated that substantial numbers of right whales moved to the northeast margin of Cape Cod Bay, closely associated with a very rich patch of late stage *Calanus finmarchicus* at the entrance to Provincetown Harbor. During that abbreviated habitat sampling cruise a second group of 15-20 whales were sighted in the central portion of the southern Bay, with animals observed socializing and subsurface feeding in the upper water column. Movement through the day of the northern aggregation was toward Race Point, the location through which whales usually exit the Bay; it is likely that the rich zooplankton resources of the northeastern Bay are flushing out of the system and that portions of the very dense aggregations of whales observed on 9 April are shifting toward this area. Nevertheless, substantial numbers of right whales remain along the margins of the land in Provincetown and in a broad region covering the southwestern and southern-central Bay where extensive patches of *Calanus* remain.

The very rich zooplankton resource observed at all sampling locations indicates that the expected enrichment by late-stage, nutritionally-rich *Calanus finmarchicus* is well underway and is, as anticipated, coupled with a distinct decline in *Pseudocalanus* spp. While discrete-depth water column sampling was hampered by windy conditions, net collections indicate that a dense *Calanus* layer has formed at shallow depths in much of the Bay. With increases in late stage *Calanus* at densities sometimes exceeding the feeding threshold by two orders of magnitude and with the widespread extent of the patch areas, we forecast the continued development of aggregations of whales and increased potential for near-surface feeding in southern Cape Cod Bay, with movement of the whales likely to be to the east and north in the coming week. The whales in the northeast quadrant may remain associated with zooplankton resources for several days, but steady dissipation of the whale aggregations (as the zooplankton resource flushes out of the Bay) may be expected. Broadly, we forecast that right whale numbers will decline from the very high abundance observed on 9 April, though substantial numbers of whales will remain in the southern quadrants of the Bay where food resources remain high.

The extremely high concentrations of zooplankton along the northeastern and southern margins of the Bay suggest that aggregation and near-surface feeding activity by whales will likely continue and that the risk of vessel-strike will remain elevated in these areas. In the northeastern Bay, it is expected that unusually high concentrations of whales will continue to be found feeding in loose aggregations throughout the nearshore areas spanning from Provincetown Harbor to Race Point and beyond to the Highland Light. Because of the vertical distribution of the food resource, whale behavior may present few surface clues to the presence of whales, and so the risk of collision is significantly elevated in these areas of increasing vessel traffic. **Mariners should reduce speed and be alert to whales in the high risk forecast area encompassed by 42º 06'/70º 21' and 42º 06'/69º 55' and 41º 59' /69º 55' and 41º 59'/70º 21' .**

These observations are considered preliminary pending detailed analysis and final assessment reporting.

The assessment and prediction reports are a product of the Right Whale Surveillance Program at the Provincetown Center for Coastal Studies – a management study supported by the Division of Marine Fisheries of the Commonwealth of Massachusetts and funded by the National Marine Fisheries Service, NOAA, Department of Commerce. (study conducted under NMFS research permit #633-1483-06)

Cape Cod Bay Right Whale Habitat
Right Whale High Risk Alert and Preliminary Assessment Report
Cruise SW694, 11 April 2008

Cruise SW694 was directed at the collection of prey field information in the vicinity of high concentrations of feeding right whales aggregated between Provincetown Harbor and the western shore of Wellfleet. More than 100 zooplankton samples were collected from 6 shallow transects and 2 vertical profiles in an area of intense surface and subsurface feeding by 15-20 right whales. A detailed report on the results of the study will be forthcoming.

Sampling and whale distribution reinforces the observations of the previous High Risk Alert that unusually dense aggregations of whales, estimated to exceed 70 individuals, are to be found throughout Cape Cod Bay. Combined information from cruises SW692-SW694 (9-11 April) indicates that a very strong *Calanus* resource, composed principally of late stages, is found in the upper 3-4 meters of the water column; this widespread resource is having a very strong influence on the behavior and distribution of the whales. Activity including surface and near-surface feeding and socializing behavior, making whales particularly vulnerable to vessel collision, may be found anywhere in Cape Cod Bay. Of greatest concern are those areas of the Bay traversed by shipping lanes, those within 5 miles of land from Provincetown Harbor to Race Point and around the eastern outer shore of the Cape, and an additional area in the shipping lanes at the eastern end of the Cape Cod Canal where food resources have been elevated during the last 3 days.

We forecast that the conditions of high risk will continue for the next week and that the area of greatest risk of collision and entanglement will lie east of a line between Manomet and Race Point, Provincetown. Rotation of the resource and the whales to the east and eventually to the north is anticipated over the next week to 10 days, with an associated decline in density of whales. While no region of the Bay will be out of the area of concern, we anticipate that the northwestern quadrant of the Bay may be exempt from particular concern within the next several days, as the food resource in that region have declined. The absence of *Pseudocalanus* and dominance of *Calanus* suggests that feeding activities will no longer be located in the engybenthic layer but instead within the upper 3-4 meters of the water column throughout the Bay.

With the unusual number of whales, their intensive feeding activities, and their movement over much of the Bay, all of Cape Cod Bay should be considered a vessel collision high risk area. We continue particularly to warn that mariners should reduce speed and be alert to whales in the high risk forecast area encompassed by 42º 06'/70º 21' and 42º 06'/69º 55' and 41º 59' /69º 55' and 41º 59'/70º 21' (previously reported). WE ADD AN OVERLAPPING WARNING AREA covering much of the remainder of Cape Cod Bay, an area east of a line between Manomet (41º 54' /70º 32') and Race Point (42º 06'/70º 21'), the northwest point of the aforementioned warning area.

These observations are considered preliminary pending detailed analysis and final assessment reporting.

The assessment and prediction reports are a product of the Right Whale Surveillance Program at the Provincetown Center for Coastal Studies – a management study supported by the Division of Marine Fisheries of the Commonwealth of Massachusetts and funded by the National Marine Fisheries Service, NOAA, Department of Commerce. (study conducted under NMFS research permit #633-1483-06)

Cape Cod Bay Right Whale Habitat
Preliminary Assessment Report: Cruise SW696
15 April 2008

Cruise SW696 was carried out in clear conditions and a moderate northeasterly wind. Although SW696 was dedicated to the survey and assessment of the zooplankton resource controlling the distribution and behavior of the right whales, 31 whales were recorded during the cruise. The DMF/PCCS survey aircraft flew and the detailed results of their survey and photo-identification efforts will be issued separately.

The dense concentration of right whales in Cape Cod Bay is being influenced by an unusually rich zooplankton resource dominated by late-stage *Calanus finmarchicus* (stage 4 through adult) that is patchy and widely distributed along the entire southern margin of the Bay. Areas of rich *Calanus* patches more than an order of magnitude greater in concentration than the estimated feeding threshold were found principally within 5 miles of the shores of Dennis, Barnstable, and Sandwich. An additional area of high zooplankton concentration was found at stations 6N and 6M in the northeastern quadrant of the Bay. The more than 60 samples from transect and regular net sampling indicate that the fully developed and exceptionally rich late-stage *Calanus* resource was concentrated within the water column and absent from the upper 1-2 meters. As a result of the stratification of the resource all foraging whales were documented feeding beneath the surface but within the upper 3 meters of the water column; this feeding behavior is particularly risky because they are within the depth of greatest risk of vessel strike but are not visible.

The distribution of the zooplankton along the near-shore margin of the southern Bay in an area of relatively low flushing suggests that the strong *Calanus* resource influencing the whales will persist and that the whales will remain aggregated and feeding near or at the surface. We forecast that the resource will continue to rotate slowly to the east and, eventually, north over the next week and that the whales, while slowly decreasing in numbers, will follow the same pattern. Strong wind events and the gradual grazing-down of the resource will affect the near-term stability of the situation.

The previous alert of ship-strike risk remains appropriate given the large numbers of whales present in the Bay and their behavior in response to the near-surface layer of *Calanus*. Areas of particular risk within the southern Bay include the entire area of elevated zooplankton resource in the near-shore (within 5 miles of land) between the eastern entrance of the Cape Cod Canal and Billingsgate Shoals; however, ship-strike risk will remain high throughout the previously delineated eastern 2/3 of Cape Cod Bay.

We will endeavor to revise the risk alert as appropriate after the next habitat assessment cruise.

These observations are considered preliminary pending detailed analysis and final assessment reporting.

The assessment and prediction reports are a product of the Right Whale Surveillance Program at the Provincetown Center for Coastal Studies – a management study supported by the Division of Marine Fisheries of the Commonwealth of Massachusetts and funded by the National Marine Fisheries Service, NOAA, Department of Commerce. (study conducted under NMFS research permit #633-1483-06)

Cape Cod Bay Right Whale Habitat
Preliminary Assessment Report: Cruise SW697, 21 April 2008
Right Whale High Risk Alert

Efforts during cruise SW697 were directed at sampling the zooplankton resource in the eastern region of Cape Cod Bay, in the vicinity of aggregations of feeding right whales. Cruise SW697 was ½ day in duration with sea conditions calm and visibility excellent. More than 18 right whales were sighted from the vessel, with all animals observed feeding at the surface or in the near subsurface.

The zooplankton resource in the upper 2 meters of the water column throughout the areas sampled was exceptionally rich and dominated by late-stage *Calanus finmarchicus*. Combining recent DMF/PCCS aircraft survey observations and zooplankton samples from 11 April to the present, we forecast that right whales will continue to feed at or near the surface in eastern Cape Cod Bay and will continue to present a high risk of collision with vessels in that area. With the persistent zooplankton resource continuing to form particularly rich patches, we anticipate that the previously forecast counter-clockwise rotation of the resource along the eastern shore of the Bay will continue, as will the northward movement of the widely distributed aggregation of whales. Whale density in the eastern Bay is expected to slowly decline over the next week to 10 days, however numbers should remain high until flushing and graze-down reduces the richness of the resource. While the area between Barnstable Harbor and Race Point will continue to present the highest risk of ship strike, mariners should be alert to potential collision throughout the Bay.

With the unusual number of whales, their intensive near-surface feeding activities, and their movement over much of the Bay, all of Cape Cod Bay should be considered a an area of high risk of vessel collision. We continue particularly to warn that mariners should reduce speed and be alert to whales' presence in the area encompassed by 42º 06'/70º 21' and 42º 06'/69º 55' and 41º 59'/69º 55' and 41º 59'/70º 21' (previously reported). We revise the bay-wide warning area introduced on 11 April to now cover 3/5 of Cape Cod Bay east of a line from Sandy Neck in Barnstable at 41º 44'/70º 21' to the northwest point of the aforementioned warning area off Race Point in Provincetown at 42º 06'/70º 21'.

These observations are considered preliminary pending detailed analysis and final assessment reporting.

The assessment and prediction reports are a product of the Right Whale Surveillance Program at the Provincetown Center for Coastal Studies – a management study supported by the Division of Marine Fisheries of the Commonwealth of Massachusetts and funded by the National Marine Fisheries Service, NOAA, Department of Commerce. (study conducted under NMFS research permit #633-1483-06)

Cape Cod Bay Right Whale Habitat
Preliminary Assessment Report: Cruise SW698
23 April 2008

Field efforts during SW698 focused on sampling the zooplankton resource in the eastern and central regions of Cape Cod Bay. Sea conditions and visibility for the duration of the cruise were excellent and 18 to 23 right whales, 3 humpback whales, and 7 fin whales were sighted. The DMF/PCCS aircraft flew a survey of the Bay after fog lifted in the mid-morning.

The *Calanus finmarchicus* resource reported over the last 2 weeks throughout much of the eastern Bay has declined precipitously to levels unacceptable for right whale feeding. Samples from regular stations in the central and southern portions of the Bay, while more dense than in the east, were nevertheless only slightly more dense than the estimated feeding threshold. Right whale activity and in-path sample collections close to aggregations of whales indicated that small, moderately rich zooplankton patches persist only in central Cape Cod Bay; conditions in the far western portion of the Bay, recently reported as poor, could not be assessed today due to time constraints. The decline of the zooplankton resource in the east, while more pronounced than anticipated, probably reflects both processes of advection out of the eastern Bay and the heavy grazing by right whales reported in recent assessments.

The present conditions suggest that right whales will continue to aggregate in the central and north central Bay and continue to move north. Both the decline in the previously strong zooplankton signal in the east and indications of a modest resource in the central Bay indicate that the movement of whales out of Cape Cod Bay will continue.

While the zooplankton resource in the eastern areas of the Bay has become impoverished, the previous alert of ship strike risk in eastern Cape Cod Bay and along the shipping lanes around Provincetown remains appropriate because of the likelihood that the resource found at the central stations will move north and east and result in aggregations of whales feeding and socializing at the surface. Future cruises will be directed at continued assessment of the resources along the eastern edge of the critical habitat. Modification of the previous alert area may be anticipated after the next sampling cruise.

These observations are considered preliminary pending detailed analysis and final assessment reporting.

The assessment and prediction reports are a product of the Right Whale Surveillance Program at the Provincetown Center for Coastal Studies – a management study supported by the Division of Marine Fisheries of the Commonwealth of Massachusetts and funded by the National Marine Fisheries Service, NOAA, Department of Commerce. (study conducted under NMFS research permit #633-1483-06)

Cape Cod Bay Right Whale Habitat
Preliminary Assessment Report: Cruise SW699, 25 April 2008
Discontinuation of Ship Strike Risk Warning

Cruise SW699 was carried out in excellent visibility and sea conditions. All eight regular stations were sampled for zooplankton both at the surface and with oblique tows, permitting an assessment of all quadrants of the Cape Cod Bay system. Additional samples were taken in the southwest quadrant of the Bay where a small group of right whales was observed subsurface feeding; a shallow vertical sampling profile was collected in the feeding area. A total of five right whales were recorded during the cruise, the lowest number sighted from the vessel in the last month of surveys. The DMF/PCCS survey aircraft did not fly.

The continued precipitous decline in the zooplankton resource was evident at all stations throughout the Bay. Only in the relatively small area in the southwest quadrant was a total zooplankton concentration estimated to be at or slightly above the threshold for feeding. Observations of the feeding pattern of the whales and of the associated zooplankton in the feeding area strongly suggest that only a small patch of resource was available to the whales; vertical sampling identified a modest *Calanus finmarchicus* resource within the upper 10 meters of the water column. The *Calanus* resource, which for several weeks has supported an unusually large and widespread concentration of right whales, has continued to decline to levels that make nearly all of Cape Cod Bay unacceptable to foraging right whales.

We continue to forecast a decline in the food resource within the Bay and the associated decline in right whale density throughout Cape Cod Bay. Absent an unlikely influx of a new and rich *Calanus finmarchicus* resource, nearly all of the remaining right whales within the Bay will depart within the next several days to a week.

As seen in the observations from cruise SW699, it remains possible that small patches of the once-rich *Calanus* resource will continue to influence the distribution and behavior of remaining right whales; however, conditions within the Bay do not favor further aggregation. While zooplankton samples were not collected along the outer shore of Provincetown and Truro where zooplankton resources have resulted in moderate densities of right whales feeding near the surface, the conditions within Cape Cod Bay suggest that the area immediately beyond Race Point will also become unfavorable for right whale feeding within the next week. **Hence, we discontinue the areas of high risk of ship strike covering the eastern 3/5 of Cape Cod Bay and the shipping lanes around Provincetown and Truro. It should be noted, however, that moderate numbers of right whales will likely remain scattered within Cape Cod Bay and along the outer shore between Provincetown Harbor and Highland Light, Truro. Furthermore, sightings from cruises SW698 and SW699 combined with recent air survey observations indicate that high densities of other species of endangered whales – fin and humpback – may be found throughout Cape Cod Bay and the waters north and east of Cape Cod. Vessel operators should continue to exercise caution within this region.**

These observations are considered preliminary pending detailed analysis and final assessment reporting.

The assessment and prediction reports are a product of the Right Whale Surveillance Program at the Provincetown Center for Coastal Studies – a management study supported by the Division of Marine Fisheries of the Commonwealth of Massachusetts and funded by the National Marine Fisheries Service, NOAA, Department of Commerce. (study conducted under NMFS research permit #633-1483-06)

Cape Cod Bay Right Whale Habitat
Preliminary Assessment Report: Cruise SW700
3 May 2008

Although moderate to rough seas and cold, rainy conditions throughout cruise SW700 prevented sampling in the far northwest (station 9N) of Cape Cod Bay, the surface and water column zooplankton resource was successfully sampled at 7 regular stations and 1 special station. In fair sighting conditions, large numbers of fin and humpback whales (10-15 individuals of each species) were documented in the southeastern and southern-central Bay; dolphin and seal sightings were also high, however no right whales were sighted by vessel-based observers. Poor weather conditions and a low ceiling prevented the DMF/PCCS aircraft survey.

The concentration of the zooplankton resource has continued to decline throughout the Bay, making the entire study area unacceptable to right whales, as previously forecast. With the right whale food resource at an estimated concentration of a few hundred organisms/m^3 at all stations and depths, none of the stations in the Bay were assessed as being attractive to right whales. Conditions do not and will not likely favor feeding by whales; hence, right whales will neither aggregate nor feed within the area of the Bay and any remaining individuals (excepting occasional strays) in the area of the assessment survey will leave the Bay. The low food abundance and unattractiveness of the habitat to right whales, the basis for these forecasts, will likely apply for at least the coming week.

These observations are considered preliminary pending detailed analysis and final assessment reporting.

The assessment and prediction reports are a product of the Right Whale Surveillance Program at the Provincetown Center for Coastal Studies – a management study supported by the Division of Marine Fisheries of the Commonwealth of Massachusetts and funded by the National Marine Fisheries Service, NOAA, Department of Commerce. (study conducted under NMFS research permit #633-1483-06)

Cape Cod Bay Right Whale Habitat
Preliminary Assessment Report: SW701
22 May 2008

Cruise SW701 was directed toward resource sampling at stations within Cape Cod Bay; the samples collected represent the current resource at this end of the right whale season. Despite excellent sighting conditions, no marine mammals were observed during the cruise. The DMF/PCCS survey aircraft did not fly because of the tragic passing of our long-time friend and pilot, John Ambroult.

The zooplankton resource was sampled at all eight regular stations, from both the surface and the water column.

Although the concentration of zooplankton that is estimated to release right whale feeding behavior was not reached in any of the 16 samples collected, the zooplankton resource in the bay has increased to levels above those seen in recent weeks past. While the principal copepod taxa through much of the bay appear to be smaller calanoids, significant further enrichment could make Cape Cod Bay marginally acceptable to right whales for feeding. A surface sample at station 6M in the northeastern quadrant of the bay was particularly rich, with a concentration estimated close to the right whale feeding threshold; it was composed primarily of larger zooplankters, including late stage *Calanus finmarchicus* and *Tortanus* sp.

Given the moderate concentration of zooplankton observed throughout the survey area, and absent a dramatic and unexpected enrichment of the zooplankton resource, we forecast that the bay will remain unacceptable for right whale feeding and aggregation for the foreseeable future.

These observations are considered preliminary pending detailed analysis and final assessment reporting.

The assessment and prediction reports are a product of the Right Whale Surveillance Program at the Provincetown Center for Coastal Studies – a management study supported by the Division of Marine Fisheries of the Commonwealth of Massachusetts and funded by the National Marine Fisheries Service, NOAA, Department of Commerce. (study conducted under NMFS research permit #633-1483-06)

Appendix III

Right Whale Habitat Studies Risk Alerts and DMF Advisories: Boxes 1-8

2008

Cape Cod Bay Right Whale Habitat
High Risk Alert and Preliminary Habitat Assessment: Cruises SW692&SW693
9-10 April 2008

Cruises SW692 and SW693 (both ½ day) were directed at the collection of resource information in the vicinity of high concentrations of feeding right whales distributed over much of Cape Cod Bay. Using discrete-depth sampling through the water column, regular station net sampling, and net collections in the feeding path of whales, conditions within Cape Cod Bay were assessed with respect to potential risks to right whales (see below). SW692 was conducted on 9 April in calm conditions and excellent visibility; unusually high concentrations of right whales (in excess of 50 individuals) were located by the DMF/PCCS aerial survey team throughout the southwestern quadrant of the Bay, with most animals subsurface- and skim-feeding. Coincident vessel-based sightings of more than 25 right whales included at least 15 non-duplicates, suggesting that more than 70 whales may have been present in the Bay on 9 April. Sighting conditions on 10 April were limited, with visibility for the morning below 200 meters and sea conditions moderate; vessel-based observations indicated that substantial numbers of right whales moved to the northeast margin of Cape Cod Bay, closely associated with a very rich patch of late stage *Calanus finmarchicus* at the entrance to Provincetown Harbor. During that abbreviated habitat sampling cruise a second group of 15-20 whales were sighted in the central portion of the southern Bay, with animals observed socializing and subsurface feeding in the upper water column. Movement through the day of the northern aggregation was toward Race Point, the location through which whales usually exit the Bay; it is likely that the rich zooplankton resources of the northeastern Bay are flushing out of the system and that portions of the very dense aggregations of whales observed on 9 April are shifting toward this area. Nevertheless, substantial numbers of right whales remain along the margins of the land in Provincetown and in a broad region covering the southwestern and southern-central Bay where extensive patches of *Calanus* remain.

The very rich zooplankton resource observed at all sampling locations indicates that the expected enrichment by late-stage, nutritionally-rich *Calanus finmarchicus* is well underway and is, as anticipated, coupled with a distinct decline in *Pseudocalanus* spp. While discrete-depth water column sampling was hampered by windy conditions, net collections indicate that a dense *Calanus* layer has formed at shallow depths in much of the Bay. With increases in late stage *Calanus* at densities sometimes exceeding the feeding threshold by two orders of magnitude and with the widespread extent of the patch areas, we forecast the continued development of aggregations of whales and increased potential for near-surface feeding in southern Cape Cod Bay, with movement of the whales likely to be to the east and north in the coming week. The whales in the northeast quadrant may remain associated with zooplankton resources for several days, but steady dissipation of the whale aggregations (as the zooplankton resource flushes out of the Bay) may be expected. Broadly, we forecast that right whale numbers will decline from the very high abundance observed on 9 April, though substantial numbers of whales will remain in the southern quadrants of the Bay where food resources remain high.

The extremely high concentrations of zooplankton along the northeastern and southern margins of the Bay suggest that aggregation and near-surface feeding activity by whales will likely continue and that the risk of vessel-strike will remain elevated in these areas. In the northeastern Bay, it is expected that unusually high concentrations of whales will continue to be found feeding in loose aggregations throughout the nearshore areas spanning from Provincetown Harbor to Race Point and beyond to the Highland Light. Because of the vertical distribution of the food resource, whale behavior may present few surface clues to the presence of whales, and so the risk of collision is significantly elevated in these areas of increasing vessel traffic. **Mariners should reduce speed and be alert to whales in the high risk forecast area encompassed by 42º 06'/70º 21' and 42º 06'/69º 55' and 41º 59' /69º 55' and 41º 59'/70º 21' .**

These observations are considered preliminary pending detailed analysis and final assessment reporting.

The assessment and prediction reports are a product of the Right Whale Surveillance Program at the Provincetown Center for Coastal Studies – a management study supported by the Division of Marine Fisheries of the Commonwealth of Massachusetts and funded by the National Marine Fisheries Service, NOAA, Department of Commerce. (study conducted under NMFS research permit #633-1483-06)

Box 1. Preliminary Assessment and Risk Alert following cruises SW692 and SW693, on 9 and 10 April 2008. The alert gives bounding coordinates for the area of particularly high risk, as well as some detail on the animals' behavior.

Paul J. Diodati
Director

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Deval Patrick
Governor
Ian A. Bowles
Secretary

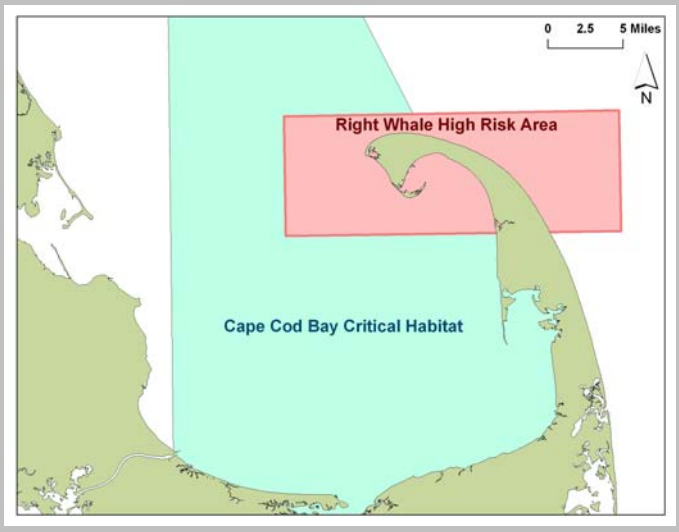
ADVISORY TO MARINERS

AGGREGATION OF RIGHT WHALES AROUND TIP OF CAPE COD

An aggregation of right whales around Provincetown has prompted the Division of Marine Fisheries (*MarineFisheries*) to issue an advisory to all vessel operators. Unusually high concentrations of whales are present throughout the nearshore areas spanning Provincetown Harbor to Race Point and beyond to Highland Light. **Operators are advised to reduce speed (10 knots), post lookouts, and proceed with caution to avoid colliding with this highly endangered whale.**

Vessels are prohibited by state and federal law from approaching within 500 yards of a right whale. Massachusetts Environmental Police and U.S. Coast Guard are authorized to enforce the 500-yard rule. Fishermen are reminded that the approach rule also prohibits them from starting fishing operations (setting or hauling gear) within 500 yards of a right whale.

The DMF/CCS aerial survey team has reported an aggregation of 50-70 subsurface feeding right whales around the tip of Cape Cod. Extremely high concentrations of zooplankton along the northeastern margins of the Bay suggest that aggregation and near-surface feeding activity by whales will likely continue and that the risk of vessel strike will remain elevated in these areas. The zooplankton resource will be analyzed again in the next few days, at which time we will re-evaluate the level of risk. When right whales depart the area, the advisory will be lifted.



Department of Fish and Game
Mary B. Griffin, *Commissioner*

Whales that are surface and subsurface feeding on dense blooms of zooplankton (copepods) are at great risk for vessel strike. More vessel traffic is expected in this area over the next few weeks with seasonal increases in recreational and commercial fishing, as well as whale watching, and passenger ship activity. Right whales are the most endangered large whale in the North Atlantic, with a population of approximately 400 animals. Vessel strike is a major cause of human-induced mortality for right whales.

Management of maritime activities near right whales is part of the *MarineFisheries* Right Whale Conservation Program. The Right Whale Conservation Program is a cooperative effort between *MarineFisheries* and the Provincetown Center for Coastal Studies (CCS) to study and protect right whales in Cape Cod Bay.

Real-time monitoring of right whales through vessel and aerial–based surveillance, and forecasting of right whale presence through habitat analysis, makes the Massachusetts Right Whale Conservation Program the most comprehensive of any program throughout the species' range. The presence of whales is also being monitored by *MarineFisheries* and Cornell University researchers through real-time acoustic listening stations.

The National Marine Fisheries Service (NOAA Fisheries) issues warnings to mariners via the Northern Right Whale Sighting Advisory System (SAS). Participating agencies in the SAS include *MarineFisheries* and the Massachusetts Environmental Police, the U.S. Coast Guard, the U.S. Army Corps of Engineers (ACOE), CCS, and other research groups. Advisories can be viewed at the NOAA Fisheries Northeast Region web site (http://rwhalesightings.nefsc.noaa.gov) and are broadcast over NOAA weather radio (http://205.156.54.206/nwr/).

For more information, visit the *MarineFisheries* website at www.mass.gov/marinefisheries or contact Erin Burke (Erin.Burke@state.ma.us, 978 551-0152) or Dan McKiernan (dan.mckiernan@state.ma.us, 617 626-1536). Center for Coastal Studies (www.coastal studies.org) right whale researchers Dr. Charles (Stormy) Mayo and Dr. Nathalie Jaquet can be reached at (508) 487-3623.

###

Box 2. DMF's advisory put into effect on April 11 2008 as a result of the PCCS advisory shown in Box 1.

Cape Cod Bay Right Whale Habitat
Right Whale High Risk Alert and Preliminary Assessment Report
Cruise SW694, 11 April 2008

Cruise SW694 was directed at the collection of prey field information in the vicinity of high concentrations of feeding right whales aggregated between Provincetown Harbor and the western shore of Wellfleet. More than 100 zooplankton samples were collected from 6 shallow transects and 2 vertical profiles in an area of intense surface and subsurface feeding by 15-20 right whales. A detailed report on the results of the study will be forthcoming.

Sampling and whale distribution reinforces the observations of the previous High Risk Alert that unusually dense aggregations of whales, estimated to exceed 70 individuals, are to be found throughout Cape Cod Bay. Combined information from cruises SW692-SW694 (9-11 April) indicates that a very strong *Calanus* resource, composed principally of late stages, is found in the upper 3-4 meters of the water column; this widespread resource is having a very strong influence on the behavior and distribution of the whales. Activity including surface and near-surface feeding and socializing behavior, making whales particularly vulnerable to vessel collision, may be found anywhere in Cape Cod Bay. Of greatest concern are those areas of the Bay traversed by shipping lanes, those within 5 miles of land from Provincetown Harbor to Race Point and around the eastern outer shore of the Cape, and an additional area in the shipping lanes at the eastern end of the Cape Cod Canal where food resources have been elevated during the last 3 days.

We forecast that the conditions of high risk will continue for the next week and that the area of greatest risk of collision and entanglement will lie east of a line between Manomet and Race Point, Provincetown. Rotation of the resource and the whales to the east and eventually to the north is anticipated over the next week to 10 days, with an associated decline in density of whales. While no region of the Bay will be out of the area of concern, we anticipate that the northwestern quadrant of the Bay may be exempt from particular concern within the next several days, as the food resource in that region have declined. The absence of *Pseudocalanus* and dominance of *Calanus* suggests that feeding activities will no longer be located in the engybenthic layer but instead within the upper 3-4 meters of the water column throughout the Bay.

With the unusual number of whales, their intensive feeding activities, and their movement over much of the Bay, all of Cape Cod Bay should be considered a vessel collision high risk area. We continue particularly to warn that mariners should reduce speed and be alert to whales in the high risk forecast area encompassed by 42º 06'/70º 21' and 42º 06'/69º 55' and 41º 59' /69º 55' and 41º 59'/70º 21' (previously reported). WE ADD AN OVERLAPPING WARNING AREA covering much of the remainder of Cape Cod Bay, an area east of a line between Manomet (41º 54' /70º 32') and Race Point (42º 06'/70º 21'), the northwest point of the aforementioned warning area.

These observations are considered preliminary pending detailed analysis and final assessment reporting.

The assessment and prediction reports are a product of the Right Whale Surveillance Program at the Provincetown Center for Coastal Studies – a management study supported by the Division of Marine Fisheries of the Commonwealth of Massachusetts and funded by the National Marine Fisheries Service, NOAA, Department of Commerce. (study conducted under NMFS research permit #633-1483-06)

Box 3. Preliminary Assessment and Risk Alert following cruises SW694, on 11 April 2008. The alert gives bounding coordinates for the area of particularly high risk, and adds a new area.

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APRIL 14, 2008 - ADVISORY TO MARINERS

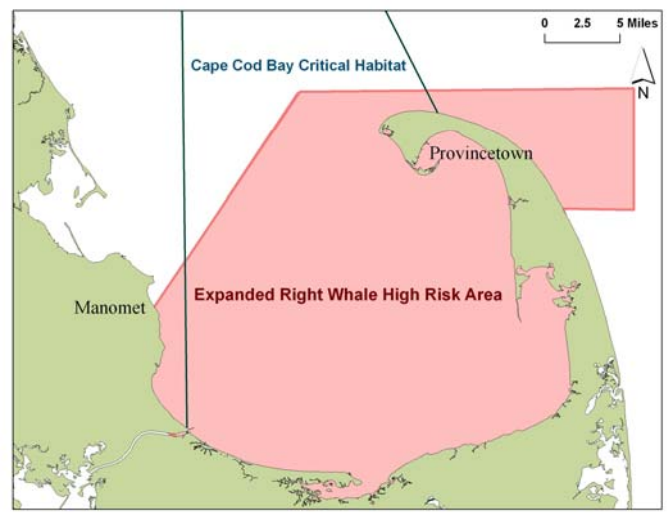
(This advisory replaces the April 11, 2008 notice)

EXPANDED HIGH RISK AREA FOR RIGHT WHALES

Aerial and habitat surveys on April 11, 2008 revealed an unprecedented number of right whales in Cape Cod Bay. With the unusual number of whales, their intensive feeding activities, and their movement over much of the Bay, all of Cape Cod Bay should be considered a High Risk Area for right whales. **Vessel operators are strongly urged to reduce speed (less than 10 knots), post lookouts, and proceed with caution to avoid colliding with this highly endangered whale.**

Vessels are prohibited by state and federal law from approaching within 500 yards of a right whale. Massachusetts Environmental Police and U.S. Coast Guard are authorized to enforce the 500- yard rule. Fishermen are reminded that the approach rule also prohibits them from starting fishing operations (setting or hauling gear) within 500 yards of a right whale.

We forecast that the conditions of high risk will continue for the next week and that the area of greatest risk of collision lies east of a line between Manomet and Race Point, Provincetown. When right whales depart the area, the advisory will be lifted.



Department of Fish and Game
Mary B. Griffin, *Commissioner*

Whales that are surface and subsurface feeding on dense blooms of zooplankton (copepods) are at great risk for vessel strike. More vessel traffic is expected in this area over the next few weeks with seasonal increases in recreational and commercial fishing, as well as whale watching, and passenger ship activity. Right whales are the most endangered large whale in the North Atlantic, with a population of approximately 400 animals. Vessel strike is a major cause of human-induced mortality for right whales.

Management of maritime activities near right whales is part of the *MarineFisheries* Right Whale Conservation Program. The Right Whale Conservation Program is a cooperative effort between *MarineFisheries* and the Provincetown Center for Coastal Studies (CCS) to study and protect right whales in Cape Cod Bay.

Real-time monitoring of right whales through vessel and aerial–based surveillance, and forecasting of right whale presence through habitat analysis, makes the Massachusetts Right Whale Conservation Program the most comprehensive of any program throughout the species' range. The presence of whales is also being monitored by *MarineFisheries* and Cornell University researchers through real-time acoustic listening stations.

The National Marine Fisheries Service (NOAA Fisheries) issues warnings to mariners via the Northern Right Whale Sighting Advisory System (SAS). Participating agencies in the SAS include *MarineFisheries* and the Massachusetts Environmental Police, the U.S. Coast Guard, the U.S. Army Corps of Engineers (ACOE), CCS, and other research groups. Advisories can be viewed at the NOAA Fisheries Northeast Region web site (http://rwhalesightings.nefsc.noaa.gov) and are broadcast over NOAA weather radio (http://205.156.54.206/nwr/).

For more information, visit the *MarineFisheries* website at www.mass.gov/marinefisheries or contact Erin Burke (Erin.Burke@state.ma.us, 978 551-0152) or Dan McKiernan (dan.mckiernan@state.ma.us, 617 626-1536). Center for Coastal Studies (www.coastal studies.org) right whale researchers Dr. Charles (Stormy) Mayo and Dr. Nathalie Jaquet can be reached at (508) 487-3623.

###

Box 4. DMF's advisory put into effect on 12 April 2008 as a result of the PCCS advisory and recommendation to expand the area under alert for mariners, shown in Box 3.

Cape Cod Bay Right Whale Habitat
Preliminary Assessment Report: Cruise SW697, 21 April 2008
Right Whale High Risk Alert

Efforts during cruise SW697 were directed at sampling the zooplankton resource in the eastern region of Cape Cod Bay, in the vicinity of aggregations of feeding right whales. Cruise SW697 was ½ day in duration with sea conditions calm and visibility excellent. More than 18 right whales were sighted from the vessel, with all animals observed feeding at the surface or in the near subsurface.

The zooplankton resource in the upper 2 meters of the water column throughout the areas sampled was exceptionally rich and dominated by late-stage *Calanus finmarchicus*. Combining recent DMF/PCCS aircraft survey observations and zooplankton samples from 11 April to the present, we forecast that right whales will continue to feed at or near the surface in eastern Cape Cod Bay and will continue to present a high risk of collision with vessels in that area. With the persistent zooplankton resource continuing to form particularly rich patches, we anticipate that the previously forecast counter-clockwise rotation of the resource along the eastern shore of the Bay will continue, as will the northward movement of the widely distributed aggregation of whales. Whale density in the eastern Bay is expected to slowly decline over the next week to 10 days, however numbers should remain high until flushing and graze-down reduces the richness of the resource. While the area between Barnstable Harbor and Race Point will continue to present the highest risk of ship strike, mariners should be alert to potential collision throughout the Bay.

With the unusual number of whales, their intensive near-surface feeding activities, and their movement over much of the Bay, all of Cape Cod Bay should be considered a an area of high risk of vessel collision. We continue particularly to warn that mariners should reduce speed and be alert to whales' presence in the area encompassed by 42º 06'/70º 21' and 42º 06'/69º 55' and 41º 59'/69º 55' and 41º 59'/70º 21' (previously reported). We revise the bay-wide warning area introduced on 11 April to now cover 3/5 of Cape Cod Bay east of a line from Sandy Neck in Barnstable at 41º 44'/70º 21' to the northwest point of the aforementioned warning area off Race Point in Provincetown at 42º 06'/70º 21'.

These observations are considered preliminary pending detailed analysis and final assessment reporting.

The assessment and prediction reports are a product of the Right Whale Surveillance Program at the Provincetown Center for Coastal Studies – a management study supported by the Division of Marine Fisheries of the Commonwealth of Massachusetts and funded by the National Marine Fisheries Service, NOAA, Department of Commerce. (study conducted under NMFS research permit #633-1483-06)

Box 5. Preliminary Assessment and Risk Alert following cruises SW697, on 21 April 2008. This is a continuation of the high risk alert.

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APRIL 22, 2008 - ADVISORY TO MARINERS

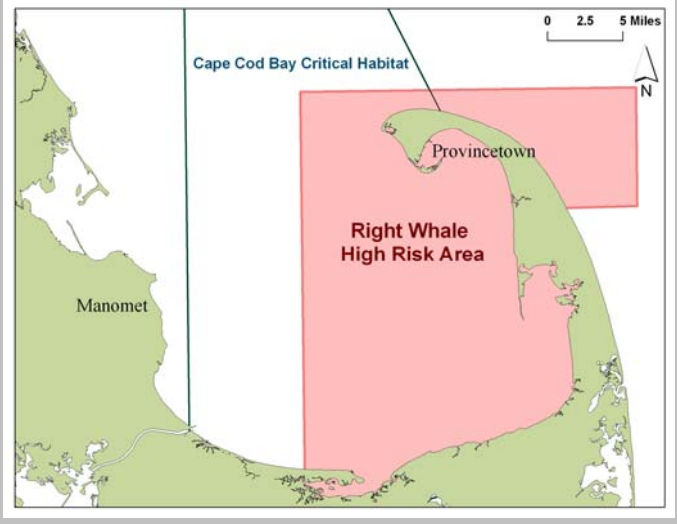
(This advisory replaces the April 14, 2008 notice)

REVISED HIGH RISK AREA FOR RIGHT WHALES

Aerial and habitat surveys on April 21, 2008 showed approximately 50 right whales still feeding in Cape Cod Bay. The High Risk Area has been revised because the location of feeding aggregations has shifted since the last advisory was issued. Based on habitat sampling, we forecast that persistent zooplankton patches will continue to rotate counter-clockwise along the eastern shore of the Bay, as will the northward movement of the widely-distributed aggregation of whales. The area between Barnstable Harbor and Race Point continues to present the highest risk of vessel strike, but mariners should be alert to potential collision throughout the Bay. **Vessel operators are strongly urged to reduce speed (less than 10 knots), post lookouts, and proceed with caution to avoid colliding with this highly endangered whale.**

Vessels are prohibited by state and federal law from approaching within 500 yards of a right whale. Massachusetts Environmental Police and U.S. Coast Guard are authorized to enforce the 500- yard rule. Fishermen are reminded that the approach rule also prohibits them from starting fishing operations (setting or hauling gear) within 500 yards of a right whale.

When right whales depart the area, the advisory will be lifted.



Department of Fish and Game
Mary B. Griffin, *Commissioner*

Whales that are surface and subsurface feeding on dense blooms of zooplankton (copepods) are at great risk for vessel strike. More vessel traffic is expected in this area over the next few weeks with seasonal increases in recreational and commercial fishing, as well as whale watching, and passenger ship activity. Right whales are the most endangered large whale in the North Atlantic, with a population of approximately 400 animals. Vessel strike is a major cause of human-induced mortality for right whales.

Management of maritime activities near right whales is part of the *MarineFisheries* Right Whale Conservation Program. The Right Whale Conservation Program is a cooperative effort between *MarineFisheries* and the Provincetown Center for Coastal Studies (CCS) to study and protect right whales in Cape Cod Bay.

Real-time monitoring of right whales through vessel and aerial–based surveillance, and forecasting of right whale presence through habitat analysis, makes the Massachusetts Right Whale Conservation Program the most comprehensive of any program throughout the species' range. The presence of whales is also being monitored by *MarineFisheries* and Cornell University researchers through real-time acoustic listening stations.

The National Marine Fisheries Service (NOAA Fisheries) issues warnings to mariners via the Northern Right Whale Sighting Advisory System (SAS). Participating agencies in the SAS include *MarineFisheries* and the Massachusetts Environmental Police, the U.S. Coast Guard, the U.S. Army Corps of Engineers (ACOE), CCS, and other research groups. Advisories can be viewed at the NOAA Fisheries Northeast Region web site (http://rwhalesightings.nefsc.noaa.gov) and are broadcast over NOAA weather radio (http:// 205.156.54.206/nwr/).

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Box 6. DMF's advisory put into effect on 22 April 2008 in response to the PCCS advisory and recommendation to reduce the area under alert for mariners, shown in Box 5.

Cape Cod Bay Right Whale Habitat
Preliminary Assessment Report: Cruise SW699, 25 April 2008
Discontinuation of Ship Strike Risk Warning

Cruise SW699 was carried out in excellent visibility and sea conditions. All eight regular stations were sampled for zooplankton both at the surface and with oblique tows, permitting an assessment of all quadrants of the Cape Cod Bay system. Additional samples were taken in the southwest quadrant of the Bay where a small group of right whales was observed subsurface feeding; a shallow vertical sampling profile was collected in the feeding area. A total of five right whales were recorded during the cruise, the lowest number sighted from the vessel in the last month of surveys. The DMF/PCCS survey aircraft did not fly.

The continued precipitous decline in the zooplankton resource was evident at all stations throughout the Bay. Only in the relatively small area in the southwest quadrant was a total zooplankton concentration estimated to be at or slightly above the threshold for feeding. Observations of the feeding pattern of the whales and of the associated zooplankton in the feeding area strongly suggest that only a small patch of resource was available to the whales; vertical sampling identified a modest *Calanus finmarchicus* resource within the upper 10 meters of the water column. The *Calanus* resource, which for several weeks has supported an unusually large and widespread concentration of right whales, has continued to decline to levels that make nearly all of Cape Cod Bay unacceptable to foraging right whales.

We continue to forecast a decline in the food resource within the Bay and the associated decline in right whale density throughout Cape Cod Bay. Absent an unlikely influx of a new and rich *Calanus finmarchicus* resource, nearly all of the remaining right whales within the Bay will depart within the next several days to a week.

As seen in the observations from cruise SW699, it remains possible that small patches of the once-rich *Calanus* resource will continue to influence the distribution and behavior of remaining right whales; however, conditions within the Bay do not favor further aggregation. While zooplankton samples were not collected along the outer shore of Provincetown and Truro where zooplankton resources have resulted in moderate densities of right whales feeding near the surface, the conditions within Cape Cod Bay suggest that the area immediately beyond Race Point will also become unfavorable for right whale feeding within the next week. **Hence, we discontinue the areas of high risk of ship strike covering the eastern 3/5 of Cape Cod Bay and the shipping lanes around Provincetown and Truro. It should be noted, however, that moderate numbers of right whales will likely remain scattered within Cape Cod Bay and along the outer shore between Provincetown Harbor and Highland Light, Truro. Furthermore, sightings from cruises SW698 and SW699 combined with recent air survey observations indicate that high densities of other species of endangered whales – fin and humpback – may be found throughout Cape Cod Bay and the waters north and east of Cape Cod. Vessel operators should continue to exercise caution within this region.**

These observations are considered preliminary pending detailed analysis and final assessment reporting.

The assessment and prediction reports are a product of the Right Whale Surveillance Program at the Provincetown Center for Coastal Studies – a management study supported by the Division of Marine Fisheries of the Commonwealth of Massachusetts and funded by the National Marine Fisheries Service, NOAA, Department of Commerce. (study conducted under NMFS research permit #633-1483-06)

Box 7. Preliminary assessment and recommendation for discontinuation of the high risk alerts previously issued, following cruise SW699 on 25 April 2008.

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FOR IMMEDIATE RELEASE
May 6, 2008

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RIGHT WHALE AGGREGATION DEPARTS CAPE COD BAY

ADVISORY LIFTED

Aerial, vessel, and acoustic surveillance efforts by the Center for Coastal Studies and the Division of Marine Fisheries have determined that the large aggregation of right whales observed in Cape Cod Bay have now departed. No right whales were sighted from the aircraft or boat, and habitat monitoring revealed a decline in the zooplankton resource, suggesting that right whale aggregations are not likely to return in the near future. The zooplankton resource remains patchy, but it is possible that the occasional right whale will be seen feeding in the outer near-shore region for 3-5 days. Mariners should remain on the lookout for any lingering right whale activity.

With the departure of these animals the Commonwealth is lifting the April 25 and May 5th advisories to mariners in the Race Point area. *MarineFisheries* would like to thank fishermen, whale watch companies, and others for their assistance and compliance with measures designed to protect this highly endangered animal. *MarineFisheries* monitors the presence of right whales in Cape Cod Bay through aerial surveys, habitat sampling, and acoustic monitoring. Sightings observed through these efforts allow *MarineFisheries* to address threats to right whales on a real-time basis. We greatly appreciate the diligence and alertness of mariners and our surveillance team during the 2007 season.

The National Marine Fisheries Service (NOAA Fisheries) issues warnings to mariners and others through the Northern Right Whale Sighting Advisory System (SAS). Advisories regarding Cape Cod Bay and surrounding waters can be viewed at the NOAA Fisheries Northeast Region web site (http://www.nero.noaa.gov/ro/doc/whale.htm) and are broadcast over NOAA weather radio (http:// 205.156.54.206/nwr/).

For more information, visit the *MarineFisheries* website at http://www.mass.gov/marinefisheries or the Center for Coastal Studies at www.coastalstudies.org.

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Box 8. Notification to mariners that there is no longer a high risk alert in Cape Cod Bay due to the departure of the right whale aggregation, following the advisory issued by PCCS shown in Box 7.

Appendix IV

Habitat Studies Special Reports
2008

Appendix IVa

The vertical distribution of zooplankton and associated North Atlantic right whale behavior

Karen Stamieszkin
Research Assistant
Right Whale Habitat Studies

On 14 March 2008 the Provincetown Center for Coastal Studies' (PCCS) right whale habitat studies team repeatedly sampled the water column two nautical miles west-southwest of Wood End, Provincetown, Massachusetts. Using a discrete depth pump we collected samples in order to determine vertical zooplankton profiles during more than five hours of observation in the presence of right whales. For each sample, 26.5 liters of water from the target depth were filtered through collection nets fitted with 333 micron mesh that mimics the filtering efficiency of right whale baleen; the captured zooplankton were counted and identified to taxon and, in some cases, developmental stage. From these counts, the concentration of zooplankton per cubic meter (zpk/m^3) was calculated and vertical profiles plotted. These vertical profiles, in combination with observations of right whale behavior throughout the sampling period, give an understanding of the association among factors that drive vertical movement and depth-selective behavior of zooplankton resources, the distribution of whales in the water column, and the consequent varying levels of risk to the whales. Diel vertical migration (DVM) is a depth-selective behavior exhibited by zooplankton in many aquatic and marine ecosystems that may influence right whale distribution in Cape Cod Bay. DVM is linked to changes in light intensity over diel cycles and zooplankton predator-avoidance. Our sampling on March 14th shows dramatic evidence of how the depth-selective behavior of zooplankton resources, potentially related to light intensity levels, affects the behavior and distribution of right whales.

Profile A (fig. 1) was sampled between 10:50 and 11:30 hours, during which a right whale was observed within 100 meters of the sampling station; the whale associated with Profile A was in the process of closing its mouth upon the first surfacing after a ten-plus minute dive. All right whales within one km of the station were noted as "fluking" before diving. The sun-angle was fairly steep, but skies were overcast, resulting in relatively low sunlight intensity. The samples collected revealed an ultra-dense engybenthic zooplankton layer against the seafloor with a maximum concentration of 58464 zooplankton per cubic meter (zpk/m^3) at 42 meters, and a dense subsurface zooplankton layer with a maximum concentration of 48122 zpk/m^3 at nine meters (fig. 1). A *Pseudocalanus* spp. complex dominated the layers, though *Calanus finmarchicus* was found in small numbers in the nine-meter layer, (fig. 2). *C. finmarchicus* is significant as it is known as a preferred food of right whales; it represented approximately 0.4% of the total zooplankton in the water column. The observed whale's fluking behavior and the fact that it was still closing its mouth while surfacing suggest that it was feeding on the nine-meter, rather then the engybenthic layer.

Profile C (fig. 3) was sampled between 13:20 and 14:20 hours, during which three to five right whales were documented as close as 100 meters of the Profile C station, performing fluking dives with no "mouth opened" behavior. This location was chosen for sampling as it approximated where the upper water parcel would have drifted from the Profile A sampling location; the two locations were approximately 1.1 km apart. During sampling for Profile C the sunlight had intensified due to clearing skies and a steep sun-angle. The samples collected identified an ultra-dense engybenthic layer with a maximum concentration of 77562 zpk/m^3 at a depth of 40.25 meters, less then 0.5 meter above the bottom; no other layers were seen the water

column (fig. 3). Again, *Pseudocalanus* spp. dominated the layer, and again *C. finmarchicus* was observed (fig. 4), though deeper in the water column than those observed in profile A, and represented 1.1% of the total zooplankton. The whales' fluking dive behavior suggested that they were feeding on the engybenthic layer dominated by *Pseudocalanus* spp.

Profile D (fig. 5) was sampled between 15:30 and 16:30 hours, during which multiple right whales in the area performed both fluking dives and skim feeding. The sunlight was sharply less intense than that during sampling for profiles A and C due to increasingly dense cloud cover and a lower sun-angle. The location of station D was chosen again in an attempt to sample a similar water parcel to that sampled for profiles A and C; this location was approximately 0.74 km southeast of the location of station C and 2.7 km southeast of station A. The samples collected for profile D revealed a dense surface layer with total zooplankton concentration of 21098 zpk/m^3, and a bottom layer centered approximately five meters above the seafloor (35 meters depth) with maximum zooplankton concentration of 20683 zpk/m3 (fig. 5). The *Pseudocalanus* spp. dominated both layers, and a small concentration of *C. finmarchicus* was found at about two meters depth (fig. 6), representing 1.0% of the total zooplankton in the water column. The whales' behavior suggested a variable feeding strategy, foraging intermittently on the surface and the bottom layers.

Three items of growing interest were suggested through the combined zooplankton profiling and whale behavior documentation on cruise SW689: 1) whale behavior is influenced by vertical structure of zooplankton resources, 2) depth-selective behavior appears to be an important feature of the dynamics of both *C. finmarchicus* and the *Pseudocalanus* spp. resources, and 3) as shown elsewhere in marine systems, variations in light intensity may mediate the depth-selective behavior of the zooplankton, thereby significantly influencing the risk to feeding whales of ship strike and entanglement. When a dense zooplankton layer was identified at the surface, whales were skimming (profile D). When a layer was found subsurface, the corresponding whale behavior appeared to be subsurface feeding (profile A). When an engybenthic layer was documented, the whales exhibited fluking dives, suggesting that they were exploiting this deep layer (profile B, profile D). Finally, when layers persisted both at depth and at the surface (profiles A and D), the whales exhibited behavior suggesting that they were choosing to alternately exploit one resource and then the other; this choice may be linked to energetic efficiency, perhaps involving dive distance to the resource and the resource composition. Further and more detailed investigation is warranted on these topics.

The ultra-dense layers of *Pseudocalanus* spp., as well as the small concentration of *C. finmarchicus* observed, were not evenly distributed throughout the water column; they were concentrated into layers and moved throughout the day (fig. 7). This depth-selective behavior and the whales' subsequent behavior shifts suggest that the forces driving the movement of zooplankton could have a profound effect upon the position of right whales in the water column, and hence their exposure to various risk factors. In the literature, the vertical migration of zooplankton is extensively discussed and is often cited as related to the rise and fall of sunlight intensity. It appears that the movement of the layers observed and described above could have been linked to the observed changes in cloud cover and sun-angle over the course of the sampling period, and could represent similar patterns to those traditionally described as DVM. Further investigation of zooplankton layer formation and movement, and corresponding right whale feeding behavior, over a diel time scale (i.e. overnight), would further our knowledge of right whale ecology as it relates to the rhythmic vertical movement of right whales' food resources, potentially leading to an understanding of situations that put right whales at increased risk of harm from industrial activities, as well as more accurate and effective management of these animals.

Figures

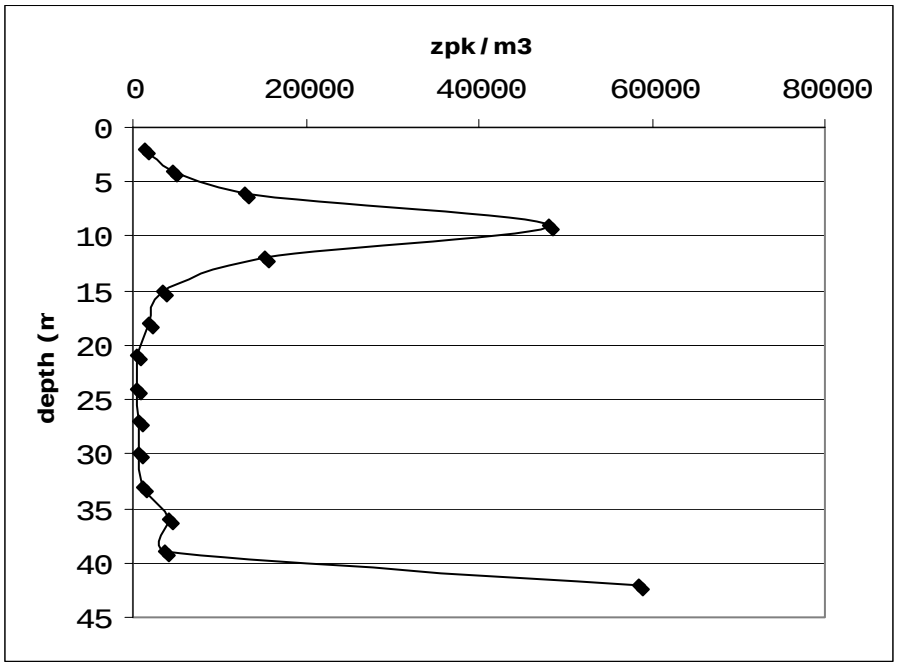

Figure 1. Profile A (note scale) of total zooplankton concentration (m^3), taken between 10:50 and 11:30 on March 14th; whale observed surfacing with mouth in process of closing, and then fluking.

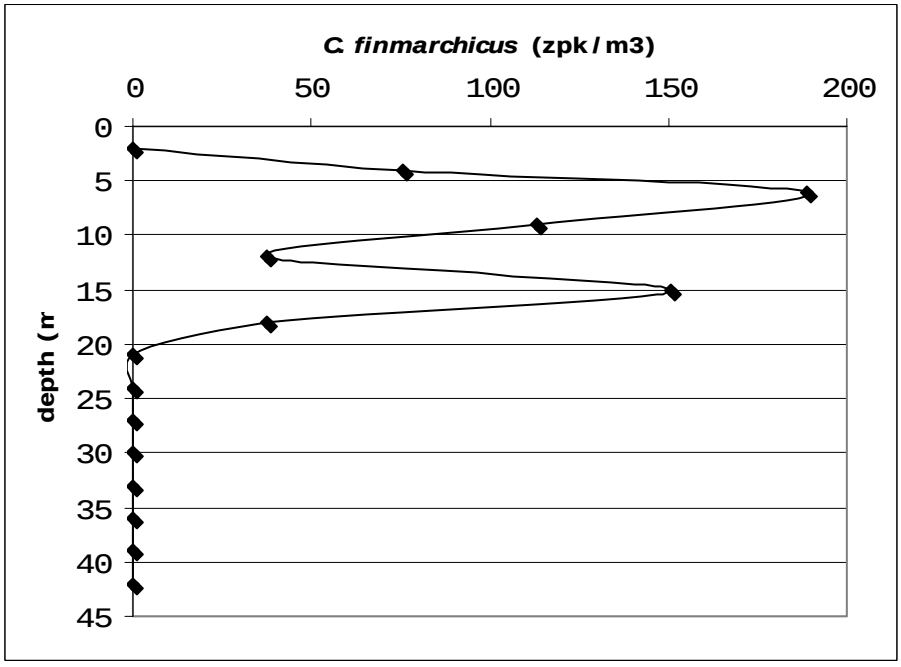

Figure 2. *Calanus finmarchicus* concentration (zpk/m^3) in profile A (note scale).

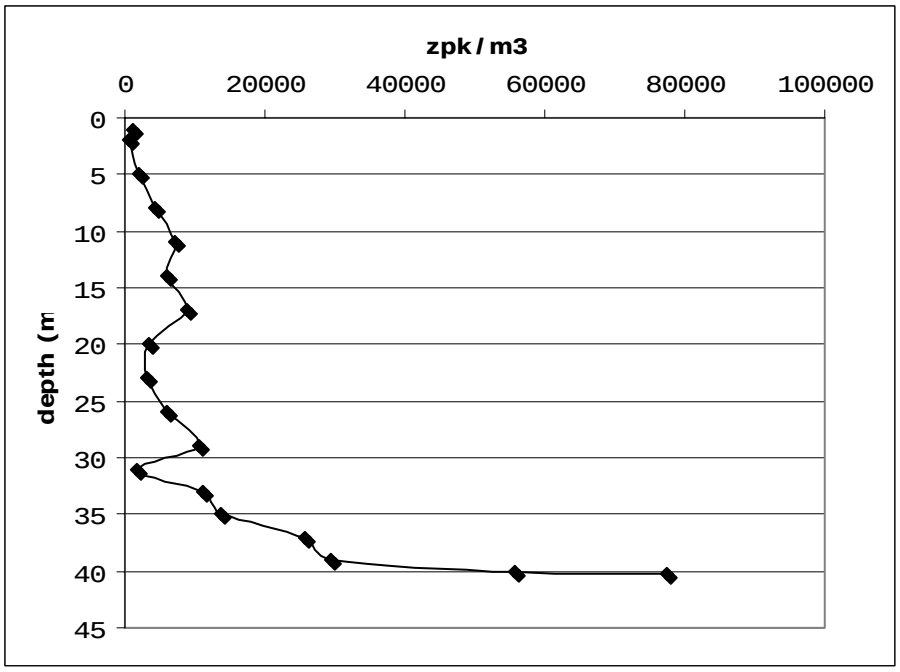

Figure 3. Profile C (note scale) of total zooplankton concentration (m^3), taken between 13:20 and 14:20 on March 14th; multiple whales on fluking dives.

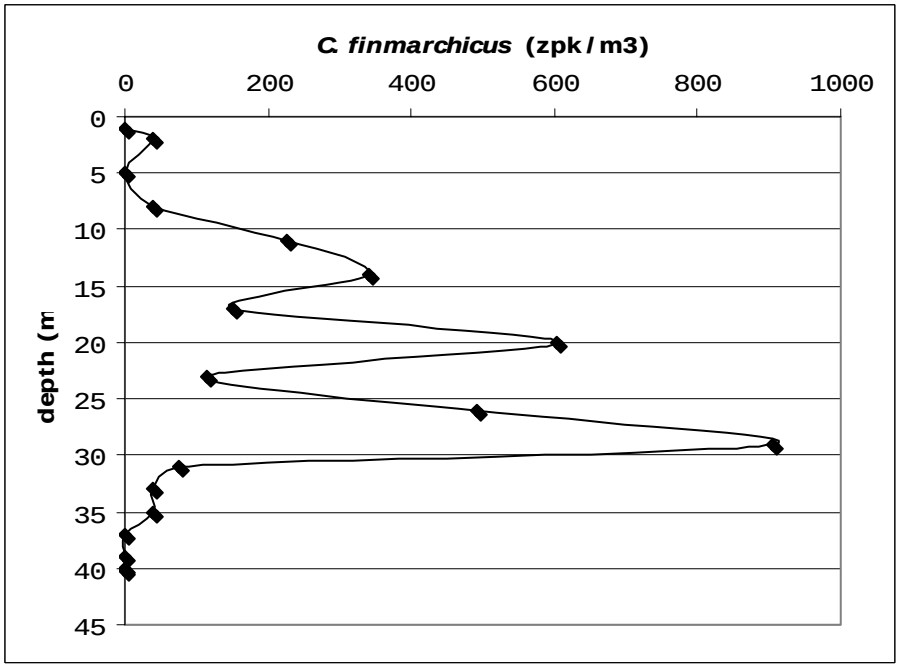

Figure 4. *Calanus finmarchicus* concentration (zpk/m^3) in profile C (note scale).

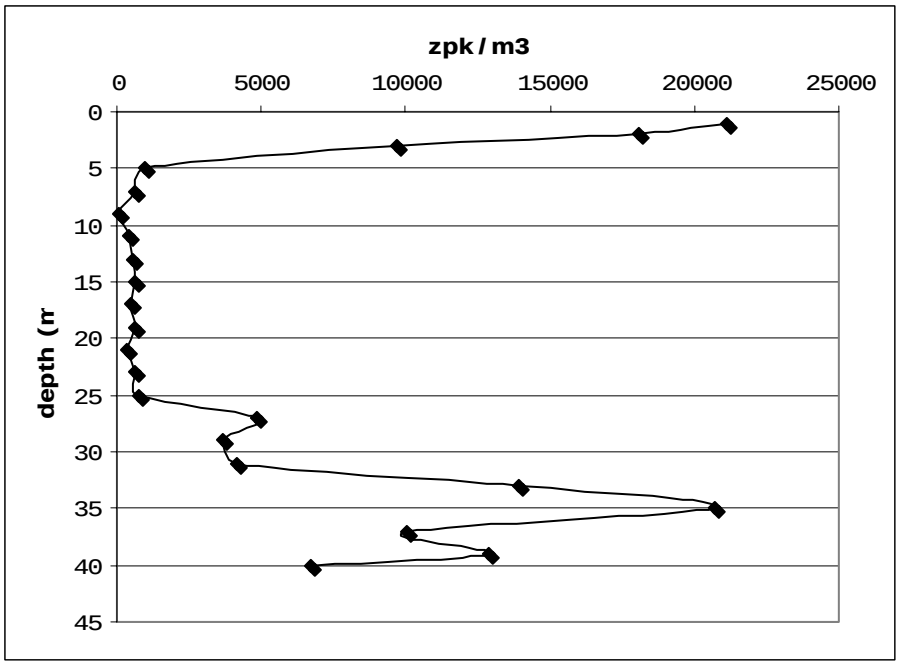

Figure 5. Profile D (note scale) of total zooplankton concentration (m^3), taken between 15:30 and 16:30 on March 14th; multiple whales on fluking dives, then skim feeding, and then exhibiting both behaviors interspersed with socialization.

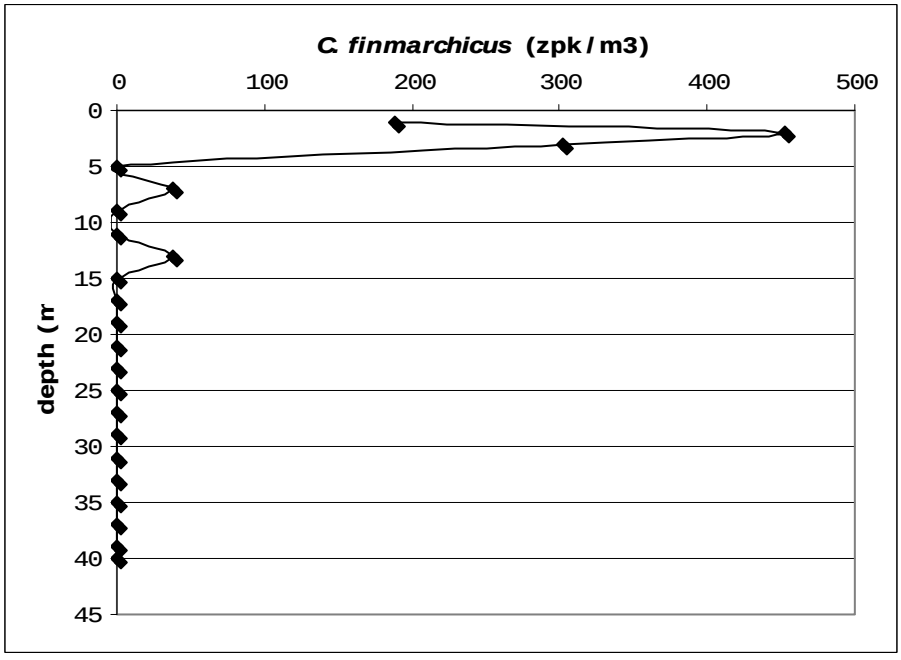

Figure 6. *Calanus finmarchicus* concentration (zpk/m^3) in profile D (note scale).

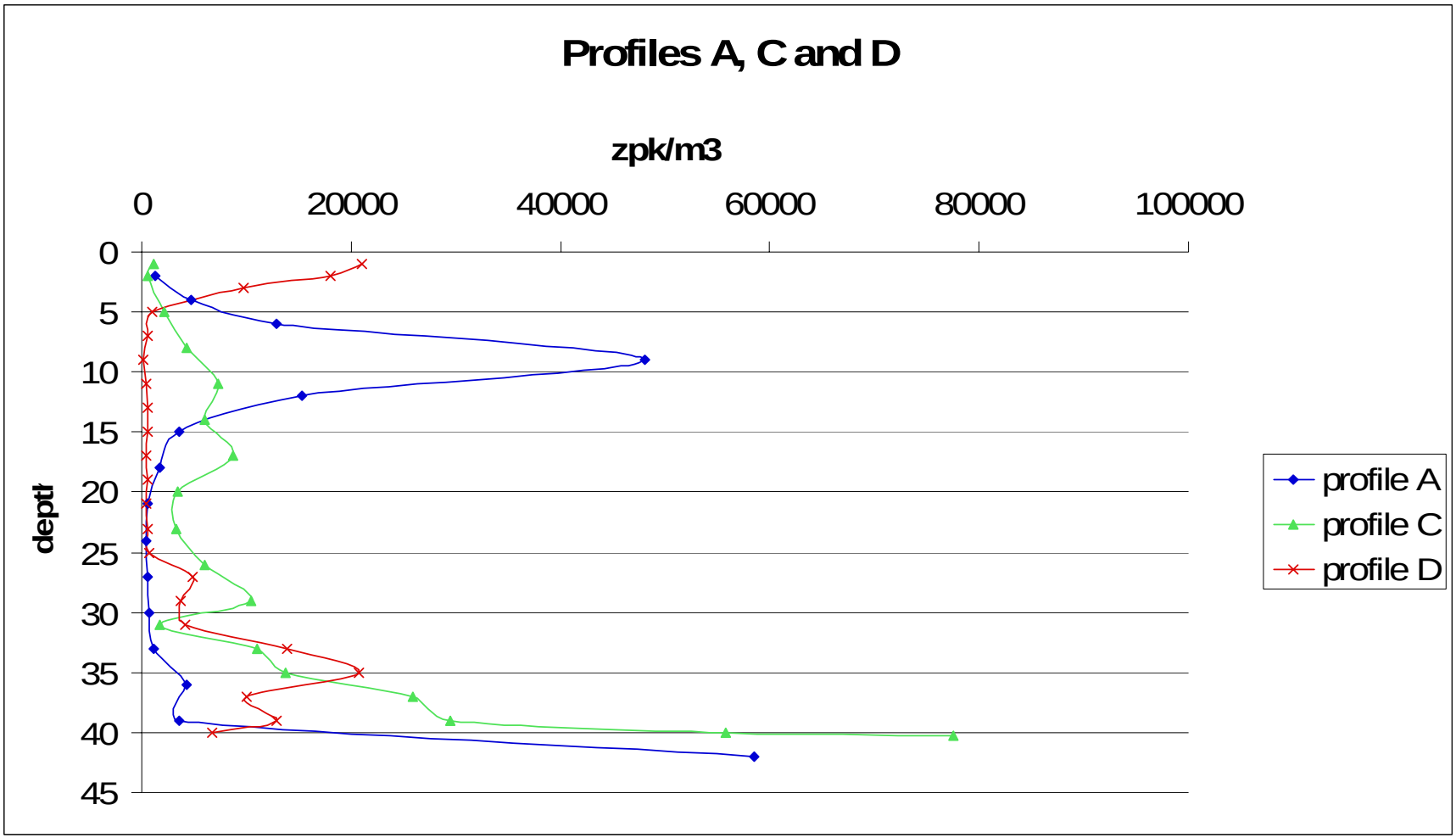

Figure 7. Profiles A, C and D illustrated together to show the concentration of zooplankton in the water column, and its movement throughout the sampling period.

Appendix IVb

Further investigation of the vertical distribution of zooplankton and its potential influence on North Atlantic right whale distribution in Cape Cod Bay

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Research Assistant
Right Whale Habitat Studies

On 27 March 2008 the Provincetown Center for Coastal Studies' (PCCS) right whale habitat studies team returned to the location at which vertical samples were collected on 14 March 2008, in the northeast portion of Cape Cod Bay, to further document the distribution of food resources described in the SW689 special cruise report. The discrete depth sampling methodology from the previous cruise, SW689, was replicated; additionally, a CTD was used to collect physical environmental data. Detailed observations of right whale behavior throughout the sampling period were also collected to expand the ongoing examination of the relationship among factors that drive vertical movement and depth-selective behavior of zooplankton resources, the distribution of whales in the water column, and the consequent varying levels of risk to the whales. In addition to the vertical profile sampled in the vicinity of the profiles from cruise SW689 (profile 691A), two more sets of mid-water samples were collected at new locations in the northwest portion of the Bay, where an estimated 15 right whales were aggregating (profiles 691B and 691D).

Profile 691A (fig. 1) was sampled between 11:10 and 11:45 hours, during which no whales were present. The zooplankton densities throughout the water column at this location were much lower than those seen during cruise SW689; the maximum zooplankton density observed in profile 691A was 3,019 organisms/m^3, compared with a maximum observed density of 77,562 organisms/m^3 on cruise SW689 (fig. 2) at the same location. During sampling at station 691A, the sun-angle was fairly steep but skies were overcast resulting in relatively low sunlight intensity. The CTD temperature data indicated one shallow thermocline, below which a very small amount of zooplankton had aggregated (fig. 1 in red). The lack of whales in the area and the concurrent lack of dense zooplankton layers, made especially obvious when profile 691A is compared with profiles from cruise SW689 (fig. 2), illustrates the strength of the relationship between the distribution of right whales and their food resource.

Profile 691B (fig. 3) was sampled between 13:20 and 14:10 hours at the western-central portion of the Bay, during which several whales were documented as close as 20 meters performing long fluking dives. This location (41.94017° north, -70.40200° west) was chosen due to the presence of 10 to 15 right whales in the area (within one to two kilometers). During sampling for Profile 691B, the skies grew increasingly overcast, further decreasing sunlight intensity. A profile of the collected samples showed the presence of a dense engybenthic layer with a maximum total zooplankton concentration of 10,719 organisms/m^3at 40 meters depth, less than 0.5 meters above the bottom, as well as a less dense layer at 6.0 meters depth, with a maximum total zooplankton concentration of 3,435 organisms/m^3 (fig. 3). *Pseudocalanus* spp. dominated the engybenthic layer, while *C. finmarchicus* dominated the shallower layer (fig. 4). The whales' long fluking dives suggested that they were feeding on the engybenthic layer dominated by *Pseudocalanus* spp. The CTD temperature data showed a shallow thermocline, as

well as a secondary deeper thermocline, beneath each of which zooplankton layers were found (fig. 3 in red).

Profile 691D (fig. 5) was sampled between 15:10 and 15:45 hours, during which at least five right whales in the area were performing long fluking dives, at the same location as profile 691B. The skies brightened slightly, but the sun-angle was low, and overcast conditions prevailed, resulting in low sunlight intensity. The samples collected for profile 691D revealed a dense engybenthic layer with a maximum total zooplankton concentration of 21,589 organisms/m^3 at 39.0 meters, about 1.5 meters above the seafloor. A less dense subsurface layer was also observed with a maximum total zooplankton concentration of 4,491 organisms/m^3 at 2.0 meters depth (fig. 5). Again, the CTD data revealed two thermoclines; the subsurface zooplankton layer was found above the shallow thermocline, while the engybenthic layer was found below the deeper thermocline (fig. 5 in red). *Pseudocalanus* spp. dominated both layers, and a small concentration of *C. finmarchicus* was found in the subsurface layer (fig. 6). The engybenthic layer spanned approximately nine meters of the water column, just above the seafloor, with a zooplankton concentration above the threshold for right whale feeding through the entire nine meters. The relative thickness of this concentrated layer indicates a very high zooplankton biomass that is particularly attractive to right whales. The whales' long fluking dives suggested that they were feeding on this engybenthic layer.

With the vertical profiles sampled during cruise SW689, three aspects were explored: 1) how whale behavior is influenced by vertical structure of zooplankton resources, 2) depth-selective behavior exhibited by *C. finmarchicus* and the *Pseudocalanus* spp. resources, and 3) variations in light intensity mediating the depth-selective behavior of the zooplankton, thereby significantly influencing the risk to feeding whales of ship strike and entanglement. In profile 691A, at the location of intense whale feeding behavior and zooplankton resource two weeks prior, no significant resource was observed; neither were whales. Further, whales were consistently observed executing long fluking dives in the vicinity of profiles 691B and 691D, both of which revealed dense layers of *Pseudocalanus* spp. Akin to the observations of zooplankton resources and right whale behavior from cruise SW689, the profiles from cruise SW691 demonstrate that the distribution of zooplankton in the Bay and the depth-selective behavior of zooplankton appeared to profoundly influence right whale distribution and behavior.

In the report of cruise SW689, light intensity, which potentially mediates vertical migration, was raised as a factor that controls the distribution of zooplankton in the water column. While the collection techniques and sea conditions during cruise SW691 were not ideal for observing such migration, a minimal upward shift of zooplankton layers over the course of the afternoon was documented (fig. 7). In addition, the temperature profiles collected with the CTD and the positions of zooplankton layers relative to the documented thermoclines indicate that water temperature and density may also play a role in the distribution of organisms in the water column. To better understand the causes of documented depth-selective behavior, longer sampling periods, over diel time scales, and changing light intensity, as well as more information on local oceanographic and other physical environmental conditions, are necessary. Nevertheless the vertical profiles from cruises SW689 and SW691 confirm the phenomenon of depth-selective behavior in the zooplankton species that make up right whales' preferred food resource. Observations of whale behavior during these cruises suggests that the influence of zooplankton dynamics upon right whale distribution and behavior is strong, further illuminating the need for a deeper understanding of diel zooplankton movement in Cape Cod Bay.

Figures

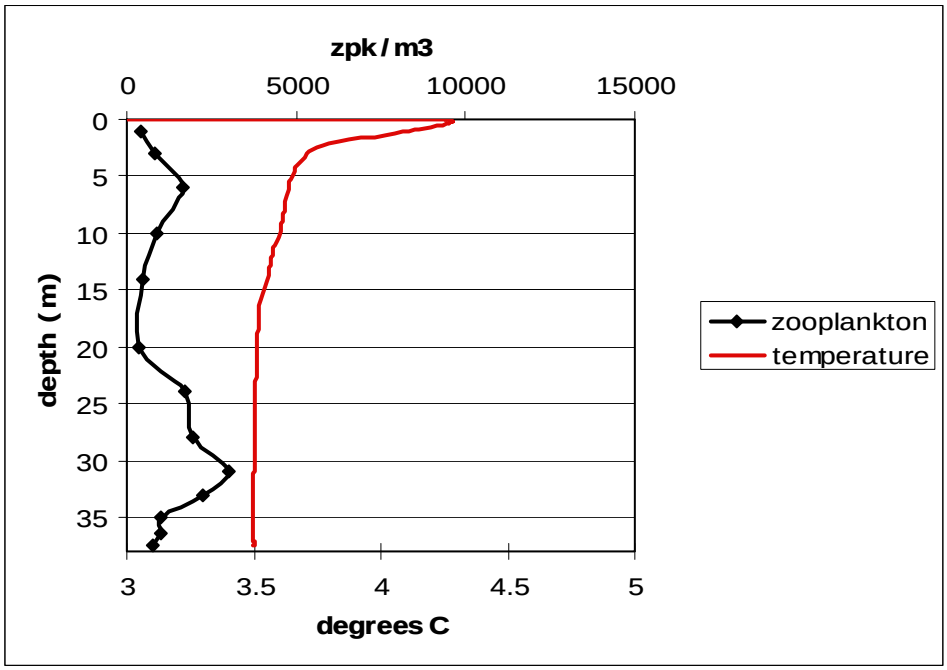

Figure 1. Profile 691A (note scale and that bottom depth is bottom of the y-axis) of total zooplankton concentration (zpk/m^3) and temperature (°C), taken between 11:10 and 11:45 on 27 March 2008; no whales were present.

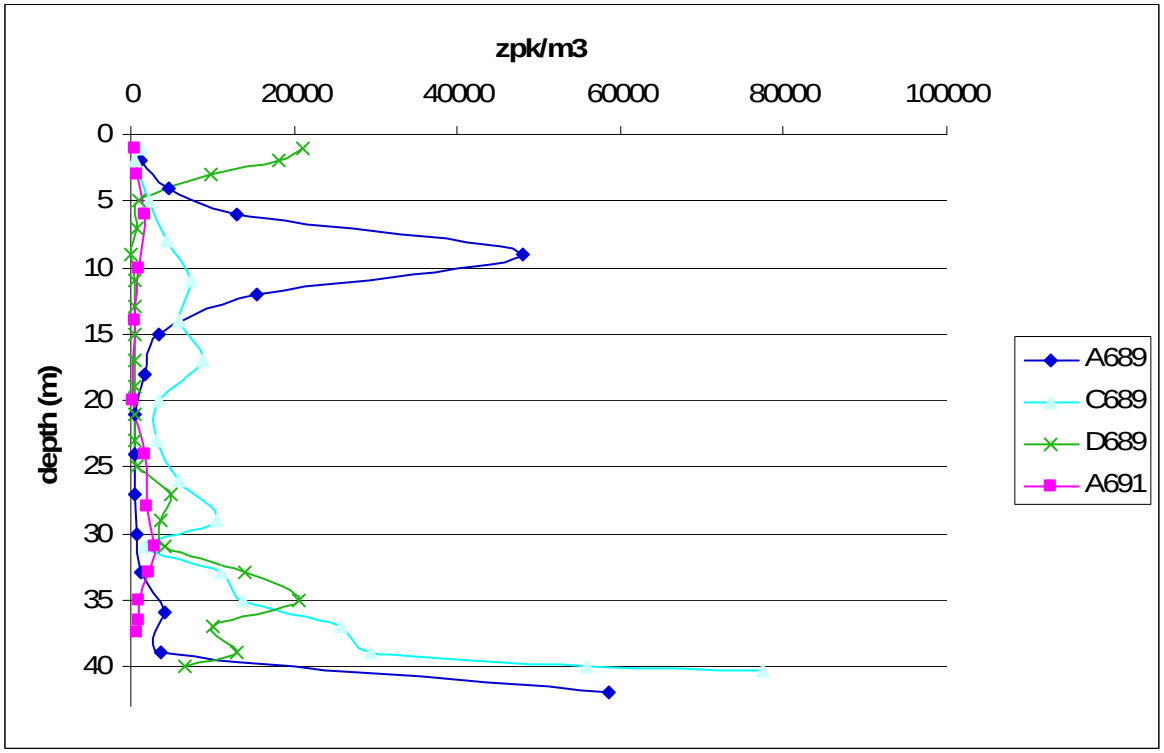

Figure 2. Profile A from cruise 691 (691A) illustrated with profiles A, C and D from cruise 689 (A689, C689 and D689) for comparison; whales were present, and presumably feeding, coincident with the zooplankton profiles from

cruise SW689, while no whales were present when 691A was sampled. Bottom depth is variable, but no greater than 42.5 meters.

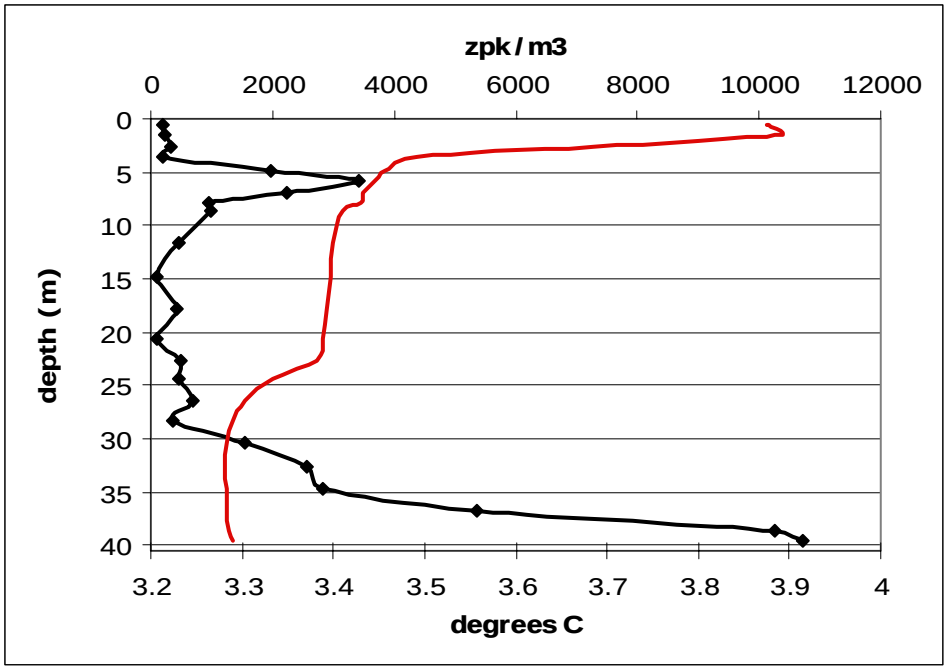

Figure 3. Profile 691B (note scale and that bottom depth is bottom of the y-axis) of total zooplankton concentration (zpk/m^3) and temperature (°C), taken between 13:20 and 14:10 on 27 March 2008; many whales were present in the area, performing long fluking dives.

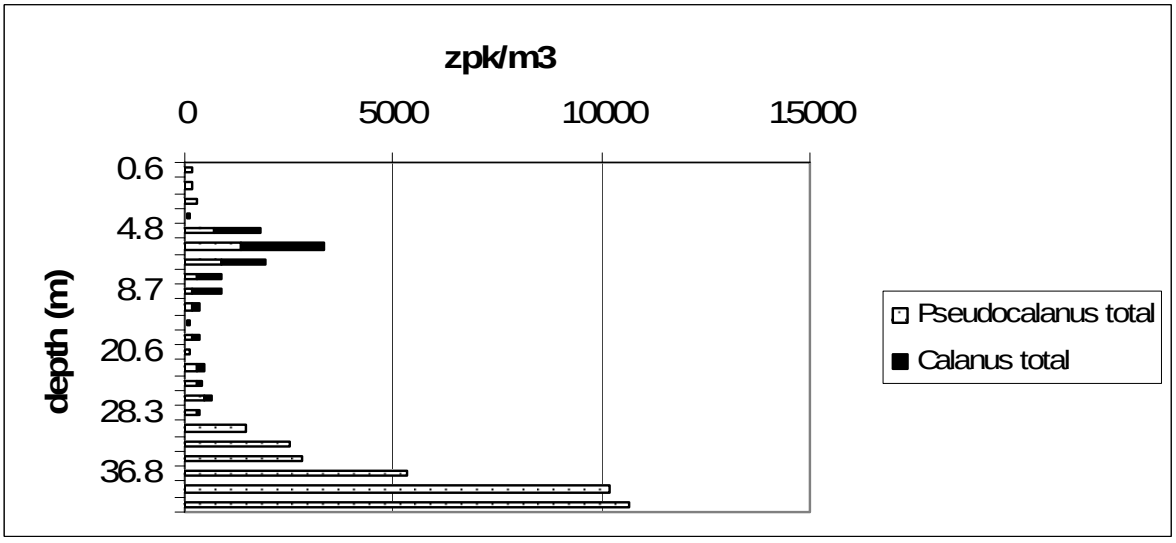

Figure 4. Total *Pseudocalanus* and total *C. Finmarchicus* present in profile 691B. Bottom depth is 40.5 meters.

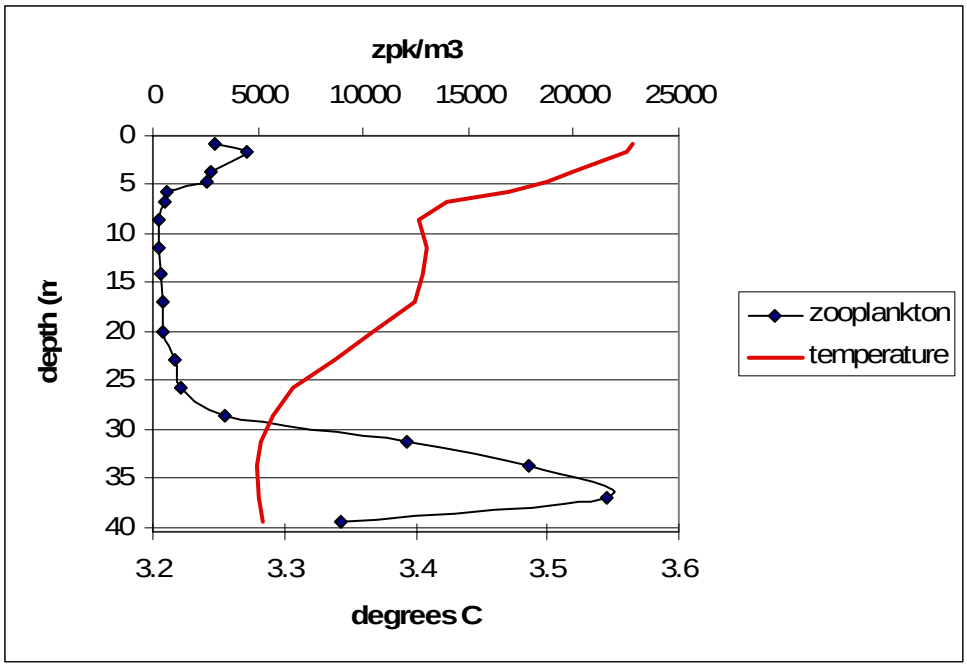

Figure 5. Profile 691D (note scale and that bottom depth is bottom of the y-axis) of total zooplankton concentration (zpk/m^3) and temperature (°C), taken between 15:10 and 15:45 on 27 March 2008; five or more whales were present in the area, executing long fluking dives.

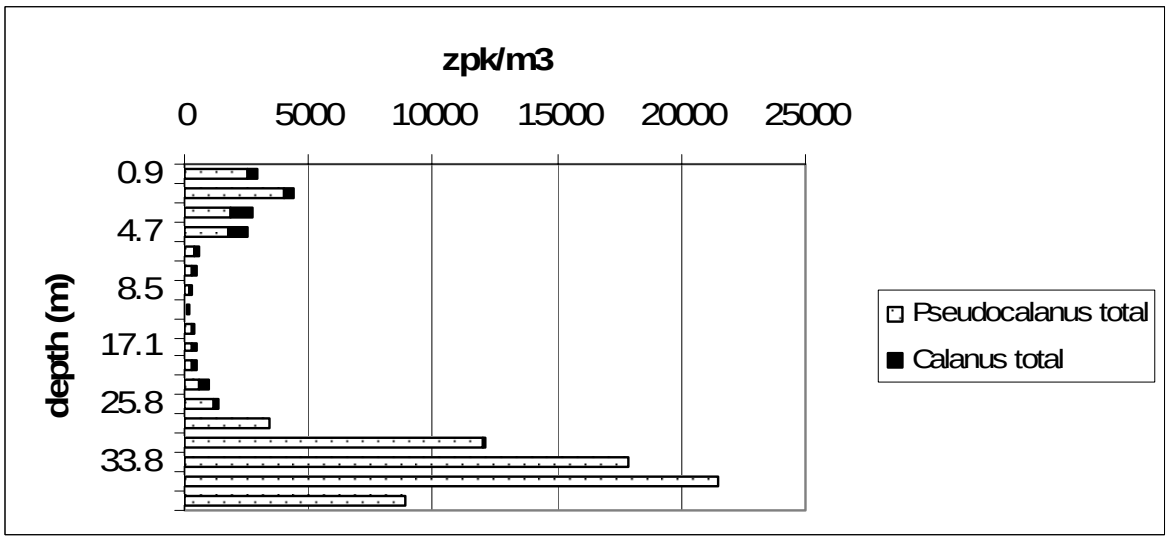

Figure 6. Total *Pseudocalanus* and total *C. Finmarchicus* present in profile 691D. Bottom depth is 40.5 meters.

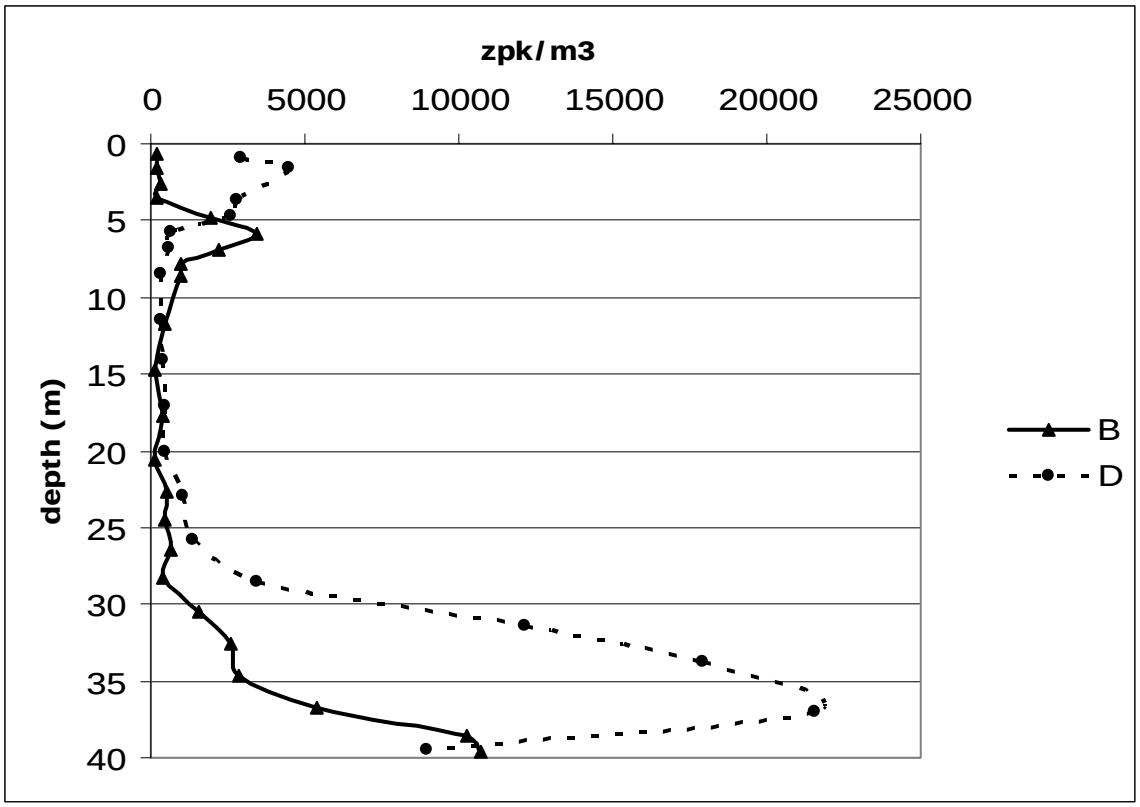

Figure 7. Profiles 691B and 691D shown together to illustrate the vertical movement of zooplankton layers; in both cases, whales were exhibiting long fluking dives. Bottom depth is 40.5 meters.