Surveillance, Monitoring and Management of North Atlantic Right Whales in Cape Cod Bay and Adjacent Waters - 2003

Final Report

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Executive Summary

In 2003, the right whale surveillance program for the Division of Marine Fisheries (DMF), Commonwealth of Massachusetts was conducted in Cape Cod Bay and adjacent waters by the right whale research team at the Center for Coastal Studies (CCS) from 1 January through mid May. The program included bi-weekly aerial surveys, weekly habitat sampling and collaboration with researchers at Cornell University on passive acoustic sampling with bottom-mounted hydrophones deployed throughout the season from 21 November through 21 May.

The right whale research team was ready to survey for 135 days between 1 January and 15 May 2003. The period of time right whales were known to be present in Cape Cod Bay, as determined by visual means from the aerial and vessel programs combined, was 102 days from 18 January through 30 April. There was a gap of 46 days from 10 February through 28 March when no right whales were seen during nine surveys of Cape Cod Bay, although they were observed off the eastern shore of Cape Cod. Right whales were seen again in Cape Cod Bay on 7 April through 30 April.

After the completion of the season it was possible to compare the visual and acoustic records. The hydrophone system was recording calls for 175 days. The first vocalization was heard on 23 November in the southern part of the Bay; no calls were heard after 4 May. Vocalization rates from hydrophone recordings were very low during this period of apparent absence from the Bay, which also coincided with the lowest plankton concentrations of the season as determined from net tows during habitat sampling. Thus, the period of time right whales were in Cape Cod Bay as determined during post-season analysis of passive acoustic data was 162 days from 23 November through 4 May.

There were a total of 254 sightings of right whales from both the aerial and vessel platforms, of which 224 right whales were photographed and analyzed for this report. Of those 224, 75 were from Cape Cod Bay and 149 were from waters along the outer coast of Cape Cod. To date, of those 224 photographed sightings, 126 of 224 (56%) have been matched to 72 known right whales. These results are preliminary because most of the matches have yet to receive final confirmation. There were a minimum of 27 different right whales identified in Cape Cod Bay, and 54 outside of Cape Cod Bay. The area totals are greater than the total number of identified right whales because nine whales were seen both in Cape Cod Bay and in one of the areas outside the Bay. Photo analysis is still underway to match the remainder; the number of right whale identifications for Cape Cod Bay is expected to increase by 22 animals, and outside Cape Cod Bay by 27 animals for estimated area totals of 49 and 81 right whales respectively.

All sightings were reported upon completion of each survey to the NOAA Fisheries Sighting Advisory System (SAS) and the US Army Corps of Engineers Cape Cod Canal Field Station. These aerial and vessel surveys are the principal source of right whale sightings for NOAA Fisheries/SAS in the winter months through March for waters in the northeast north of latitude 41°N. Two additional conservation measures were implemented in 2003. NOAA Fisheries, Northeast Regional Office implemented a voluntary Dynamic Area Management action on 10 April based on aerial sightings of an aggregation of right whales east of Chatham. The DMF issued an advisory to mariners extending the fishing gear modifications for nine days beyond 30 April and a request for boaters to slow down and post a lookout when traveling in Cape Cod Bay.

The close relationship between the four measures of food richness and the presence of right whales, as documented in the aircraft surveys and the acoustic monitoring program, demonstrates the value that zooplankton sampling has in the development of a coherent strategy for managing the Cape Cod

Bay Critical Habitat. Both at bay-wide and at smaller scales, the density of calanoid copepods clearly is reflected in the distributional patterns of the whales. Thus, we have demonstrated that the measures of zooplankton can be used to confirm the likely presence or absence of right whales and the prediction of their occurrence. The aircraft and acoustic surveys applied during the 2003 studies, while providing snap shot visual and acoustic assessments of whale presence respectively, cannot offer the predictive capacity available from zooplankton assessment. Therefore, the assessment of food resource is a significant contribution to the ability of managers to develop conservation plans in a timely fashion.

The results of the 2003 zooplankton assessment program resulted in the development of techniques and reporting procedures that will allow the wide dissemination of the predictive instruments needed to direct management actions. We recommend that future efforts to assess the habitat coupled with survey studies be directed at further verifying the close relationship between whale occurrence and patterns of zooplankton density and distribution in Cape Cod Bay. We also recommend that these techniques be expanded, when possible, to nearby waters when right whales aggregate outside of the critical habitat to test if the hypotheses formulated in Cape Cod Bay have a broader application.

The presence of right whales in adjacent waters outside of the Cape Cod Bay Critical Habitat in 2003 and in past years suggests that a re-evaluation of the area protected by Critical Habitat designation in Cape Cod Bay and the Great South Channel is needed and timely to adequately reflect the seasonal residency, distribution and movements of right whales. The use of these areas has only come to light with the expanded survey efforts of the last six years, and many of the locations where right whales have been seen are in areas between the two critical habitats. Since these areas are used for fishing activity and are transected by a major shipping lane between Boston and New York, we recommend that the data collected over the last six years be evaluated to determine if the concentrations and seasonality of right whale use in this region warrant greater protection.

It has been without a doubt a pleasure and a privilege to work on right whale conservation with the state biologists from the Division of Marine Fisheries. This program is the most comprehensive research effort on right whales in any of their habitat areas along the east coast of the US and Canada. The data collected from research efforts over the last six years has resulted in management measures that will help foster the recovery of this endangered species. The flexibility of the program has encouraged new hypotheses about right whale habitat use and given researchers a unique opportunity to explore and test those hypotheses in the field. Many challenges remain, but there is hope that solutions can be developed, tested and implemented that will make a difference for right whales.

Acknowledgments

We are most grateful to all of our dedicated colleagues who spent the winter and spring in planes and on boats in Cape Cod Bay to make this work possible. Aerial observers included Cyndi Browning (CCS intern), Desray Reeb (WHOI research associate on loan from South African right whales) and Philip Kibler (CCS research assistant). Special appreciation is extended to John Ambroult, Chandler Lofland and Jack O'Brien of Ambroult Aviation (Chatham, MA) who kept our planes, Skymaster N5382S and N700AM, flying smoothly all season. We would also like to extend our thanks to Captain James Murray of the US Coast Guard, Group Woods Hole, for taking our radio guard and to Air Station Cape Cod for providing us with a pre- and post-flight call-in service. Special thanks to Marc Costa who kept R/V *Shearwater* shipshape under winter conditions and an extra thank you for additional cruises with the Cornell University team to deploy and recover acoustic monitoring equipment in the Bay day and night. We would also like to thank Fran Donovan, Bill Norman and the operators at the Cape Cod Canal Field Station of the US Army Corps of Engineers for relaying right whale sighting locations to the marine community, especially during the weeks when right whales favored the western side of Cape Cod Bay. Thank you to Peter Hanlon, MEP, for always keeping a look out for right whales.

The oceanographic sampling and photo-identification efforts from on board the R/V *Shearwater* were carried out as skillfully as ever by Moriah Bessinger (CCS researcher) and Jenni Konken (CCS intern) under a myriad of weather conditions from snow and freezing spray to brilliant sunshine. Phytoplankton analysis was carried out by Anne Hampton (Castleton State College, Castleton, VT). Many thanks to Peter Borrelli, John Shea, Maryann Firmes and Jan Young for keeping everything running smoothly on the administrative end of the project. A special thanks to Jennifer Beaudin Ring, and her assistants, Noah and Willem, for proofing sighting data and preparation of the figures for this report.

The vessel and aerial surveys were conducted under a Scientific Permit to Take Marine Mammals No. 633-1483-04 issued by NOAA Fisheries to Dr. Charles Mayo. This permit is valid until 31 March 2004. A report of our research activities for 2003 will be submitted to the NOAA Fisheries permitting office in December 2003. The data collected on this project are archived at CCS and submitted to the New England Aquarium and the University of Rhode Island as part of our participation in the North Atlantic Right Whale Consortium. This work was supported by a grant from the Massachusetts Division of Marine Fisheries (DMF).

The goal of this project is to implement and refine the State's long-term right whale conservation program. The role of DMF has consisted of far more than providing funding for research. We would like to take this opportunity to extend our thanks to Daniel McKiernan, deputy director, DMF. We have worked together with Dan on all aspects of this project since its inception in 1998, and he has personally participated in the fieldwork, both in the air and on the water. He has used the results of our surveys and habitat sampling to continually refine the State's conservation plan and bring the marine industry in as a partner in the right whale conservation effort. We would also like to thank DMF biologist Edward Lyman, who assists Dan with administration of the contract and brings years of whale experience into our ongoing efforts to protect right whales.

The 2003 season was an especially difficult one with the loss of our colleagues and friends on January 26, 2003 in the southeast US. Jackie Ciano, Michael Newcomer, Emily Argo and pilot Tom Hinds were highly respected and very dedicated to research and conservation of right whales. We deeply regret their loss and they are in our thoughts daily. We hope we can carry on their work in a manner in which they would be proud.

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

Cover Photograph: Owen Nichols

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Surveillance of North Atlantic Right Whales in Cape Cod Bay and Adjacent Waters - 2003

Final Report
Chapter One

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Introduction

The Cape Cod Bay ecosystem is one of five known seasonal high-use habitat areas for right whales (*Eubalaena glacialis*) in the western North Atlantic. A Critical Habitat for the North Atlantic right whale in Cape Cod Bay was federally designated in 1994 (Federal Register 59 FR 28793). This was in recognition of the seasonal importance of Cape Cod Bay as a critical area for feeding, socializing, and as a nursery area for cows and calves (Watkins and Schevill 1979, Schevill *et* al. 1986, Hamilton and Mayo 1990, Mayo and Marx 1990, Kraus and Kenney 1991), including a number of cows that are rarely seen in the other three northern habitat areas (Knowlton *et al.* 1992, Brown 1994). Cape Cod Bay has a long history as an important habitat area for right whales. Photographic identifications date from 1959 (Hamilton *et al.* 1997) to the present, and whaling records provide evidence of right whales in this area in the late autumn and winter through late spring from at least the early 1600s (Allen 1916, Mitchell and Reeves 1983, Reeves *et al.* 1999, Reeves *et al.* 2002).

Since the 1980s, right whales have been known to occur in Cape Cod Bay, Massachusetts, and adjacent waters* in all months of the year, with the peak of occurrence from February through April (Schevill *et al.* 1986, Winn *et al.* 1986, Hamilton and Mayo 1990, Payne *et al.* 1990, Brown 1994). The number of right whales documented and the survey effort has shown annual variation. For the period of 1978 through 1986, using photographed sightings of right whales collected from whale watch boats and research cruises, the total number of individually identified right whales in Cape Cod Bay ranged from a single animal in 1978 to 47 individuals in 1986 (Hamilton and Mayo 1990). Expanded surveillance and monitoring efforts in the winter and spring over the last six years (1998 – 2003) have demonstrated that Cape Cod Bay is an important feeding and socializing area from December to May for at least 85 to 95 individuals annually, almost a third of the known catalogued population (Brown and Marx 1998, 1999, 2000, Brown, Marx and Nichols 2001, Brown *et al.* 2002).

Range-wide Concerns

Despite international protection from commercial hunting since 1935, the North Atlantic right whale is the most endangered large whale in the world. No more than 350 remain (CeTAP 1982, Brownell *et al.* 1986, Kraus *et al.* 1988, NMFS 1991, Knowlton *et al.* 1994, IWC 2001). In the United States, the northern right whale is listed as "endangered" under the Endangered Species Act (ESA) of 1973. Scientists and conservationists have long been concerned about the status of the North Atlantic right whale population and its slow rate of growth (about 2.5% per year in the 1980s, Knowlton *et al.* 1994). The reproductive output of this population has not changed in the last two decades, on average researchers have documented 12 calves per year (Knowlton *et al.* 1994 and NEAq unpublished data). Recent analyses showing a decrease in the reproductive rate (fewer calves per mature female per year), an increase in the calving interval (Kraus *et al.* 2001, Kraus 2002), and a decline in the survival rate (Caswell *et al.* 1999, Fujiwara and Caswell 2001) suggest we should view the present situation with greater concern (Reeves *et al.* 2001).

The apparent failure of this population to recover has also been attributed to anthropogenic factors including mortality from collisions with ships and entanglements in fixed fishing gear (Kraus 1990, Kenney and Kraus 1993, Knowlton and Kraus 2001). There have been 60 right whale deaths documented between 1970 and 2003 (Knowlton and Kraus 2001, NEAq unpublished data). Of those 60, 21 (35%) right whale fatalities were due to ship strikes, and six (10%) were the result of entanglement in fixed fishing gear, 16 were of natural causes (27%) and 17 (28%) of unknown cause

* 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.

(Knowlton and Kraus 2001, NEAq unpublished data). Ship collisions kill more right whales than any other documented causes of mortality and more than half of the ship collision mortalities have been recorded since 1990. Entanglements, however, can result in long-term deterioration and may be responsible for more deaths than previously thought (Knowlton and Kraus 2001), and are now thought to be equally responsible for right whale deaths as ship collisions (Kraus 2002). In addition, many animals disappear from the population (presumed dead when not seen in more than 6 years; n=105 through 2003), and it is obvious that not all deaths are seen on the beach (Knowlton and Kraus 2001). Caswell *et al.* (1999) estimated that if human related mortality is not reduced this population could become extinct in less than 200 years and upon further analysis suggested that the preventing the death of only two female right whales per year would increase the population to replacement level (Fujiwara and Caswell 2001).

Right Whales in Cape Cod Bay and Adjacent Waters

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), however, since the cessation of whaling in the late 1800s, other human activities have affected the right whales using the area relatively recently. Right whales are slow moving (particularly when accompanied by a calf) and very difficult to see for vessel-based observers when the whales are feeding at or just below the surface. They do not always appear to avoid approaching vessels, especially when socializing or feeding near the surface. There is a moderate level of commercial shipping in the area; Cape Cod Canal is one of three entrances into the Port of Boston. There are about 550 transits annually by inbound and outbound vessels through the canal and along the western portion of the Bay (Kite-Powell and Hoagland 2002). The habits of the whales and the moderate level of ship traffic in the region make the right whale vulnerable to collisions with vessels in Massachusetts waters. Knowlton and Kraus (2001) documented two right whales that have likely been killed by collisions with ships near this area, one in 1986 (found off Provincetown), the second in 1996 (found near Wellfleet). A third right whale was found dead in Cape Cod Bay in April 1999. A necropsy 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.

Right whales are at risk of entanglement in fixed fishing gear in the area; however, there have been attempts to reduce that risk with management actions taken by the Division of Marine Fisheries, Commonwealth of Massachusetts. Some fishing activity is prohibited (gill nets), or use of modified gear is required in the Cape Cod Bay Critical Habitat area. These modifications include sinking or neutrally buoyant ground line between lobster pots, traps set in trawls of four pots or more with vertical buoy lines on each end or in "doubles" where two pots are strung together with only one buoy line, and a 500-pound break away link in all buoy lines (322 CMR 12.05 Critical Habitat gear restrictions during January 1 to May 15). The modified gear is marked with twin orange flags on the buoy stick. Most of the fixed fishing gear in the Cape Cod Critical Habitat area is located in the northern margins along tracklines one, two and three (Figure 1a) in depths greater than 30 fathoms. A few right whales have been reported west of the critical habitat area in the past (see Figures 8 and 9). There is fixed fishing gear set to the west of the western margin (070°30'W) of the Critical Habitat in State waters that is not subject to the above gear restrictions because it is outside the federally designated critical habitat area; that gear is now modified as described above as of January 2003. In addition to the above conservation measures, there is a ghost gear removal program carried out in the winter months by the Division of Marine Fisheries.

Over the last twenty years, more than 70% of the catalogued population of right whales has been photo-documented in Cape Cod and Massachusetts Bays at some time during their lives (CCS and

NEAq, unpublished data). These photographic data have been collected by various means. Recent survey efforts include twice-weekly aerial surveillance flights and weekly vessel-based habitat studies annually from January to mid-May from 1998 to 2003 (Brown and Marx 1998, 1999, 2000, Brown, Marx and Nichols 2001, Brown *et al.* 2002 and this report). Prior to 1998, there were weekly vessel surveys and limited aerial surveys in the winter and spring in 1997 (Hamilton *et al.* 1997, Mayo 1997) and annual studies on foraging of right whales in the winter and spring since 1984 (Mayo and Marx, 1990). Researchers gathered opportunistic sightings from whale watching vessels from April through October from the late 1970s until 1996. The latter platform, which yielded many valuable sightings of right whales (including some rarely seen mothers with calves) in the spring, summer and fall (NEAq unpublished data), and reports of entanglements, is no longer available due to a 500-yard exclusion zone around right whales for non-permitted vessels.

Program Objectives - 2003

In order to gain a better understanding of both the spatial and temporal distribution of individually identified right whales in Cape Cod Bay, an extensive surveillance and monitoring research program was undertaken in the winter and spring of 1998 (Brown and Marx 1998), 1999 (Brown and Marx 1999), 2000 (Brown and Marx 2000), 2001 (Brown, Marx and Nichols), 2002 (Brown *et al.* 2002) and 2003 (this report). The program of research directly addresses concerns identified by the Right Whale Conservation Plan submitted by the Commonwealth of Massachusetts to federal courts in 1996 and by the Northeast Implementation Team, and supports goals in the federal Atlantic Large Whale Take Reduction Plan, the Right Whale Recovery Plan (NMFS 1991), and the ESA. Here we report on the results of the research activities as described below. The objectives of the 2003 surveillance, monitoring, management and research program in Cape Cod Bay and adjacent waters were:

I) To document the right whales in the Cape Cod Bay Right Whale Critical Habitat area and adjacent waters from January through mid-May, 2003, using standard photo-identification techniques to identify individual whales. These data provide information on the age, sex, reproduction, distribution, abundance and patterns of habitat use (residency) of right whales in Cape Cod Bay and help refine long-term, range-wide analyses on presumed mortality, incidence of scarring and demographics. Photographic and sighting data were integrated into the right whale photo-identification catalogue at the New England Aquarium and the sighting database at the University of Rhode Island.

II) To provide sighting data to the NOAA Fisheries Sighting Advisory System (SAS). Sighting locations of right whales were reported promptly to NOAA Fisheries/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 DMF/CCS program is the principle source of right whale sighting data for the region from January through March. Sightings of right whales in Cape Cod Bay were also reported to the US Army Corps of Engineers canal operators.

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

IV) To describe the distribution and abundance of any other marine mammals and shipping activity in Cape Cod Bay and adjacent waters from January through mid-May, 2003.

V) To collect oceanographic information on weekly vessel cruises, from January to mid-May, 2003, designed to develop an understanding of the characteristics of the habitat to which right whales respond. These oceanographic data, combined with data from past habitat studies in Cape Cod Bay by the Center for Coastal Studies, provide additional information on the conditions, which are believed to cue the movements and activities of right whales in Cape Cod Bay and adjacent waters. The results of this research program are presented in the second chapter of this report (Bessinger *et al.* 2003).

Methods

I) Aerial Surveys

Aerial surveys were conducted from 10 December 2002 through mid-May 2003 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 tracklines were flown latitudinally (east - west) at 1.5 nautical mile (nm) intervals from the mainland to the Cape Cod Bay shoreline (Figure 1a). An additional trackline, 25 nm in length, paralleled the outer coast of Cape Cod from east of Chatham to the eastern end of trackline one at a distance of about three nm from shore (Figure 1a, trackline number 16). The east-west flight pattern in Cape Cod Bay was chosen for scientific and safety reasons. In these latitudes, winter aerial surveys are hampered by low sun angles in the early and late hours of a survey day; glare is a significant factor in sightability of marine mammals. On east-west tracklines, although glare was a factor in one of the forward quadrants, there was always a section of the survey swath that could be observed without being compromised by glare. It was also safer to have the aerial survey tracklines begin and end near land. A total of 320 nm of 'on-trackline' miles were flown during each completed survey (Table 1a). "On-trackline" miles were those miles flown while surveying due east or due west in Cape Cod Bay and along the outer coast of Cape Cod, but excluded all miles flown between tracklines (cross legs) or while circling. Additional tracklines were established and flown at various times during the season to respond to reports of right whales in adjacent waters or to search for right whales in nearby locations when they were not being seen in the Bay (Tables 1b-h, Figures 1b-f).

The surveys were flown under VFR (visual flight rules) conditions up to and including Beaufort sea state four. Surveys were aborted in Beaufort sea state five and/or when visibility decreased below two miles in fog, rain or snow. Most aerial surveys originated at Chatham Airport, Chatham, MA, although on occasion surveys also originated out of Provincetown Airport or Hyannis Airport. Aerial surveys were conducted in a Cessna 337 Skymaster (N5382S or N700AM), a twin engine, high-wing aircraft with retractable landing gear. The aircraft was equipped with two GPS (global positioning system) navigation systems, full IFR (instrument flight rules) instrumentation, marine VHF radio with external antenna, and wing-tip mounted VHF tracking antennas. Safety equipment included a life raft, four survival suits, signal flares, a medical kit, a waterproof VHF radio, a portable 406 EPIRB, and an aircraft mounted ELT (emergency locator transmitter). All occupants wore aircraft FAA approved PFDs (personal floatation device) during the entire flight.

Surveys were conducted at a standard altitude of 750 feet (229 meters) and a ground speed of approximately 100 knots, using methodology developed by CeTAP (Scott and Gilbert 1982, CeTAP 1982). The survey team consisted of a pilot, data recorder, and two observers positioned on each side of the aircraft in the rear seats. The two rear seat observers scanned the water surface from 0° - 90°, out to at least two nautical miles and reported sightings when they were abeam of the aircraft. In order to maintain a standardized sighting effort, the pilot and data recorder were instructed not to alert

the observers to any sighting of marine mammals until after it had been passed by the aircraft and clearly missed by the observers. The turn at the end of each trackline was initiated and completed about 1.5 nm from shore in Cape Cod Bay to maximize the opportunity to observe any whales near shore.

All sightings of marine animals except birds were recorded. Sightings identified as species other than right whales were counted, logged and passed without breaking the trackline and circling in order to maximize flight time available for investigating right whale sightings. Sightings of all vessels in the area were recorded by location and type. At sightings identified as right whales, as well as sightings of large whales, which were not immediately identified by species, the aircraft broke track at right angles to the sighting, reduced altitude to 500 feet (153 meters) and circled over the animal to obtain photographs. Photographs were obtained of as many individual right whales within a given aggregation as possible. For each right whale, behavior and interaction with other whales or any nearby vessels or fishing gear was noted. In a few instances, when right whales were spotted from the plane in close vicinity to R/V *Shearwater*, the vessel was contacted from the plane and photographs were taken from the vessel so that the plane could devote more time to surveying. The right angle distance of each sighting from the flight track was determined from GPS positions.

At the conclusion of photographic effort at each sighting, the aircraft regained altitude to 750 feet (229 meters) and returned to the trackline at the point of departure using the GPS position recorded in the log. These methods conform to research protocols followed by the North Atlantic Right Whale Consortium (CCS, NEAq, URI, and WHOI) and approved by NOAA Fisheries. Trackline and sighting data from the daily logs were entered into the Right Whale Initiative DBase program designed for compatibility with the Right Whale Consortium database. Copies of the daily logs from the aerial surveys are on file at CCS and URI.

II) Habitat Sampling

CCS maintains a 40' (12m) long, twin diesel engine research vessel *Shearwater*. The R/V *Shearwater* has been used successfully for habitat sampling and photo-identification in the winter and spring surveillance program in Cape Cod Bay from 1997 through 2003 (Mayo 1997, 1998, Mayo *et al.* 2000, 2001a, 2001b, 2002). The R/V *Shearwater* is equipped with oceanographic sampling equipment including a CTD profiler (conductivity, temperature, depth), plankton nets, surface plankton pump, and flow meter as well as photographic equipment and disentanglement gear. The results of this part of the program are reported on in Chapter two of this report (Bessinger *et al.* 2003).

Although the primary objective of these vessel cruises was habitat sampling (see Chapter two of this report), some photographs were collected opportunistically of right whales in the vicinity of the boat during sampling and on transits to and from sampling locations. Photographs of right whales obtained during habitat studies were collated and integrated with the photographs collected during aerial surveillance. These vessel-based sightings are also included in the tables on residency, capture rates, demographics, and life history. The vessel sighting data were included in the report to the NOAA Fisheries/SAS system. Sighting data from the daily vessel logs were entered into the Right Whale Initiative DBase program as opportunistic sightings.

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

III) Notification of Agencies

Prior to and following an aerial survey, both Group Woods Hole (US Coast Guard) and Air Station Cape Cod at Otis Air National Guard Base were notified of our planned survey, departure time, estimated return and a verbal summary of what was seen. In addition, in 2003 we notified the shift commander at the Pilgrim Nuclear Power Plant of our flights. Following the completion of each aerial survey, the number of right whales seen and the location of these sightings were verbally reported to the NOAA Fisheries Sighting Advisory System coordinator. The NOAA Fisheries/SAS office disseminates this information by fax, Navtex, and marine weather radio to the appropriate agencies and mariners. Prior to reporting to the NOAA Fisheries/SAS, on days when any other whale research vessels were operating in Cape Cod Bay and adjacent waters, additional sightings, if any, were added to the report if from an area not already included in the CCS report. A daily summary of the location and number of right whale sightings was faxed to DMF. In the event that a right whale was seen in Cape Cod Bay, the US Army Corps of Engineers Canal operators were also notified at the completion of a flight so they could relay the sighting location to transiting ships. If right whales were sighted in close proximity to Canal traffic, sightings were relayed during flight via VHF radio.

The Center for Coastal Studies records all species of marine mammals seen on aerial surveys. On several occasions when pilot whales and dolphins were observed, this information was reported after the flight to the stranding coordinators at the Cape Cod Stranding Network and at NOAA Fisheries Woods Hole to help them prepare for a possible stranding event.

IV) Photographic Techniques

i) Identification Photographs

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

ii) Photo-analysis and Matching

Photographs of right whale callosity patterns are used as a basis for identification and 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). 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 29,801 sightings of 447 individual right whales have been archived, of which 326 are thought to be alive, as of December 2002 (H. Pettis, NEAq, pers. comm.)

The matching process consists of separating photographs of right whales into individuals and inter-matching between days within the season. To match different sightings of the same whale, composite drawings and photographs of the callosity patterns of individual right whales are compared to a limited subset of the catalogue that includes animals with a similar appearance. For whales that look alike in

the first sort, the original photographs of all probable matches are examined for callosity similarities and supplementary features, including scars, pigmentation, lip crenulations, and morphometric ratios. A match between different sightings is considered positive when the callosity pattern and at least one other feature can be independently matched by at least two experienced researchers (Kraus *et al*. 1986). Exceptions to this multiple identifying feature requirement include whales that have unusual callosity patterns, large scars or birthmarks, or deformities so unique that matches from clear photographs can be based on only one feature. Preliminary photo-analysis and inter-matching was carried out at CCS, with matches confirmed using original photographs catalogued and archived at NEAq.

iii) Photographic Data Archiving

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

V) Data Management, Analysis, and Interpretation

i) Data Management – Aerial surveys

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

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

All sightings are incorporated and integrated into the right whale catalogue and Consortium database with existing data on life histories for each individual identified by CCS. Integration of the sighting data collected during these surveys with previously collected data are used to describe the number, age, sex, and reproductive status of the right whales using the Cape Cod Bay habitat area in 2003. Sighting data from the aircraft are charted to establish patterns of distribution and assess the seasonal and spatial residency patterns of right whales in the critical habitat and adjacent waters. The data on vessel locations are charted and compared with the locations of right whales to assess the level of overlap between right whales and vessels in the area. The exact location of fishing activity was not recorded during the aerial surveys; rather observers record the trackline number and the beginning and end of the fixed gear on that trackline. Following discussions between the researchers and state biologist Dan McKiernan, it was determined that counting and recording of fishing activity on every flight would take away observer effort from obtaining marine mammal sightings and identification photographs of right whales. Since fishing effort is already documented by other agencies, the protocol was changed; the general location of fixed fishing gear along the trackline was recorded on the first flight of the month.

We used the individual identifications of right whales obtained during this study to examine capture rate, residency and number of days between first and last sighting in Cape Cod Bay. An analysis of the age and sex composition of the winter and spring population was carried out using data from all CCS surveys to assess demographics and habitat use patterns. Right whales, first identified as calves,

ranging in age from one to eight years of age were classified as juveniles, individuals age nine or older were classified as adults (based on classifications by Hamilton *et al.* 1995). Whales that were not first sighted as calves were classified as unknown age for the first eight years of their sighting history and as adults thereafter. All females who have calved are classified as adult. Sexes were assigned based on one of three methods: 1) direct observation of the genital area; 2) by association with a calf; 3) by testing biopsy samples with a sex specific DNA marker (Brown *et al* 1994).

Results and Discussion

Aerial Surveys

In 2003, the right whale aerial surveillance team was in position to survey for 135 days from 1 January through 15 May. In addition, CCS staff carried out two preseason flights on 10 and 13 December 2002, but no right whales were seen (Table 2). Sightings of dolphins and pilot whales seen during these two surveys (Table 2, Figure 5) were reported to the stranding coordinators of the Cape Cod Stranding Network and to NOAA Fisheries Woods Hole.

Our first flight of the 2003 season over Cape Cod Bay was conducted on 6 January, no right whales were observed (Table 2). The first right whales (5 individuals) were documented by the aerial survey team on 25 January (Table 2 and Figure 2b).

Mid Season Changes to Aerial Survey Methods

While the CCS/DMF right whale team was flying a survey over Cape Cod Bay on Sunday January 26, 2004, one of the right whale survey planes flying over the calving grounds in the southeast US was lost with all crewmembers on board. Upon receiving the news of the tragic aircraft accident, CCS and DMF jointly decided to suspend aerial surveys over Cape Cod Bay for an indefinite period of time. In the days that followed safety practices for over-water aerial surveys were reviewed and discussed at length. The CCS/DMF aerial survey team participated in an aircraft-ditching course at Survival Systems USA in Groton Connecticut that had been scheduled prior to the accident. Aerial surveys over Cape Cod Bay resumed on 6 February with several modifications that were phased in to the aerial survey protocols over the next several flights:

1. Both surveys and photographic data collection were performed at an altitude of 750 feet (229 meters);
2. For aerial surveys outside of Cape Cod Bay, the surveys were flown and photographs were collected at an altitude of 1000 feet (328 meters)
3. An emergency egress plan was developed for our survey aircraft and all crew members were familiar with the plan;
4. Front seat crew members (pilot and recorder) were equipped with helmets;
5. USCG Group Woods Hole took our radio guard during aerial surveys with scheduled communications every 30 minutes at the top and bottom of the hour;
6. An emergency response plan was developed to facilitate activation of all available resources to assist in a search and rescue;
7. The restraint system for front seat passengers was changed from a lap belt to shoulder harness system.

When aerial surveys resumed on the afternoon of 6 February, the team was able to complete most of the survey lines and one right whale was seen (Table 2, Figure 2c). However, there were no right whales seen on the next nine aerial surveys of Cape Cod Bay over a 46-day period from 10 February through 28 March (Table 2). This coincided with the lowest plankton densities of the season as

determined from net tows during habitat sampling (see Chapter 2). Right whales were seen again in Cape Cod Bay on 7 April through to 30 April (Tables 2 and 3).

There were a total of 36 aerial surveys conducted for the season including the two-preseason flights in December (Table 2). Of the 36 aerial surveys, 25 were carried out over Cape Cod Bay and 11 aerial surveys were conducted in adjacent waters including Stellwagen Basin, Stellwagen Bank, Wildcat Knoll and the Great South Channel (Table 2 and Figures 1a-f). There were four days on which two surveys were conducted on the same day (15, 23, 28 March and 21 April), the first survey of the day was in Cape Cod Bay and the second one along the eastern shore of Cape Cod or over Stellwagen Basin/Wildcat Knoll. These additional surveys were logged as separate surveys under the adjacent waters section of Table 2. Most of the aerial surveys originated from Chatham airport or Provincetown Airport. There were two surveys in February that originated out of Hyannis Airport because the Chatham airport was closed due to snow on the runway. These two surveys were possible because Ambroult Aviation had a second plane available based at Hyannis airport.

The systematic pre-set tracklines in the Cape Cod Bay Critical Habitat area (Table 1a, Figure 1a) were surveyed on average in approximately 3.6 hours during those surveys that were not aborted due to an increase in wind speed, sea state (above Beaufort 4) or decrease in sighting conditions (to visibility less than two nm). Completed surveys ranged in duration from about three to more than five hours. The time spent in the air depended on the number of right whales encountered and the amount of time spent circling to obtain photographs. On two occasions, 14 April and 28 April, additional time was spent in the air to obtain documentation and provide support for a disentanglement attempt following the sighting of an entangled right whale.

The final aerial survey of the season was conducted in adjacent waters over the Great South Channel on 15 May. The CCS/DMF team was part of a three-plane survey following tracklines established in the late 1980s over the Great South Channel (Table 1h, Figure 1f and 4b, SCOPEX lines; Kenney *et al*. 1995). The joint one-day three-plane survey of the Great South Channel, carried out in collaboration with the two NOAA Fisheries aerial survey teams from the NEFSC, has been carried out once per season for five of the last six seasons and provides a synoptic view of the Great South Channel critical habitat for right whales. With the completion of this last survey, the CCS/DMF right whale aerial survey team had spent almost 130 hours in the air surveying over 8900 nautical miles in Cape Cod Bay and adjacent waters (Table 2).

Habitat Sampling

In 2003, the right whale habitat sampling team was in position in Cape Cod Bay for 135 days from 1 January through 15 May. The R/V *Shearwater* was out on the water for a total of 24 cruises, 21 of which were for habitat sampling in Cape Cod Bay and adjacent waters between 9 January and 14 May (Table 3a). Habitat sampling cruises ranged in duration from 2.5 hours to 8.3 hours (average 6 hours) depending on sea state and temperature conditions. Some trips were shortened because of equipment freezing or ice build-up on the hull and deck from freezing spray that endangered the stability of the vessel. The vessel crew located the first right whale on 18 January, but no photos were obtained. Right whales were not seen again from the vessel until 7 April. The last day on which right whales were seen in Cape Cod Bay was 30 April, the same day as the aerial team last encountered right whales (Table 3a).

The primary purpose of the habitat sampling cruises was to collect oceanographic data in the Cape Cod Bay Critical Habitat area on a weekly basis for 19 weeks to compare concentrations of right whales from aerial surveys with the food resource determined from plankton samples obtained at sea.

Please see chapter two of this report for the results and discussion of this portion of the program (Bessinger *et al.* 2003). In addition to the habitat sampling, the vessel team also photographed five right whales (Table 3a) during the course of their work, three of which were only seen from the vessel in Cape Cod Bay. These three whales (# 1208 and # 1817 and her calf) were encountered in the Bay on days when the plane was not surveying.

The R/V *Shearwater* was used to survey for right whales on three days. The first systematic vessel survey (Table 3a, SW310) of Cape Cod Bay was carried out in conjunction with a habitat sampling cruise on 29 January. This survey was designed to continue to provide surveillance of Cape Cod Bay during the time the aircraft was grounded; no right whales were seen. The second survey in Cape Cod Bay on 10 April documented a group of right whales located south of Provincetown (Table 3b). On 24 March a habitat monitoring cruise was planned along the eastern shore of Cape Cod where an aggregation had been spotted by the aircraft team on 20 March. Some additional crewmembers on the vessel kept watch while underway, however the first right whale seen was entangled. At that point the cruise switched gears for a disentanglement attempt.

The CCS right whale team spent a total of almost 140 hours at sea in 2003. In addition to the work described above, there were several cruises in collaboration with Cornell University to deploy and recover bottom mounted autonomous acoustic sensors (acoustic pop-ups) in six locations in Cape Cod Bay (see Appendix IV) and to collect plankton samples for a study with the University of Rhode Island.

All of the photographs collected during habitat sampling cruises, systematic vessel surveys and disentanglement attempts have been compared to the ones obtained from the aircraft and were taken through the same matching process as detailed above and are included in the following analyses.

Sightings and Photo Analysis

In 2003, from all aerial and shipboard efforts in all areas combined, there were a total of 254 right whale sightings, of which 224 were photographed and analyzed for this report (Tables 2 and 3). Of those 224 photographed sightings, 75 were from Cape Cod Bay, 149 were from the area along the outer coast of Cape Cod between Chatham and Provincetown, Stellwagen/Bank/Wildcat and nine were from the one aerial survey of the Great South Channel. To date, of those 224 photographed sightings, 126 of 224 (56%) have been matched to 72 known right whales; photo analysis is still underway to match the remainder. Most of the matches have yet to be confirmed.

Platform and Location	Photographed sighting	Identified to a known Eg	Sightings to be matched	Unmatchable sightings
Aerial – CCB	56	24 (23)	22	10
Aerial – Outside CCB	149	86 (78)	27	36
Habitat boat – CCB	7	6 (6)	1	0
Survey boat - CCB	12	10 (8)	2	0
Totals	224	126 (115)	52	46

The breakdown of the photographic analysis by area and platform is presented in the table above (outside Cape Cod Bay, CCB, includes Stellwagen Bank/Wildcat Knoll, eastern shore of Cape Cod and the Great South Channel). The number in brackets represents the number of different individuals from those sightings (see Appendix II). This number is higher than the total number of individuals identified (n=72) because 27 whales were seen more than once, nine whales were seen in more than one habitat area (Appendix II) and two of the five whales seen from the research boat

were also seen from the plane. There were three right whales that were only seen from the research boat in Cape Cod Bay (#s 1208 and 1817 and her calf) on two days when the plane was not surveying. The identification of right whale #1208 is tentative because the photographs may not be of sufficient quality for this preliminary match to be confirmed. However, there was a mother calf pair seen from the R/V *Shearwater* at this sighting and it does not match either of the other two mother calf pairs seen in 2003.

Of the 52 sightings that remain to be matched, all of those right whales are different from the individuals that have already been identified. Thus, as of this date, the minimum count for Cape Cod Bay is 27 identified right whales including one mother calf pair (# 1817) and one mother whose calf was not photographed (#1208) plus 22 yet to be matched for a total of 49 right whales. The minimum count for outside of Cape Cod Bay is 54 identified right whales including a second mother calf pair (#1503) plus 27 right whales to be matched for a total of 81 right whales.

The high number of unmatchable sightings (36) from aerial surveys outside of Cape Cod Bay resulted, in part, of the higher altitude from which the photographs were taken after the photographic protocol was modified (see above). The image of the whale was much smaller on the slide making it more difficult to discern the callosity pattern and other identifying features. Unmatchable photographed sightings are also attributed to splashing water obscuring the identifying features of the right whale, obtaining photographs of the whale while it is still underwater and camera motion.

Right Whale Identifications

The sighting histories of the right whales photographed and matched to an individual in the catalogue are presented in Appendix I. Right whales seen in Cape Cod Bay are classified in this appendix as M for Massachusetts Bay. For the last two years (2002, 2003) when the sighting occurred outside of Cape Cod Bay and north of 42°06' a regional identifier was used (such as STB for Stellwagen Bank). For those right whales seen along the eastern shore of Cape Cod Bay in 2003, sightings north of 42°00' and west of 69°50' were classified as in Massachusetts Bay, while those south of 42°00' and east of 70°00'W were classified as being in the Great South Channel.

As of the date of this report, a total of 72 right whales have been identified from all survey efforts in 2003 (Appendix I and II). There were 27 different right whales individually identified in Cape Cod Bay (highlighted in bold in Appendices I and II), and 54 outside of Cape Cod Bay on Stellwagen Bank/Wildcat Knoll, along the eastern shore of Cape Cod and further offshore in the Great South Channel. The area totals are greater than the total number of identified right whales because nine whales were seen both in Cape Cod Bay and in one of the areas outside the Bay (Appendix I and II).

Of the 27 right whales identified in Cape Cod Bay, there were three new whales to the Bay (#s 1419, an adult male; 2753, a juvenile female; and 2770, a male of unknown age first seen in 1997) and 24 that had been seen in previous years. There are two sightings worth mentioning in detail; one was the return of #1133 after a two-year absence. This adult male, known as Porter, was recorded in the waters off of Norway in 1999 and has been seen in Cape Cod Bay intermittently over the last twenty years (Appendix I). The second was #2753; it was her grandmother, #1014 (Staccato) that was found floating dead in April 1999 in Cape Cod Bay. A third noteworthy sighting was the famous canal whale, #3103, which was first reported by a cyclist on 15 April 2002 swimming in the mouth of the eastern end of the Cape Cod Canal (Brown *et al.* 2002, Mazzola 2002). The whale made it about halfway to the Buzzards Bay entrance and then turned around and swam out into Cape Cod Bay. In 2003, #3103 (a 2 year old of unknown sex) was seen just once on 15 May in the Great South Channel.

Only two right whales seen in 2002 returned to Cape Cod Bay in 2003. They were #s 1706, an adult female who has been seen six out of the last seven years; and 2750, a juvenile male (first whale of the year and his fifth year in a row). Six of the right whales that were seen in Cape Cod Bay in 2003 had been seen in 2002, but north of the Bay in the vicinity of Stellwagen Bank (#s 1271, 1503, 1706, 2320, 2350 and the entangled whale 1424, Appendix I). All of these whales are females, except the entangled one (1424); and 1503 must have been pregnant at the time of her 2002 sighting since she was sighted in 2003 with a calf. Of the remaining 16 right whales identified two were calves of the year, 10 returned after a one-year gap, three after a two-year gap and two after a three-year gap in sightings (Appendix I). However, many of the right whales that were regular residents of Cape Cod Bay in the first four years of this program have not been seen in Cape Cod Bay for the last two years.

Sightings Outside the Cape Cod Bay Critical Habitat

In 2003, as in 2002, there were more individual right whales photographed outside the Cape Cod Bay Critical Habitat (n=54) than there were within the boundaries (n=27) as shown in Appendix II and Figures 2-4. The aggregation of right whales along the eastern shore of Cape Cod coincided with the departure of right whales from Cape Cod Bay, although right whales were seen in both areas during the last two weeks of April (Appendix II). Of the 54 right whales identified outside of Cape Cod Bay, 18 of those were new to the CCS right whale database, although colleagues working in other habitat areas had previously seen all of them. Of these 18 whales, 15 were adult males, one was an adult female and two were juveniles. Of note is the sighting of right whale #1036 on 23 March in the aggregation of right whales off the eastern shore of Cape Cod. This whale had last been seen in Canadian waters in 1992. This whale had been presumed dead since 1998 and will now be resurrected in the right whale catalogue on the basis of this sighting.

The location of most of the adult male right whale population in the wintertime is unknown. The sightings from the calving ground in the southeast US and from Cape Cod Bay combined only make up about one third of the catalogued right whales in the best sighting years. The location of the remaining two thirds, predominantly adult males and juveniles, is unknown. The aggregation of right whales observed from the aircraft on 20 March was located off of Nauset Beach and was dominated by adult males. This number of adult males is interesting and leads to speculation that some of the right whales that are not accounted for in the winter months may be located in the Gulf of Maine. Although the aggregation seen from the aircraft on 20 March that led to increased effort in this area was visible from the area normally surveyed on trackline 16, an aggregation only a few miles further from land would likely escape detection.

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

Conservation measures in Cape Cod Bay are in place from January 1 through mid May to correspond with what is considered to be the season of occurrence for right whales in Cape Cod Bay in the winter and spring. The longer we study right whales and the more techniques we use to find them, the longer the season of their occupancy becomes. In 1998 right whales were recorded on 4 January, the earliest documented sighting in the winter months to that date, although surveys had not been conducted in the month of December before that year. In subsequent years, aerial surveys were flown on 13 December 1999 and 19 December 2000 and right whales were encountered in Cape Cod Bay. In November of 2002, Dr. Chris Clark (Cornell University) deployed several bottom-mounted hydrophones (Appendix IV). After the completion of the season it was possible to compare the visual and acoustic records. The hydrophone system was recording calls for 175 days. The first vocalization was heard on 23 November in the southern part of the Bay; no calls were heard after 4 May. Two flights in December 2002 did not locate any right whales but there were low levels of calls heard during that time. The first right whale was seen from the vessel on 18 January, which coincided

with the increase in vocalization rate recorded on the hydrophones. There was fairly close synchrony between aerial observations of right whales and vocalization rates recorded from the hydrophones for the rest of the season, although the hydrophone data could only be analyzed following the completion of the season when the hydrophones were recovered.

The period of time right whales were resident in Cape Cod Bay in 2003, as determined from visual efforts from the vessel and aerial programs combined, was from 18 January through 30 April (102 days). However, there was a gap of 46 days from 10 February through 28 March when no right whales were seen in Cape Cod Bay although they were observed off the eastern shore of Cape Cod along the edge of the Great South Channel (Figures 2-4). The vocalization rates from the hydrophone recordings were similarly very low during this period of apparent absence from the Bay from visual survey efforts, which also coincided with the lowest plankton densities of the season (Chapter Two). Perhaps the few right whale vocalizations that were recorded on the hydrophones were of whales assessing a familiar habitat but leaving the Bay in favor of a nearby food resource. The right whales observed along the eastern shore were feeding at or near the surface and socializing in small groups. The acoustic survey using data from autonomous bottom-mounted recorders, referred to as "pop-ups", provided a different picture of seasonality from the visual surveys suggesting that right whales occupied Cape Cod Bay, albeit in low numbers at times, from late November through April in 2003 (Appendix IV).

Year	Date 1st survey		Date last survey with right whales		# days of minimum residency		Date 2nd to last survey	
1998	04 Jan 1998	(9)*	21 April 1998	(1)*	108	[75]+	19 April 1998	(3)*
1999	13 Dec 1998	(5)	02 May 1999	(1)	140	[86]	01 May 1999	(3)
2000	20 Jan 2000	(1)	11 April 2000	(3)	82	[86]	07 April 2000	(36)
2001	19 Dec 2000	(5)	29 April 2001	(2)	132	[87]	29 April 2001	(16)
2002	06 Jan 2002	(0)	15 March 2002	(3)	55	[24]	07 March 2002	(2)
2003	10 Dec 2002	(0)	30 April 2003	(8)	115	[26]	28 April 2003	(10)

* Number in parentheses is the number of right whales photographed from the airplane that survey day.
See Table 2 and 3 for the first day whales were seen each year.
+ Number in square brackets is the minimum number of right whales for the season in CCB.
The number of days of minimum residency is based on visual surveys.

In 2000 and 2001, we witnessed a dramatic departure of right whales from Cape Cod Bay. For example in 2000, there were 36 whales seen on 7 April and three on 11 April. In 2001, 16 right whales were seen on 29 April, but only two on 1 May, both of which were outside the critical habitat. In 2003, the departure at the end of the season seemed less dramatic, in part because of the few right whales observed during the season and because of the apparent departure for about 46 days during the middle of the season. In past years, there appeared to be a herd-like behavior of departing right whales, which may be the result of collapse in the food resource in the Bay. The low densities of plankton collected during the mid-season departure coupled with the increase that accompanied their return in early April suggests right whales are responding to the quantity of the food resource.

Sightings Between Habitat Areas

There were a total of nine right whales seen both in the southeast US and Cape Cod Bay (see tables below). The mean number of days between sightings in the two areas was 60 (SE ± 23) for all records and 87 ±13 days for mothers with calves. The number of days between sightings ranged from

20 to 103. Of the nine whales, five were male and four were female. The males were only seen outside of Cape Cod Bay in the Great South Channel. Of the four females all were seen in Cape Cod Bay, and the two mother calf pairs were also seen in the Great South Channel.

Catalogue Number	Southeastern US (off the coast of Florida and Georgia)	Northern sighting	Days elapsed between sightings
1208 (calf not photo'd)	5 January	19 April CCB	103
2303	25 February	27 March GSC	60
2406	25 January	20 March GSC	53
1817 and calf	26 January	23 April CCB	86
2018	7 February	23 March GSC	43
2209	18 February	27 March GSC	60
1503 and calf	24 February	9 April CCB	71
2753	3 March	21 April CCB	48
3109	6 March	27 March GSC	20

In the last six years, a total of 58 right whales (not including calves) was identified in both the southeast US and Cape Cod Bay in the same year. One whale, #2123, was documented in more than one year (1998 and 2001). There were two instances of right whales making the reverse migration from CCB to the southeast in 2000 (Brown and Marx 2000). In the first four years, most of the whales left the southeast in January, arriving in Cape Cod Bay in February to early March (Brown and Marx 1998, 1999, 2000, Brown, Marx and Nichols 2001). In 2003, right whales were last seen off the southeastern US in early January to early March and arrived in northern waters in March and April. These sightings are important because they provide some information on the timing of the migration of right whales through the mid-Atlantic region, which will be used in part to determine the season for the implementation of management measures for various ports along the east coast that will hopefully reduce the affect of shipping on right whales.

The table below summarizes the maximum transit time over the last six years (calves are not included in the total because their movements are dictated by those of their mothers at this life stage).

Year	Number and sex ratio of transiting whales (male – M; female - F)	Range of days between sightings (days)	Mean number of days between sightings
1998	6 whales; 3 M, 2 F, 1 unknown	30 - 56	46 ± 9
1999	4 whales; 1 M, 3 F	33 - 65	55 ± 15
2000	9 whales; 5 M, 4 F	10 - 86	41 ± 22
2001	17 whales; 4 M, 12 F, 1 unknown	22 - 67	40 ± 9
2002	8 whales; 1 M, 6 F, 1 unknown	36 - 114	58 ± 28
2003	9 whales; 5 M, 4 F	20 - 103	60 ± 23

Photographs from our survey efforts in the Great South Channel and Canadian habitat areas have not yet been fully analyzed, thus it is not possible to document movements of right whales between Cape Cod Bay and nearby waters later in the 2003 season at this time. The sighting summaries by whale and area presented in Appendix I have now been updated through 2001 and provide for some inter-habitat comparisons of whales seen in Cape Cod Bay over the years.

There was one unphotographed sighting of three right whales that is noteworthy. Bill Hoffman, a DMF biologist who trained with the aerial survey team in past years, saw three right whales from a

boat on 29 April 2003. The position was about 2.5 to 3 miles offshore of the towns of Marblehead and Manchester (Massachusetts) at 42°29'N x 70°44'W and 42°32'N x 70°43'W. He reported that two of the whales were skim feeding and the third was subsurface feeding. This sighting occurred just before our last sighting of right whales in Cape Cod Bay and at a time of the year when survey efforts are generally focused in the Great South Channel.

Mother Calf Pairs

There were two mother calf pairs (#s 1503 and 1817) seen and photographed in Cape Cod Bay plus a third mother (#1208) whose calf was observed but not photographed. All three pairs were previously photographed on the southeast US calving ground earlier in the winter (see table at the top of the page for the timing between sightings). All three mothers have been seen in Cape Cod Bay in previous years. The presence of these three mother/calf pairs in Cape Cod Bay represents 16% of the known reproduction (n=19) of right whales in 2003. There were no sightings of mother yearling pairs in 2003.

Capture Rates and Residency

Right whales are often seen more then once during the Cape Cod Bay season with some whales being seen multiple times over the four and a half month-long season. In 2003, it was much more common to record the presence of a whale only once during the season. That can be due in part to the spacing of the surveys, but in 2003 it appeared that right whales were only spending short periods of time in the Bay, followed by forays outside the Bay to exploit a nearby food resources.

Of the 27 right whales identified or captured in Cape Cod Bay, just five of them (#s 1712, 1934, 1980, 2406 and 2271) were seen in Cape Cod Bay on more than one day. The other 22 (81%) were only seen once in the Bay; nine whales were also seen in other areas outside of Cape Cod Bay (Appendix II).

Days Photographed in CCB 2003	1	2	3	4
Number photographed in CCB (n = 27)	22	2	2	1

The greatest number of days on which a whale was captured was only four (# 1712, an adult male; Appendix II). This whale also had the longest of the Cape Cod Bay sighting histories in 2003, spanning just 20 days. This is a much shorter period of residency than seen in the first four years, but is similar to 2002 when the longest sighting history spanned only 18 days. By comparison, in 2001 the two whales with the longest sighting histories for the season were seen over 132 days and 76 days.

Demographics

The demographic profile of right whales in Cape Cod Bay in 2003 was similar to the previous years with the exception of 2002 (see table below). Of the 27 right whales identified in Cape Cod Bay, there was no significant difference between the numbers of males (14) and females (10) observed (1 of unknown sex and 2 calves) and no significant difference from the right whale catalogue (Brown *et al.* 1994 and NEAq unpublished data).

The age structure of the catalogue right whale population is made up of 75% adults and 25% juveniles (Hamilton *et al.* 1998). The age class of right whales identified in Cape Cod Bay was 80% adults (n = 21) and 20% juveniles or calves (n = 5). This age structure is not significantly different from the right whale catalogue (Hamilton *et al.* 1998) or from the age structure observed in Cape Cod Bay since 1998, 2002 excepted. The details of the demographic structure of the population seen in Cape

Cod Bay annually is presented below and broken down by age and sex in bi-weekly intervals, in presented in Table 4.

Year	Minimum # id'd	Adult : Juvenile	# Unknown age	Males : Females	# Unknown sex
1998	75	58 : 15	2	28 : 38	9
1999	86	55 : 23	8	37 : 35	14
2000	86	64 : 15	7	42 : 36	8
2001	87	57 : 13	17	40 : 30	10
2002 CCB	19	10 : 9	0	2 : 12	5
2002 Stellwagen	21	14 : 3	4	9 : 9	3
2003 CCB	27	21 : 3 (+2 calves)	1	14 : 10 (+2 calves)	1
2003 Outside CCB	54	36 : 10 (+1 calf)	7	35 : 11 (+1 calf)	7

Many more right whales were seen outside of Cape Cod Bay this year than in 2002, the result of the aggregation off of the eastern shore. The aggregation of right whales was dominated by adult males (table above) many of which had not been documented previously in CCS research efforts. Photographic and more recent genetic data have shown that the North Atlantic right whale population is divided into two subgroups on the feeding grounds in the spring, summer and autumn months with one group using the so-called *inshore* habitats, including the Bay of Fundy and Cape Cod Bay and the second group using *offshore* area such as the Great South Channel, Roseway Basin (Kenney *et al.* 1995, Stone *et al.* 1988) and a still unidentified summering ground (Malik *et al.* 1999, Schaeff *et al.* 1993). An examination of the sighting records in Appendix I of the adult males recorded east of the Cape show that many of these males would fit into the subgroup with the *offshore* profile.

Notification of Agencies

At the completion of each survey, the information on the number of right whales and their location that day was sent to the coordinator at the SAS office at NOAA Fisheries, Northeast Fisheries Science Center in Woods Hole. Sightings in Cape Cod Bay were reported to the USACE Cape Cod Canal Field Office at the end of each flight. USACE marine traffic controllers transmitted sighting locations to traffic exiting the Canal. In order to expedite the distribution of the information to the marine community, the number and location of right whales was relayed to SAS and USACE by cell phone at the completion of each survey. During surveys in Cape Cod Bay, the USACE Field Office was contacted directly by VHF radio at the time of a sighting in close proximity to traffic exiting or entering the Cape Cod Canal. A total of 54 faxes were sent to biologists at the DMF offices in Boston and Gloucester, one fax for each aerial and shipboard survey in Cape Cod Bay and adjacent waters. Sightings from R/V *Shearwater* were noted, but not plotted, on the faxes. The DMF/CCS surveys are the principal source of right whale sighting information in the region for the NOAA Fisheries/SAS program in the winter months through March.

Sightings of Other Species

There were six other species of cetaceans, two pinniped species and one species of shark sighted while performing these surveys (Tables 2 and 3, Figures 5 and 6). Fin whales, *Balaenoptera physalus*, were the most numerous of the large whales encountered in Cape Cod Bay other than right whales. Humpback whales, *Megaptera novaeangliae,* were the most numerous outside Cape Cod Bay after right whales. Pilot whales, *Globicephala melaena,* were the most commonly seen toothed whale in Cape Cod Bay, but white-sided dolphins, *Lagenorhynchus acutus*, were the most numerous offshore. The sighting database also contains coded entries for vessel traffic observed in the area.

Commercial and military vessel traffic were compiled for the season and plotted on a single chart to show their distribution relative to right whale sightings and the critical habitat area (Figure 7).

Human Impacts

Report on entangled right whales

During aerial and vessel surveys in 2003, two right whales were observed entangled on three days: 24 March, 14 April and 28 April. Both whales had been seen entangled before their sighting during our surveys in 2003. The following summarizes each event; a full report of the entanglement history for both whales is available by request on the CCS whale rescue website.

The first whale, #2320, also known as Piper, was observed off the eastern shore of Cape Cod on 24 March. Piper, an adult female of unknown age, is trailing line that is wrapped around her rostrum, trails along her body and behind her flukes a short distance. She was first observed entangled on 2 August 2002 in the Bay of Fundy. Attempts were made on 24 March to attach a telemetry buoy to the trailing line, but the whale was quite evasive to vessel approaches and the attempt was unsuccessful. Piper was seen again from the aircraft on 28 April, this time in Cape Cod Bay. Deteriorating weather forced the aircraft and the vessel teams to abandon the scene; that day is the last known sighting of this whale in 2003.

The second whale, #1424, an adult male first seen in the Bay of Fundy in 1981, was observed in Cape Cod Bay on 19 April 2003 with line through the mouth and trailing behind the body. The description of the gear on the whale: heavy, green/blue poly or poly blend rope trailing between 150 to 300 feet behind flukes. This line runs forward and enters the left side of the mouth, exits the right side of the mouth and forms a large, loose loop that drapes back approximately 4 feet behind the blowholes before reentering the right side of the mouth. This whale has been entangled since at least 12 February 2002 when it was seen on the southeast US calving ground. The whale was not entangled at the previous sighting in the Bay of Fundy on September 17, 2001 The whale was next seen on 29 March 2002 by the CCS/DMF aerial survey team about 1 mile off Peaked Hill on the eastern edge of Cape Cod near Truro. Since then, the whale was seen just north of Stellwagen Bank on 17 April 2002, on 6 May and 12 May 2002 in the Great South Channel, in the Gulf of Maine on 18 June 2002 and then again in Cape Cod Bay on 14 April 2003. The entanglement appears as severe as in the first sighting more than a year ago. During the last sighting in Cape Cod Bay, every attempt was made to attach a telemetry buoy to the whale, but it was not successful and the whale has not been seen since 14 April 2003.

Vessel interactions

There were no known collisions or close quarter movements reported or observed between vessels and right whales in Cape Cod Bay during the 2003 field season. There were also no reports of any right whales taking a short cut through the Cape Cod Canal this year.

Conservation Measures

In addition to the regular reporting of right whale sightings through the NOAA Fisheries/SAS program (http://www.nefsc.noaa.gov/cgi-bin/rwhale.pl) and to the Canal operator of the USACE, there were two conservation measures taken in response to sightings of right whales from the CCS/DMF right whale surveillance program.

The first measure was the result of a sighting on March 23, 2003, of 42 right whales in the proximity of 41°41' N and 69° 48' W east of Cape Cod, MA. In response to the CCS/DMF sighting of right whales in this area, NOAA Fisheries took action under the Dynamic Area Management (DAM) program to provide protection for this aggregation of North Atlantic right whales. NOAA Fisheries

announced that lobster trap/pot and anchored gillnet fishermen were requested to remove their gear on a voluntary basis, and were encouraged not to set additional gear, in an area totaling approximately 1,810 square nautical miles, east and southeast of Cape Cod, MA, effective beginning at 0001 hours April 10, 2003, through 2400 hours April 25, 2003. Because the Seasonal Area Management (SAM) West zone, Cape Cod Bay Critical Habitat, and Great South Channel Critical Habitat overlapped the DAM zone, those areas were excluded from the DAM zone. They also requested the voluntary removal of all anchored gillnet gear from the Sliver Area of the Great South Channel Critical Habitat from 0001 hours April 10, 2003, through 2400 hours April 25, 2003, and asked anchored gillnet fishermen to not to set any new gear in this area during that time period.

The second conservation measure was a press release of an advisory released by DMF on 25 April to advise mariners of a late season aggregation of right whales in the southern and western portions of Cape Cod Bay. The Cape Cod Bay fishing restrictions (described on page 8 of this report) set to expire on April 30 were extended for another nine days. In addition the advisory requested mariners to reduce speed to 15 knots or slower in poor visibility and to post a lookout and be on alert. The advisory also reminded mariners that approaching right whales within 500 yards is a violation of state and federal regulation.

Sightings from Whale Watch Vessels

In 2003, there were 185 sightings of right whales from whale watch vessels operating in Cape Cod Bay and adjacent waters, both during and after the CCS/DMF field season. The sightings were recorded from 13 April to 31 July by CCS naturalists on board Dolphin Fleet whale watch vessels (Appendix III). While most of the sightings occurred during the CCS/DMF field season, there were 69 sightings (37%) after the field season ended (after 15 May). Of the postseason sightings, only 1 sighting of a mother calf pair (off Race Point) fell within the boundaries of the Critical Habitat. The rest of the sightings were located in an area northeast of the Critical Habitat boundaries (see plot in Appendix III). All of the postseason sightings from the whale watch boats occurred in July. There was also a sighting on 27 August of a mother calf pair in Cape Cod Bay off Barnstable Harbor (Cape Cod Times, August 28, 2003).

There were sightings reported by naturalists on other whale watch vessels during the same time period; but they are not included here. It is highly likely that there were additional summer sightings after July that were not reported to the NOAA Fisheries/SAS coordinator. These sightings and the presence of sei whales (*Balaenoptera borealis*) in some of the areas frequented by right whales, coupled with the relative absence of humpback and other baleen whales on Stellwagen Bank (CCS unpublished data), mimics a prey-related distributional shift that occurred in the mid-1980s (Payne *et al*. 1990). During 1986, a group of right whales, including nine mother-calf pairs, was resident in Cape Cod waters from July through October (Hamilton and Mayo 1990). During the above studies, data on cetacean distribution and photo-identification were collected primarily from commercial whale watch vessels (Hamilton and Mayo 1990, Payne *et al*. 1990). Unfortunately, photographic documentation of the 2003 right whale sightings by the whale watching industry was for the most part lost because they are not permitted to approach a right whale within 500-yards, a rule that has been in place since 1997 (62 FR 6729).

Summary

The distribution of right whales in the northern feeding areas has for many years been thought to be, in large part, a direct result of the distribution of their prey (Gaskin 1982). The residency pattern of right whales in Cape Cod Bay in 2003, their documented movements to nearby waters and the observation of them feeding in adjacent waters add more data to this premise. Although Cape Cod Bay has a long

history of right whale use in the winter and spring dating back to the 1600s (Allen 1916, Reeves *et al.* 1999, Reeves *et al.* 2002), it is clear that right whales are responding to the inter- and intra-seasonal variations in the planktonic food resource. The longer we study right whales and their food resource, the more researchers realize that the annual variations in the number and demographic composition of right whales in the five known habitat areas is the norm rather than the exception. There are increasing examples of shifts in habitat use by right whales such as the 1992 absence of right whales from the Great South Channel attributed to a shift in the regional zooplankton community (Kenney 2001) and the 1993-1999 absence of right whales from the Roseway Basin Conservation Area in the summer and fall that corresponded with triple the number seen in the Bay of Fundy (NEAq unpublished data).

The challenge with an endangered species like the North Atlantic right whale is how to predict shifts in distribution so that conservation measures can be implemented in the right location and the right time of the year to have the maximum affect on reducing human related mortality on right whales. The comprehensive CCS/DMF program over the last six years and the recent collaboration with Cornell University researchers has clearly demonstrated that the combined efforts of aerial survey, habitat sampling and acoustic monitoring is a prime example of how the amalgamation of aerial and acoustic surveys with data on the richness of the food resource can result in realistic models to predict whale presence and absence in Cape Cod Bay. Cape Cod Bay has provided us with a living laboratory in which to test our hypotheses; now the challenge is to apply the same suite of research methods to develop predictive models that can be applied on a large spatial scale outside of Cape Cod Bay.

The flexibility of the CCS/DMF program has permitted researchers to respond to variations in right whale distribution. For example, aerial surveys of areas adjacent to Cape Cod Bay have become an increasingly important aspect of the program in terms of number of right whales sighted and the identification of nearby areas of seasonal residency and importance to right whales. More right whales were identified outside of Cape Cod Bay than within the boundaries of the Critical Habitat for the last two years. The next step is to take what we have learned in Cape Cod Bay from the combination of aerial survey, habitat sampling and acoustic monitoring and expand those techniques in space and time to nearby areas to test the applicability, on a large scale, of the hypotheses and predictive models developed for Cape Cod Bay.

In terms of conservation measures to foster the recovery of this species, the presence of right whales in nearby areas outside of both Cape Cod Bay and the Great South Channel Critical Habitats in 2003 and past years suggest that a reevaluation of the area protected by ESA Critical Habitat designation is needed and timely to adequately reflect the distribution and movements of right whales. The original designations were based on about a decade of data and although they reflected the known distribution of right whales at that time, work over the last decade has refined our understanding of right whale distribution in the southern Gulf of Maine. The location of some of the right whale sightings in 2003 and previous years were in areas between the two critical habitats; and from sightings of the same animals in both Cape Cod Bay and the Great South Channel, often within days of each other, it is clear that there is regular movement between the two regions.

The use of these adjacent areas such as the eastern portion of Stellwagen Bank and Wildcat Knoll and the waters east of Cape Cod near Chatham has come to light with the expanded survey efforts of the last six years of the CCS/DMF surveillance program and work by our colleagues at NOAA Fisheries. Since this area is used for fishing activity and is transected by a major shipping lane between Boston and New York, consideration should be given to reevaluating the boundaries of the neighboring Cape Cod Bay and Great South Channel Critical Habitats. With the aggregation observed

in 2003, the areas between the two critical habitats are not just transit areas; from the behavior of the animals observed, it is apparent that at times the food resource is sufficient to result in an aggregation of whales for several days and weeks. We recommend that the data collected in the waters adjacent to the two critical habitats be evaluated to determine if the concentration and seasonality of right whale use warrants an amendment to the existing boundaries. Based on the success in Cape Cod Bay of combining visual surveys with acoustic monitoring and habitat sampling to develop predictive models on the presence and absence of right whales, these adjacent waters could also be targeted for habitat sampling and additional acoustic monitoring to further inform the assessment of the critical habitat boundaries.

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Table 1a. Aerial survey tracklines flown over Cape Cod Bay, December 2002 - mid May, 2003. (Tracklines end approximately 1.5 nm from land). For location of tracklines, cross reference by trackline number with Figure 1a.

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

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

Additional tracklines flown 1 March and 4 May, 2003.

Trackline Number	Latitude	Longitude West End	Longitude East End	Trackline Length (nm)
17	42 09.5	70 20	70 00	15
18	42 08.0	70 20	70 00	15
			Total	30

Additional north - south tracklines flown March 15, 2003.

Trackline Number	Longitude	Latitude North End	Latitude South End	Trackline Length (nm)
19	69 47	42 05	41 40	25
20	69 44	42 05	41 40	25
			Total	50

Table 1b. Aerial survey tracklines flown over Stellwagen Bank/Basin and Wildcat Knoll, 27 February and 5 May, 2003. Cross reference this table with the chart shown in Figure 1b.

Trackline Number	Latitude	Longitude West End	Longitude East End	Trackline Length (nm)
1	42 38	70 30	69 53	28
2	42 35	70 30	69 57	25
3	42 32	70 30	69 57	25
4	42 29	70 30	69 57	25
5	42 26	70 30	69 57	25
6	42 23	70 30	69 57	25
7	42 20	70 30	69 57	25
8	42 17	70 30	69 57	25
9	42 14	70 30	69 57	25
10	42 11	70 30	69 57	25
11	42 08	70 30	69 57	25
12	42 05	70 30	69 57	25
			Total	303

Table 1c. Aerial survey tracklines flown off the eastern shore of Cape Cod, 20 and 23 March*, 2003. Cross reference this table with the chart shown in Figure 1c.

Trackline Number	Latitude	Longitude West End	Longitude East End	Trackline Length (nm)
1	41 58	69 55	69 45	8
2	41 55	69 54	69 45	7
3	41 52	69 54	69 45	7
4	41 49	69 53	69 45	6
5	41 46	69 53	69 45	6
6	41 43	69 53	69 45	6
7	41 40	69 53	69 45	6
			Total	46

* Track line 1 was flown on 23 March only.

Table 1d. Aerial survey tracklines flown off the eastern shore of Cape Cod, 27 March, 2003. Cross reference this table with the chart shown in Figure 1d (southern lines).

Trackline Number	Latitude	Longitude West End	Longitude East End	Trackline Length (nm)
1	41 43	69 53	69 25	21
2	41 40	69 53	69 25	21
3	41 37	69 53	69 25	21
4	41 34	69 58	69 25	25
				88

Table 1e. Aerial survey tracklines flown off the eastern shore of Cape Cod, 28 March, 2003.
Cross reference this table with the chart shown in Figure 1d (northern lines).

Trackline Number	Latitude	Longitude West End	Longitude East End	Trackline Length (nm)
1	42 01	70 00	69 45	11
2	41 58	69 57	69 45	9
3	41 55	69 57	69 45	9
			Total	29

Table 1f. Aerial survey tracklines flown off the eastern shore of Cape Cod, 13 April, 2003.
Cross reference this table with the chart shown in Figure 1e (southern lines - dark shading).

Trackline Number	Latitude	Longitude West End	Longitude East End	Trackline Length (nm)
1	41 49	69 54	69 35	14
2	41 46	69 54	69 35	14
3	41 43	69 54	69 35	14
4	41 40	69 54	69 35	14
5	41 37	69 54	69 25	22
6	41 34	69 54	69 25	22
7	41 31	69 54	69 15	29
8	41 22	69 58	69 15	32
			Total	161

Table 1g. Aerial survey tracklines flown off the eastern shore of Cape Cod, 21 April, 2003.
Cross reference this table with the chart shown in Figure 1e (northern lines - light shading).

Trackline Number	Latitude	Longitude West End	Longitude East End	Trackline Length (nm)
1	42 07	70 11	69 45	20
2	42 04	70 02	69 45	13
3	42 01	70 01	69 45	12
4	41 58	69 57	69 45	9
5	41 55	69 57	69 35	17
6	41 52	69 55	69 35	15
			Total	86

Table 1h. Aerial survey tracklines flown over a portion of the Great South Channel, 15 May, 2003. Cross reference with chart shown in Figure 1f.

Trackline Number	WSW Latitude	WSW Longitude	ESE Latitude	ESE Longitude	Trackline Length (nm)
3	41 50.7	69 56.7	42 21.2	68 46.8	61
7	41 46.9	69 55.9	42 17.8	68 44.0	63
11	41 42.6	69 55.6	42 14.5	68 41.6	64
15	41 38.8	69 53.4	42 11.2	68 38.9	65
19	41 35.4	69 50.8	42 07.7	68 36.3	65
23	41 32.1	69 48.2	42 04.4	68 33.7	65
				Total	383

Note: These tracklines were orignally designed for the SCOPEX surveys. (Kenney et al. 1995). CCS/DMF flew this survey in collaboration with two aircraft teams from the NEFSC, Woods Hole, MA.

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

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

Table 2. Number of marine mammals and other animals seen, hours and trackline miles surveyed during aerial surveillance of Cape Cod Bay and adjacent waters, December 2002 - May 2003.

Survey#	Date	Eg Sighted	Eg Photo'd	Ba	Bp	Mn	UNLW	Gm	La	Pp	UNDO	UNSE	Cm	Hours Airborne	Trackline Miles	Tracks Completed
CCS288	10-Dec-02	0	0	0	0	1	1	0	0	0	52	0	0	3.9	320	1-16
CCS289	13-Dec-02	0	0	0	1	5	0	100	0	0	245	1	0	3.3	309	1-14,16
CCS290	06-Jan-03	0	0	0	0	0	0	0	0	0	0	0	0	3.1	320	1-16
CCS291	19-Jan-03	0	0	0	0	0	0	0	0	0	0	0	0	3.7	320	1-16
CCS292	25-Jan-03	5	5	0	0	0	0	0	0	0	0	0	0	4.1	310	1-16*
CCS293	26-Jan-03	1	1	0	0	0	0	0	0	0	0	0	0	3.9	310	1-16*
CCS294	06-Feb-03	1	1	0	0	0	1	0	0	0	20	0	0	2.6	261	1-15**
CCS295	10-Feb-03	0	0	0	0	0	0	0	0	0	0	0	0	3.2	309	1-14,16
CCS296	20-Feb-03	0	0	0	0	0	1	0	0	0	29	16	0	3.7	314	1-16*
CCS297	21-Feb-03	0	0	0	0	0	0	0	0	0	0	2	0	3.3	314	1-16*
CCS299	01-Mar-03	0	0	0	0	0	0	0	0	0	0	0	0	3.7	350	1-16+
CCS300	04-Mar-03	0	0	0	0	0	0	0	0	0	0	0	0	3.4	320	1-16
CCS301	08-Mar-03	0	0	0	0	0	0	0	0	0	0	12	0	3.3	320	1-16
CCS302	15-Mar-03	0	0	0	0	0	0	0	0	0	0	0	0	3.0	345	1-16++
CCS304	23-Mar-03	0	0	0	1	0	0	0	0	0	0	0	0	3.1	294	1-15
CCS307	28-Mar-03	0	0	0	0	0	1	0	0	0	20	1	0	3.0	294	1-15
CCS308	07-Apr-03	9	9	0	0	0	0	0	0	0	0	0	0	3.9	283	1-14
CCS310	14-Apr-03	2	2	0	0	0	0	0	0	0	58	0	0	7.0	186	7-15+++
CCS311	21-Apr-03	14	12	0	0	0	0	0	0	0	35	0	0	4.7	283	1-14
CCS312	25-Apr-03	14	8	0	0	0	1	0	0	0	9	1	0	4.3	153	9-15++++
CCS313	28-Apr-03	10	10	0	6	1	0	0	0	7	61	5	0	4.9	114	10-15+++
CCS314	30-Apr-03	8	8	3	2	4	0	0	0	0	35	0	0	5.7	320	1-16
CCS315	04-May-03	0	0	2	3	5	0	0	0	0	121	0	0	4.1	313	1-14,16+
CCS317	09-May-03	0	0	0	7	1	0	0	0	0	70	0	0	3.1	283	1-14
CCS318	14-May-03	0	0	0	3	0	1	0	0	0	0	0	0	2.6	260	1-13**
Total Cape Cod Bay		64	56	5	23	17	6	100	0	7	755	38	0	94.6	7205	
Adjacent waters																
CCS298	27-Feb-03	2	1	0	2	0	0	0	0	0	7	0	0	4.3	373	SB/WK
CCS302	15-Mar-03	0	0	0	0	0	0	0	0	0	0	0	0	1.0	50	ES
CCS303	20-Mar-03	31	30	0	0	0	0	0	0	0	0	0	0	1.7	60	ES
CCS304	23-Mar-03	42	36	1	0	1	0	0	0	0	6	0	0	3.6	73	ES
CCS305	24-Mar-03	8	8	2	0	0	0	0	0	0	0	0	0	0.5	5	ES++++
CCS306	27-Mar-03	57	49	2	3	8	0	0	0	0	67	0	0	5.1	93	ES/GSC
CCS307	28-Mar-03	10	6	0	0	6	1	0	0	0	0	0	0	2.7	33	ES
CCS309	13-Apr-03	7	7	3	4	12	3	0	0	0	13	2	0	4.0	181	ES/GSC
CCS311	21-Apr-03	1	1	1	2	1	1	0	0	0	15	0	0	1.8	86	ES
CCS316	5-May-03	2	2	2	8	3	1	0	0	0	161	0	0	4.7	339	SB/WK
CCS319	15-May-03	9	9	14	11	64	2	0	229	4	55	7	5	5.4	420	GSC
Total adjacent waters		169	149	25	30	95	8	0	229	4	318	9	5	34.8	1713	
Total all surveys		233	205	30	53	112	14	100	229	11	1053	47	5	129.4	8918	

* Tracks in southeast portion of Bay cut short due to sea ice coverage.

** Cut short western portion of survey due to weather conditions.

+ Two additional tracks added to the northeast between Race Point and Peaked Hill.

++ Additional line added north of track 1.

+++ Survey effort ended after sighting of entangled right whale.

++++ Survey ended early due to unsuitable weather conditions. Note: The 2 Egs on 5 May were off the Highland (Truro) and were reported by whale watch boats.

SB= Stellwagen Bank; WK= Wildcat Knoll; ES= Eastern Shore of Cape Cod; GSC= Great South Channel.

Table 3a. Number of opportunistic marine mammal sightings and hours collected at sea during habitat sampling cruises of Cape Cod Bay, January-mid-May 2003.
A total of 24 vessel trips are listed; 21 were for habitat sampling, one was to support research by colleagues, one was for Bay monitoring, and one was for an entangled whale.

Cruise	Date	Eg sighted	Eg photo'd	Ba	Bp	Mn	UnBa	UnLw	La	Pp	UnDo	Hg	Pv	UnSe	Hours at Sea
SW306	9-Jan-03	0	0	0	0	0	0	0	0	0	0	0	0	0	2.5
SW307*	18-Jan-04	1	0	0	0	0	0	0	0	0	0	0	0	0	n/a*
SW308	19-Jan-03	0	0	0	0	0	0	0	0	0	0	0	1	0	6.0
SW309	25-Jan-03	0	0	0	0	0	0	0	0	0	0	0	0	0	5.0
SW310**	29-Jan-03	0	0	0	0	0	0	0	0	0	3	0	4	2	8.3
SW311	07-Feb-03	0	0	0	0	0	0	0	0	0	0	0	0	1	5.5
SW312	10-Feb-03	0	0	0	0	0	0	0	0	0	0	0	0	2	6.5
SW314	20-Feb-03	0	0	0	0	0	0	0	0	1	0	0	1	5	7.0
SW315	21-Feb-03	0	0	0	0	0	0	0	0	0	0	0	0	0	6.5
SW316	27-Feb-03	0	0	0	0	0	0	0	0	1	0	0	2	1	6.8
SW318	07-Mar-03	0	0	0	0	0	0	2	0	0	0	1	0	3	6.0
SW319	13-Mar-03	0	0	0	0	0	0	0	0	0	0	0	0	0	6.0
SW320	17-Mar-03	0	0	0	0	0	0	0	0	0	1	0	0	5	7.3
SW321	23-Mar-03	0	0	0	0	0	0	0	0	0	0	0	0	0	6.0
SW323	02-Apr-03	0	0	0	0	1	0	2	0	0	0	0	1	0	4.5
SW325	09-Apr-03	1	1	0	1	0	0	0	0	0	0	0	0	1	4.0
SW327***	14 April 03	2	2	0	0	0	0	0	0	0	0	0	0	0	n/a***
SW328	19-Apr-03	3	1	0	0	2	0	0	0	0	0	0	0	0	7.5
SW330	23-Apr-03	2	2	1	0	0	0	0	0	3	0	0	0	2	7.5
SW332****	28 April 02	(1)	(1)	0	0	0	0	0	0	0	0	0	0	0	n/a****
SW333	30-Apr-03	1	1	1	0	1	0	0	0	2	0	0	0	1	6.0
SW334	4-May-03	0	0	0	1	0	0	0	10	2	0	0	0	1	6.5
SW336	10-May-03	0	0	0	0	0	0	0	50	0	0	0	0	0	6.5
SW338	14-May-03	0	0	1	1	0	1	0	0	2	0	0	0	0	4.0
Total Cape Cod Bay		9	7	3	3	4	1	4	60	11	4	1	9	24	125.9

* SW307 was a cruise to support research by colleagues and thus not included in this project, one right whale was seen off of Long Point but no photos were obtained.

**SW310 was both a habitat cruise and a systematic survey with the aerial survey team on board while the aircraft was grounded.

*** SW327 was a rescue cruise, only the photographs of two of the right whales are included in this project report. The third right whale was entangled.

**** SW332 was a Bay monitoring cruise that was aborted when the aircraft sighted an entangled whale, the one photographed whale was the entangled one, reported by the aircraft.

Table 3b. Number of marine mammal sightings collected at sea during shipboard surveys of Cape Cod Bay and adjacent waters, January - April 2003

Cruise	Date	Eg Sighted	Eg Photo'd	Ba	Bp	Mn	UNLW	La	Pp	UnDo	Pv	UNSE	Hours Surveyed	Miles Surveyed	Area Surveyed
SW322+	24-Mar-03	(1)	(1)	0	6	3	2	60	10	0	0	5	8.8	95	ES
SW326	10-Apr-03	12	12	0	0	0	0	0	0	0	0	1	3.5	13.5	CCB
Total		12	12	0	6	3	2	60	10	3	4	8	12.3	108.5	

CCB= Cape Cod Bay; ES= Eastern Shore of Cape Cod

+ SW322 was a habitat sampling cruise/shipboard survey that became a rescue cruise when the first right whale encountered was entangled.

Table 4. Number of surveys, demographic composition and number of right whales identified in Cape Cod Bay (A) and outside CCB (B) from aerial and shipboard surveys in two-week intervals from January through mid-May 2003. This table represents the minimum number of whales since photo-analysis is not yet complete.

(A) In CCB * There were two additional surveys in December not included on this table as no right whales were seen.

Two week intervals	1-14 Jan	15-28 Jan	29 Jan- 11 Feb	12-25 Feb	26 Feb- 11 Mar	12-25 Mar	26 Mar-8 Apr	9-22 Apr	23 Apr-6 May	7-15 May*	Total
Aerial surveys	1	3	2	2	3	2	2	2	4	2	23
R/V *Shearwater*	1	2	3	2	2	3	1	4	3	2	23
Demographics											
Males		1	1				1	10	3		
Females							2	3	5		
Unknown sex							1	1			
Adults			1				3	11	8		
Juveniles		1						2			
Unknown age								1			
Mother/Calves							1		1		
New Sightings	0	1	1	0	0	0	4	10	3	0	
Resightings	n/a	n/a	0	0	n/a	n/a	0	4	5	0	
Total right whales id'd in Cape Cod Bay	0	1	1	0	0	0	4 + calf	14	8	0	

(B) Outside CCB

Two week intervals	1-14 Jan	15-28 Jan	29 Jan- 11 Feb	12-25 Feb	26 Feb- 11 Mar	12-25 Mar	26 Mar-8 Apr	9-22 Apr	23 Apr-6 May	7-15 May*	Total
Aerial surveys	0	0	0	0	1	4	2	2	1	1	11
R/V *Shearwater*						1					1
Demographics											
Males					1	25	18	1		1	
Females						6	4	3	1	1	
Unknown sex						2	5	1		1	
Adult					1	23	16	2	1	2	
Juveniles						7	8	1		1	
Unknown age						3	3	2			
Mother/Calves									1	1	
New Sightings	0	0	0	0	0	33	27	3	0	2	
Resightings	n/a	n/a	n/a	n/a	n/a	1 (CCB)	12	2	1	1	
Total right whales id'd outside Cape Cod Bay					1	33	27	5	1 + calf	4 + calf	

n/a: not applicable

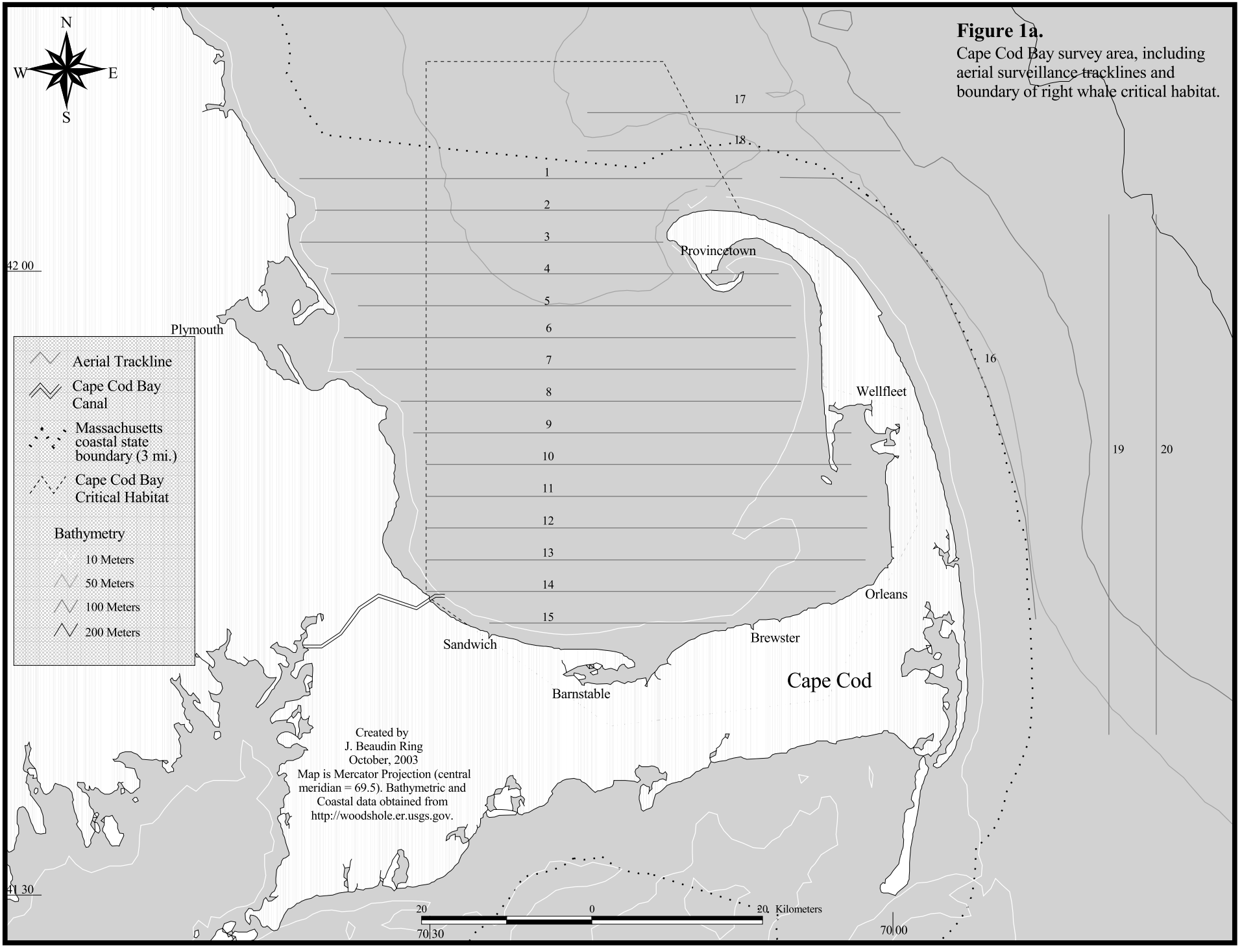


Figure 1a.
Cape Cod Bay survey area, including aerial surveillance tracklines and boundary of right whale critical habitat.

Figure 1b - f.

Additional survey tracklines flown in waters adjacent to Cape Cod Bay

Cape Cod Canal

Massachusetts State Waters Boundary (3 nm.)

Cape Cod Bay Critical Habitat

Great South Channel Critical Habitat

Stellwagen Bank National Marine Sanctuary

Shipping Lanes

Bathymetry

10 Meters

50 Meters

100 Meters

200 Meters

N W E S

Created by
J. Beaudin Ring
October, 2003
Map is Mercator projection
(central meridian = 69.5).
Coastal coverages and bathy-
metric data obtained from
http://woodshole.er.usgs.gov.

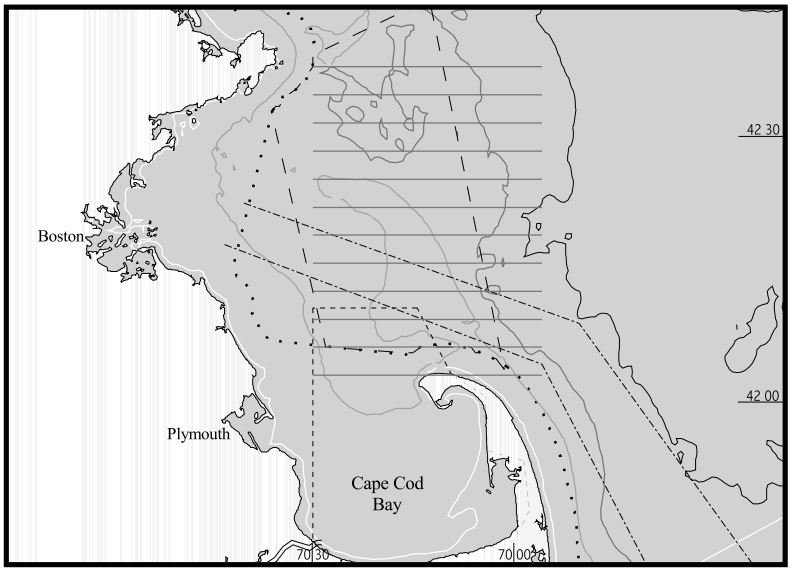


Figure 1b. 27 February and 5 May, 2003.

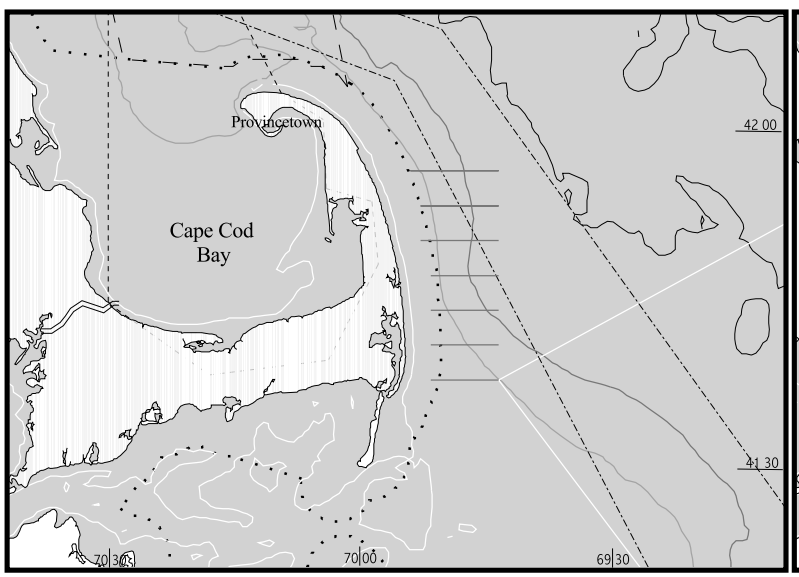


Figure 1c. 2 and 23 March, 2003.

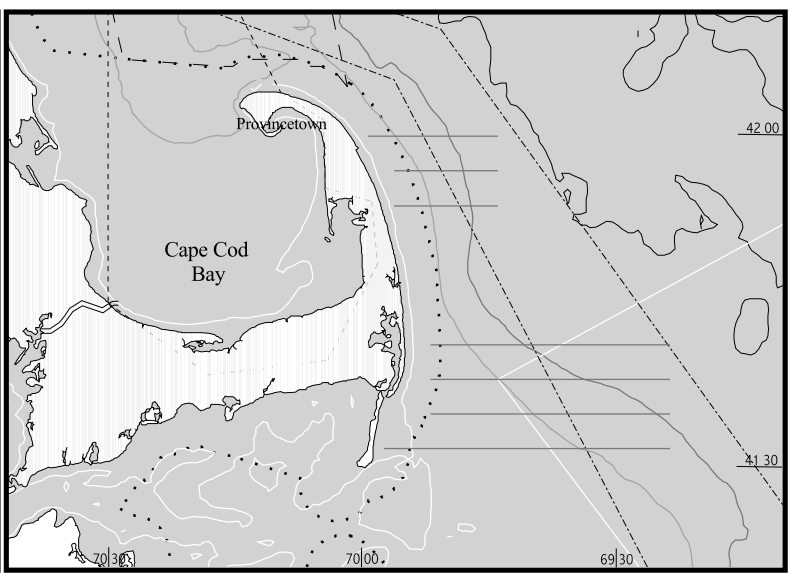


Figure 1d. 27 and 28 March, 2003.

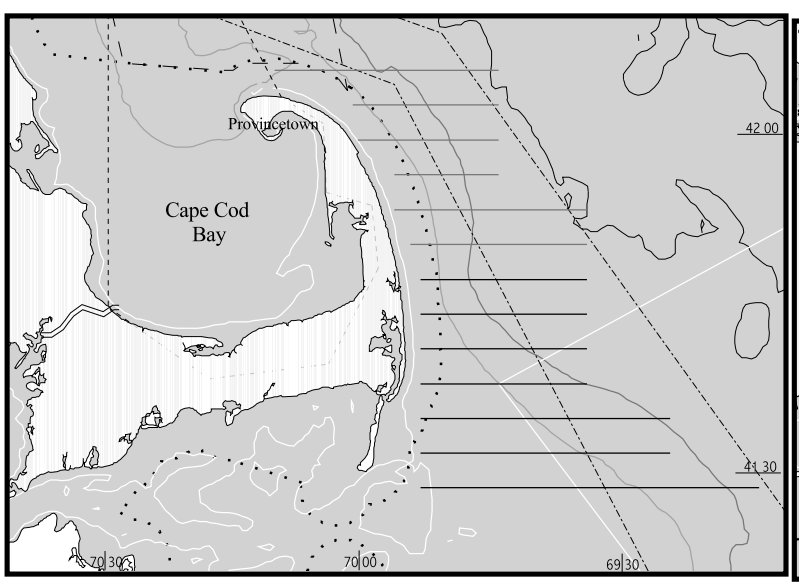


Figure 1e.13 and 21 April, 2003.

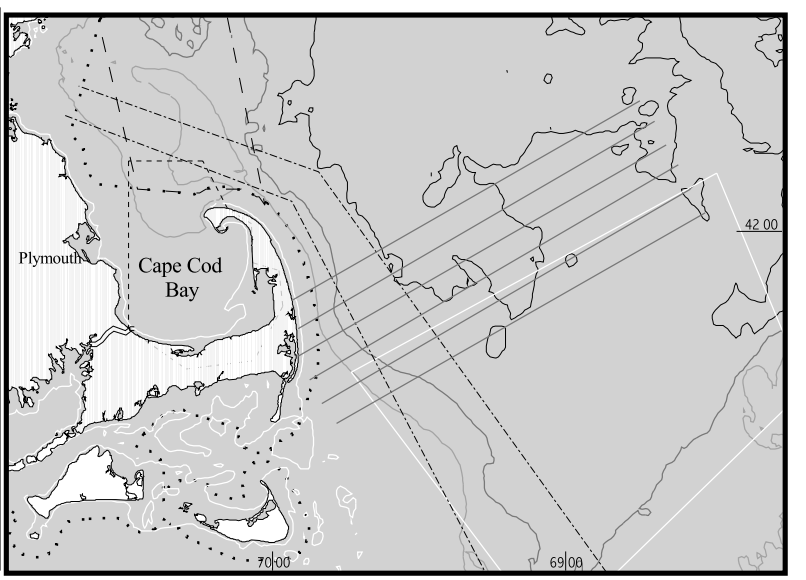
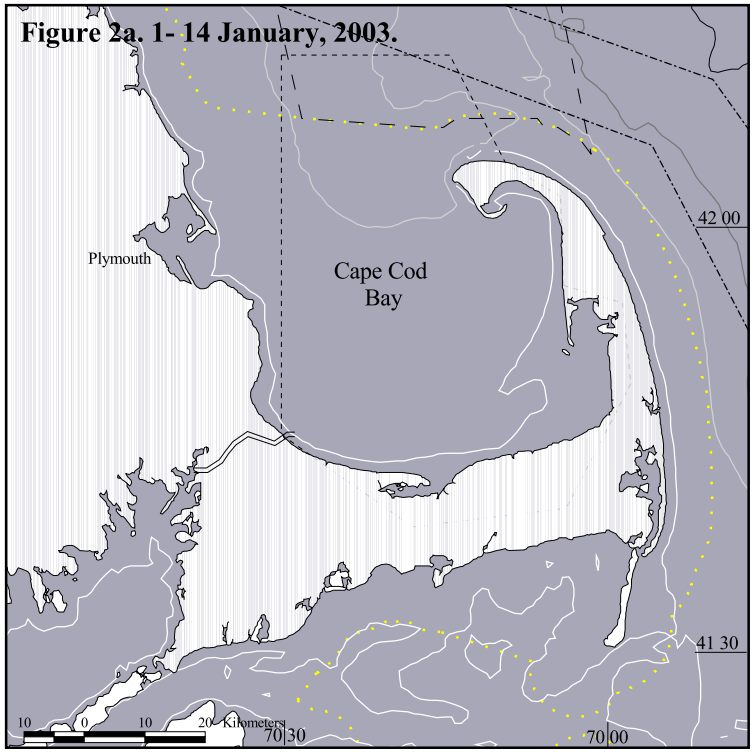
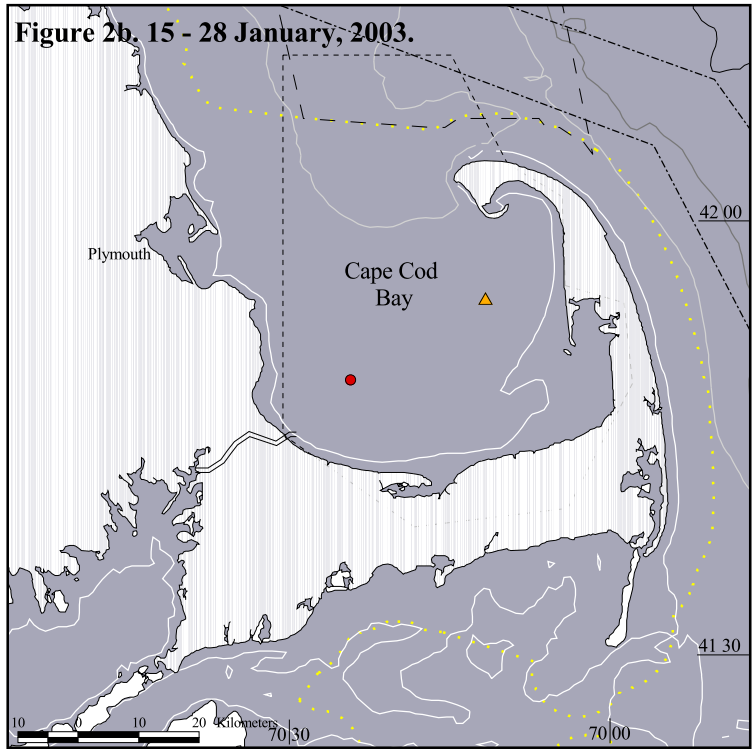
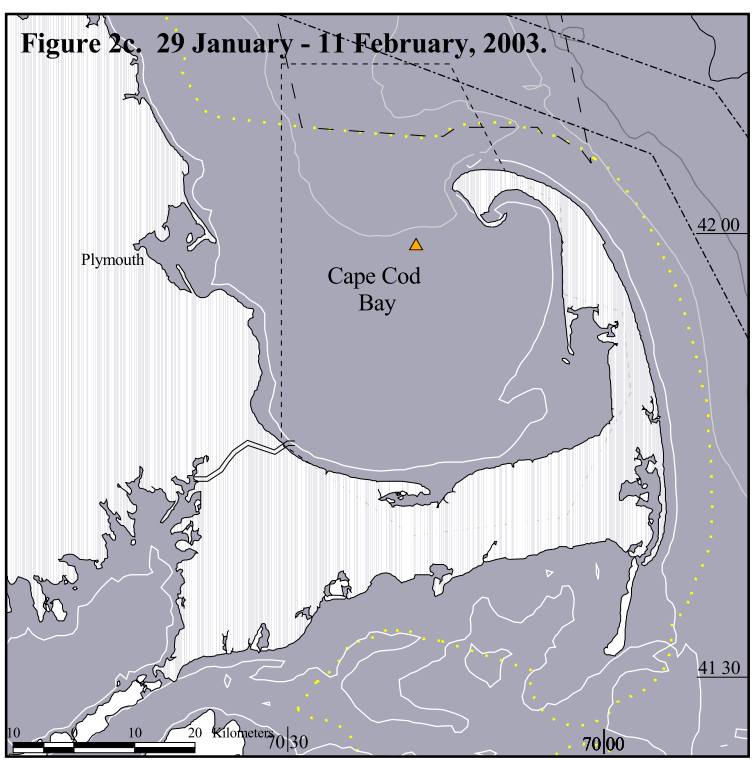


Figure 1f. 15 May, 2003.







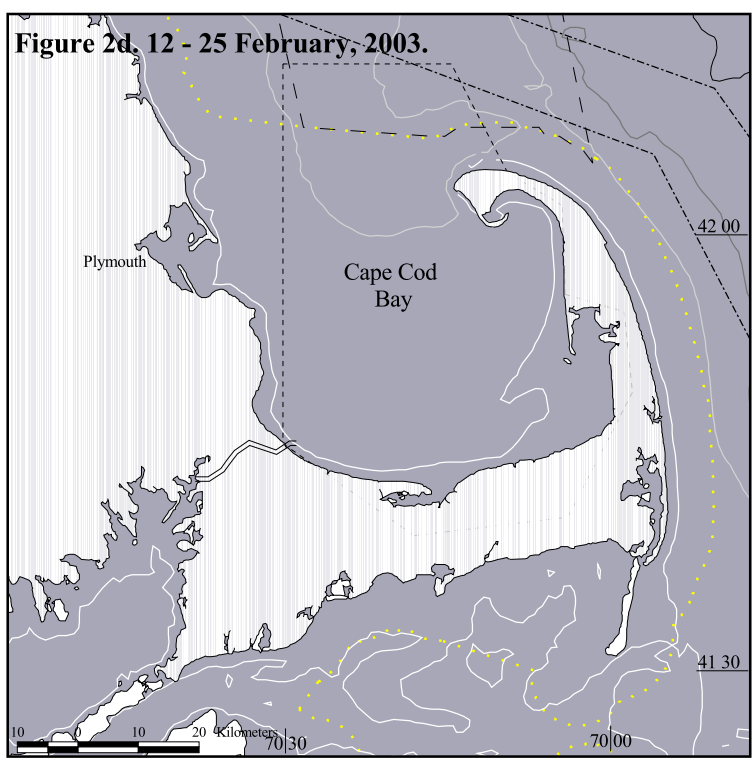


Figure 2.

Sightings of right whales from 10 aerial surveys in Cape Cod Bay, 10 December, 2002 - 25 February, 2003.

There were 2 aeral flights in December, 2002 with no right whale sightings.

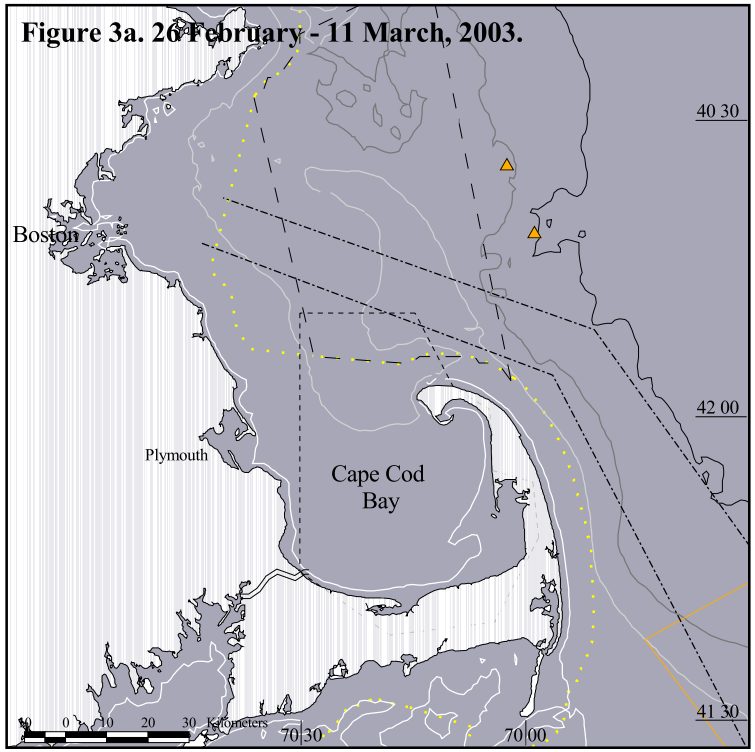
Number of Animals Sighted
- 1 animal
- 2 - 5 animals
- 6 - 10 animals
- 11 - 15 animals

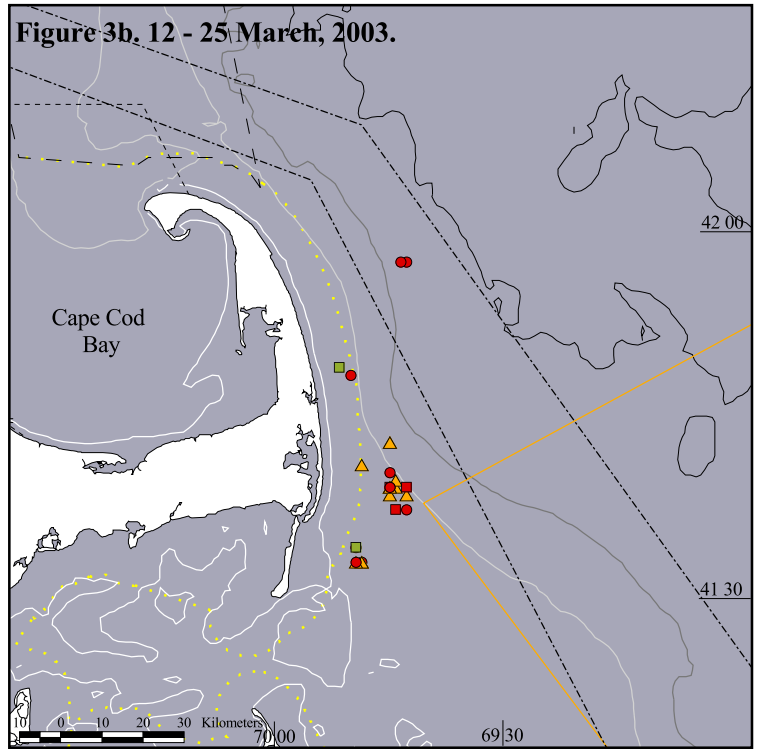
Bathymetry
- 10 Meters
- 50 Meters
- 100 Meters
- 200 Meters

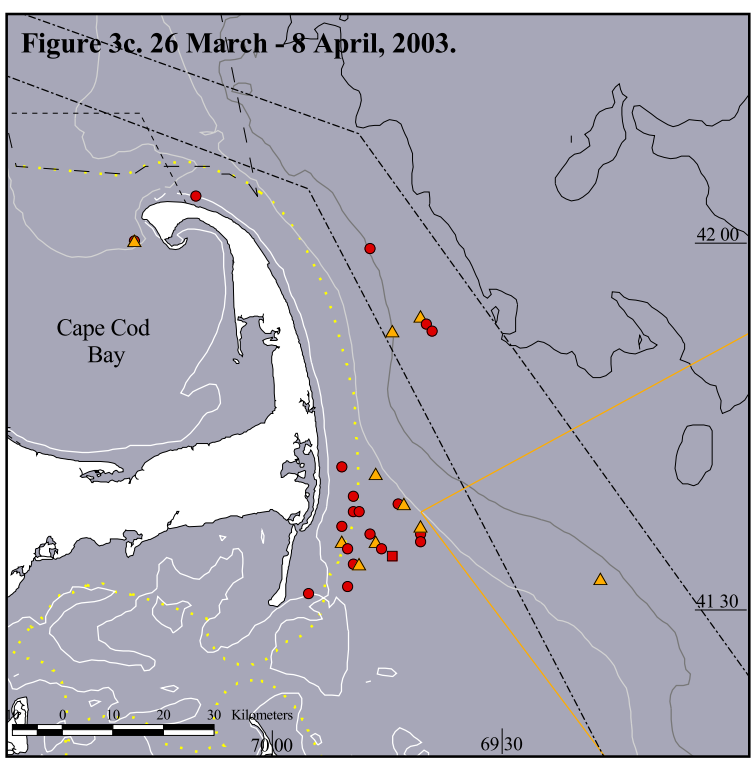
- Cape Cod Canal
- Massachusetts State Waters Boundary (3 nm.)
- Cape Cod Bay Critical Habitat
- Stellwagen Bank National Marine Sanctuary
- Shipping Lanes

Created by
J. Beaudin Ring
October, 2003
Map is Mercator Projection (central meridian = 69.5). Bathymetric and Coastal data obtained from http://woodshole.er.usgs.gov.

N
W E
S







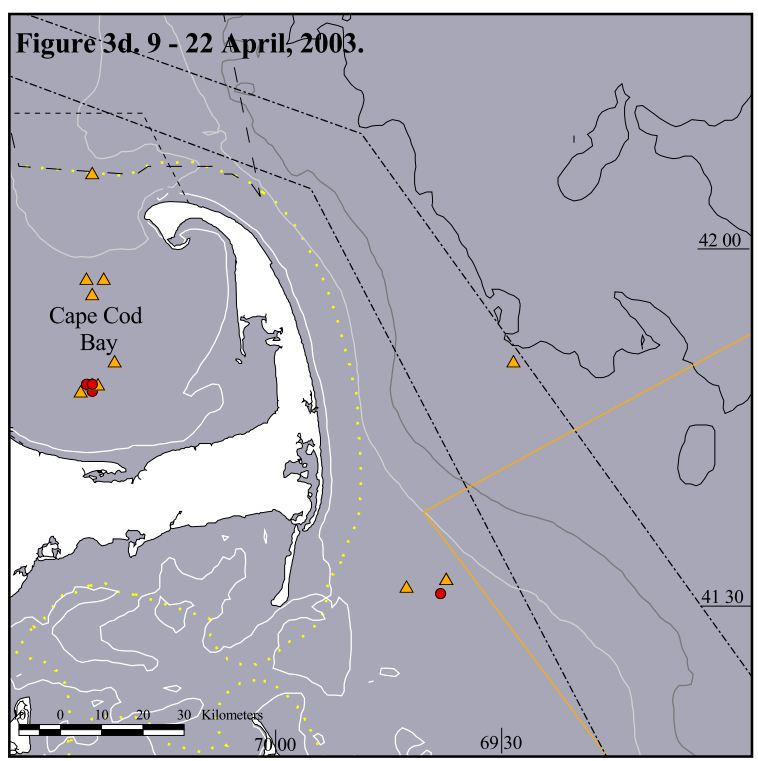


Figure 3.

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

There were no right whale sightings from 12 February - 26 March.

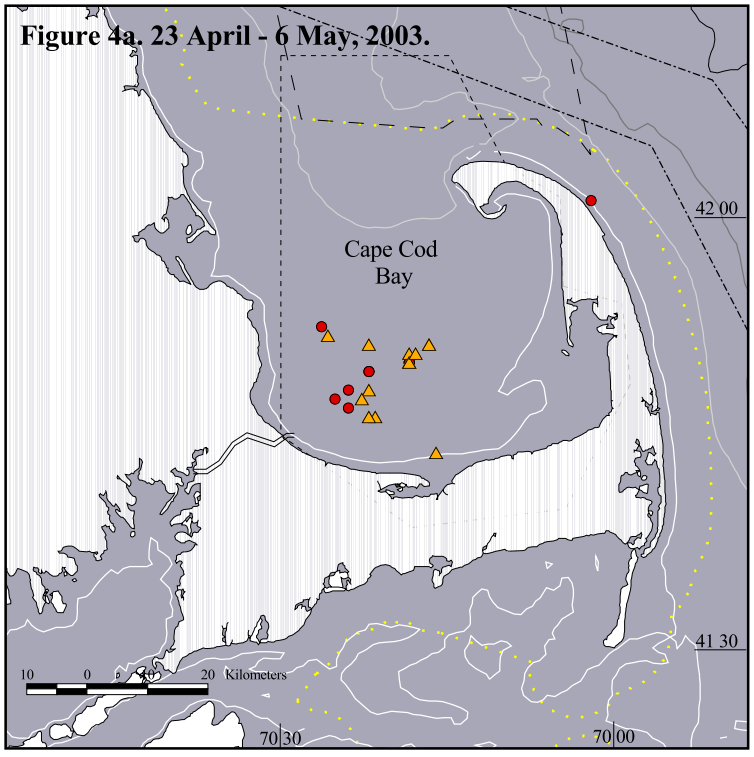
Number of Animals Sighted
- 1 animal
- 2 - 5 animals
- 6 - 10 animals
- 11 - 15 animals

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

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

Created by
J. Beaudin Ring
October, 2003
Map is Mercator Projection (central meridian = 69.5). Bathymetric and Coastal data obtained from http://woodshole.er.usgs.gov.

N
W E
S



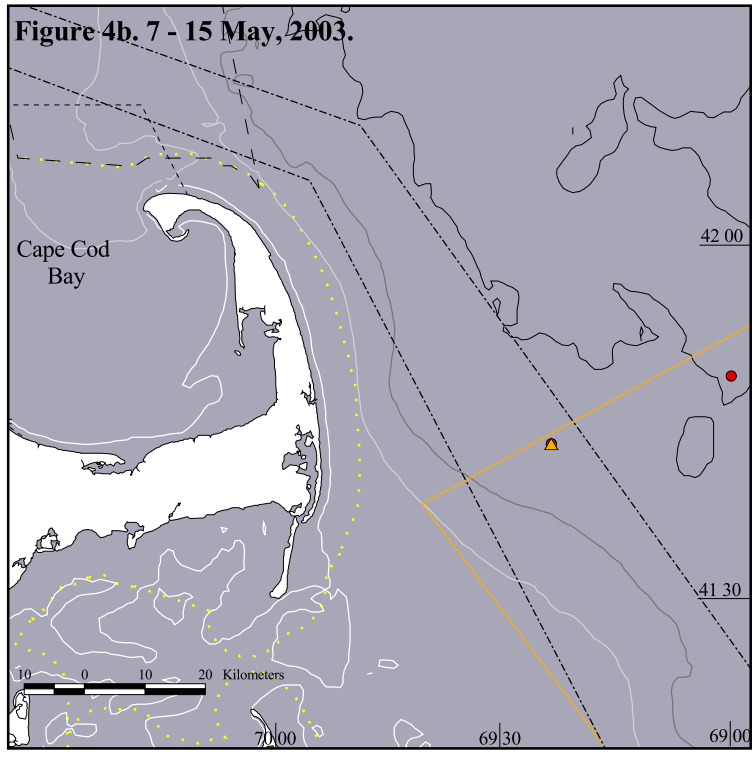


Figure 4.

Sightings of right whales from 8 aerial surveys in Cape Cod Bay and adjacent waters 23 April - 15 May, 2003.

Number of Animals Sighted
- 1 animal
- 2 - 5 animals
- 6 - 10 animals
- 11 - 15 animals

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

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

Created by
J. Beaudin Ring
October, 2003
Map is Mercator Projection (central meridian = 69.5). Bathymetric and Coastal data obtained from http://woodshole.er.usgs.gov.

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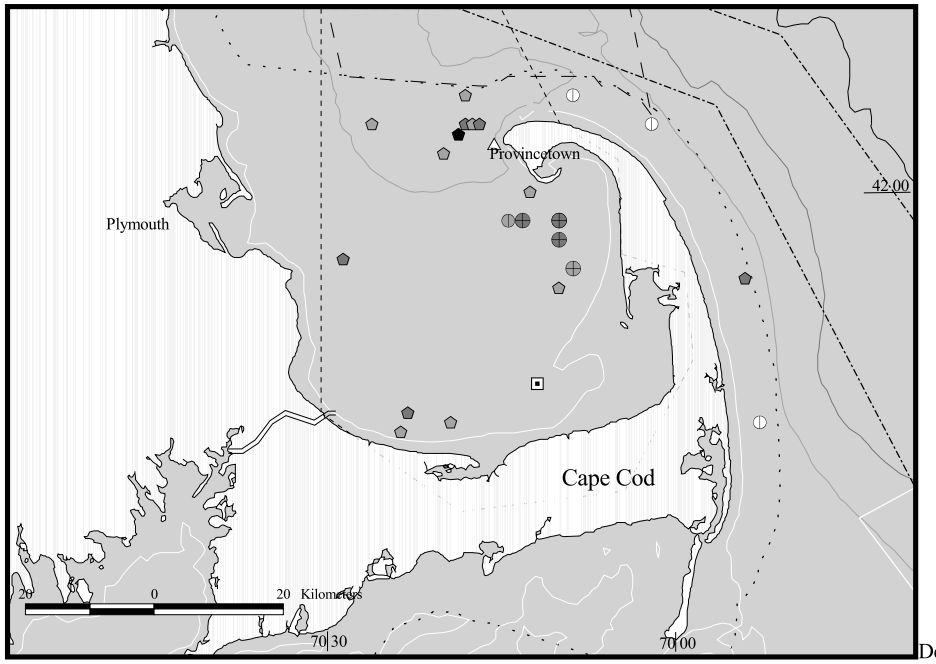
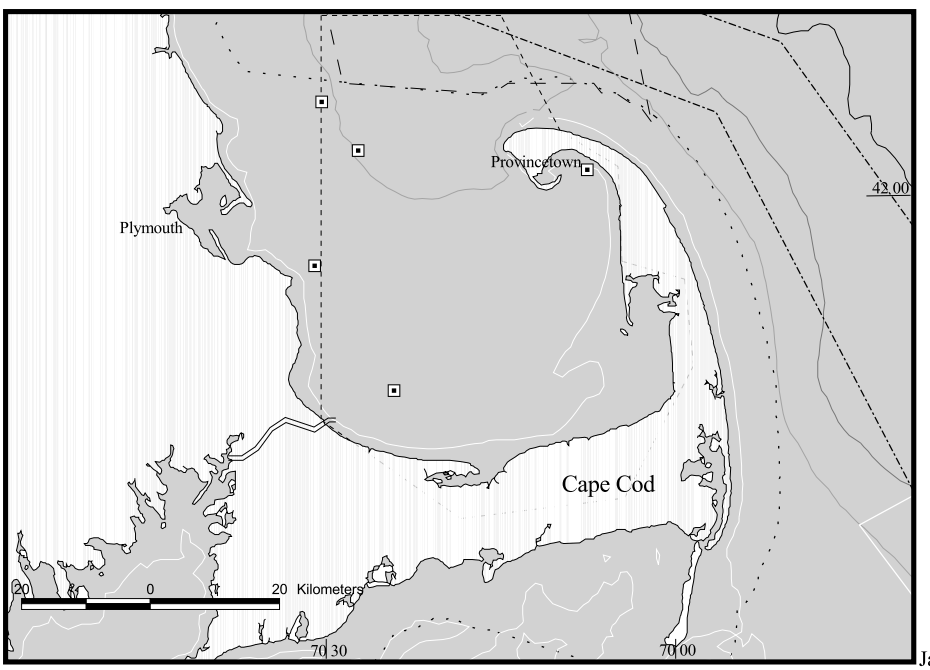
W E
S

Figure 5.

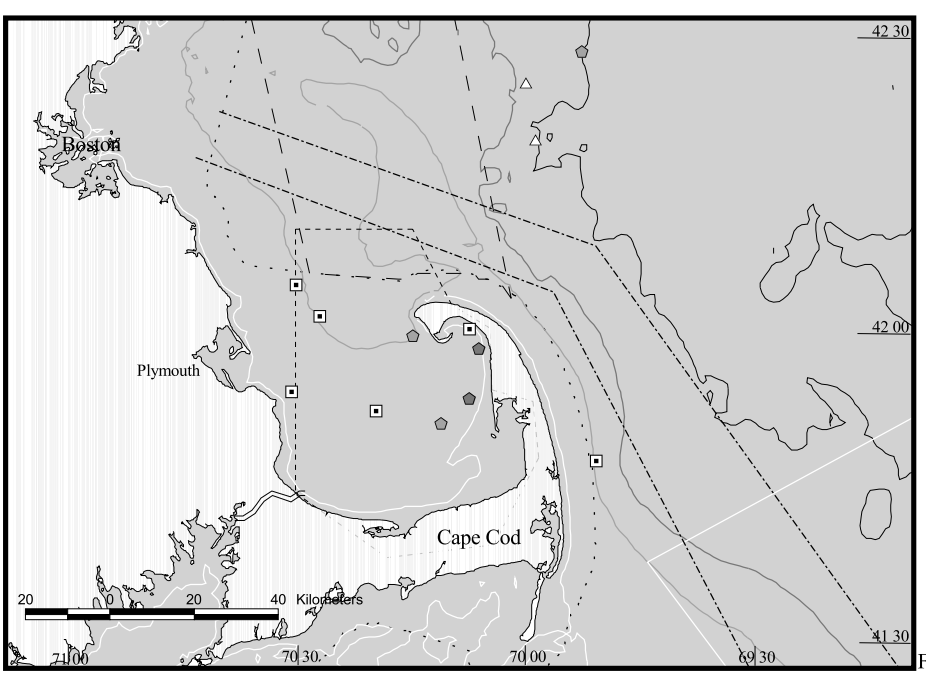
Sightings of other large whales and dolphins from aerial surveys in Cape Cod Bay, and adjacent waters December - February, 2003.



December, 2002.



January, 2003.



February, 2003.

Legend

Large Whales and Dolphins

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

Number of Animals Sighted

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

Bathymetry

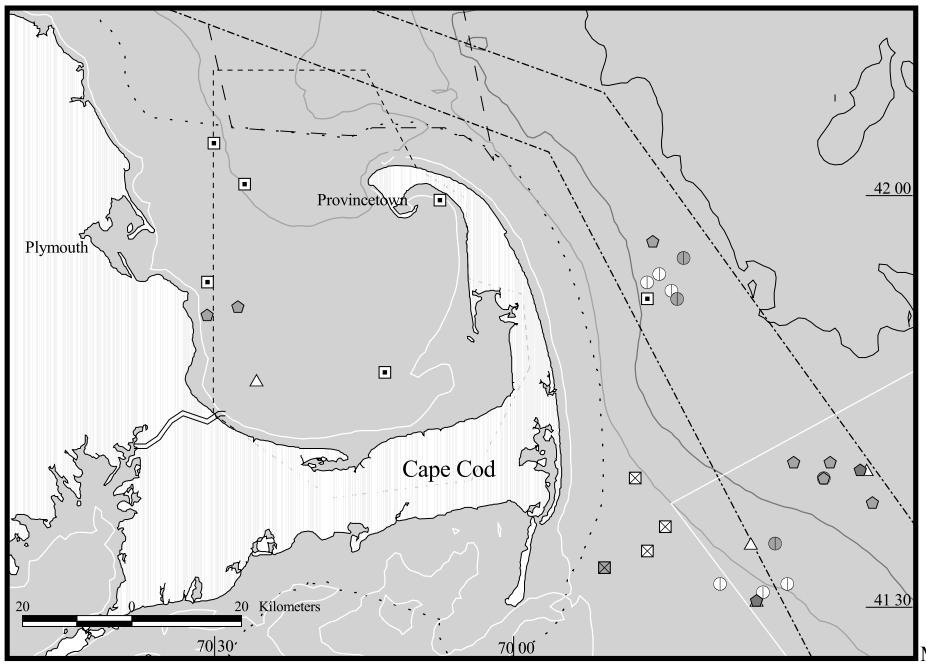
- 10 Meters
- 50 Meters
- 100 Meters
- 200 Meters

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

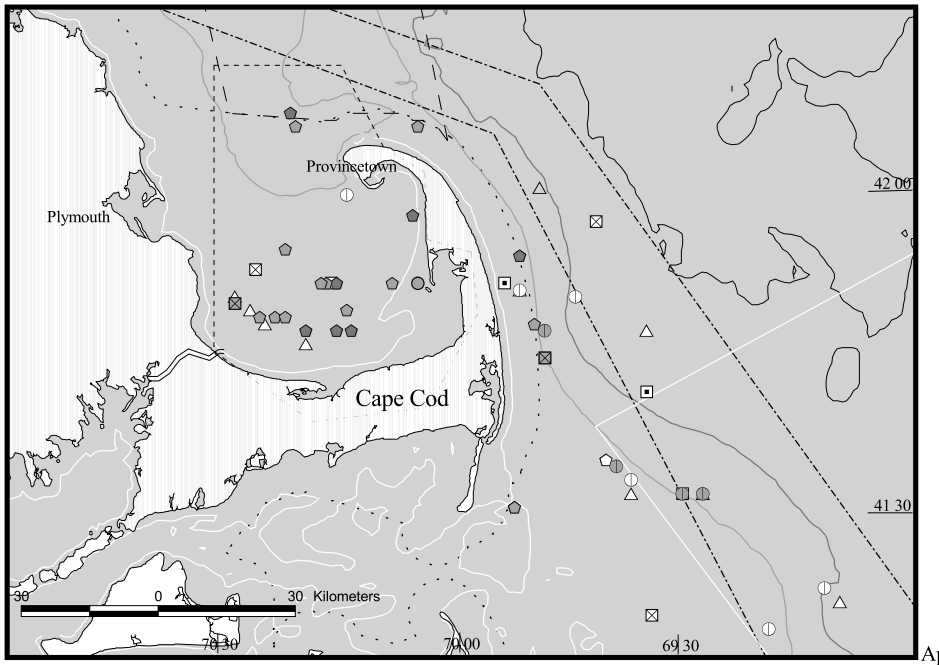
Created by
J. Beaudin Ring
October, 2003
Map is Mercator Projection (central meridian = 69.5). Bathymetric and Coastal data obtained from http://woodshole.er.usgs.gov.

Figure 6.

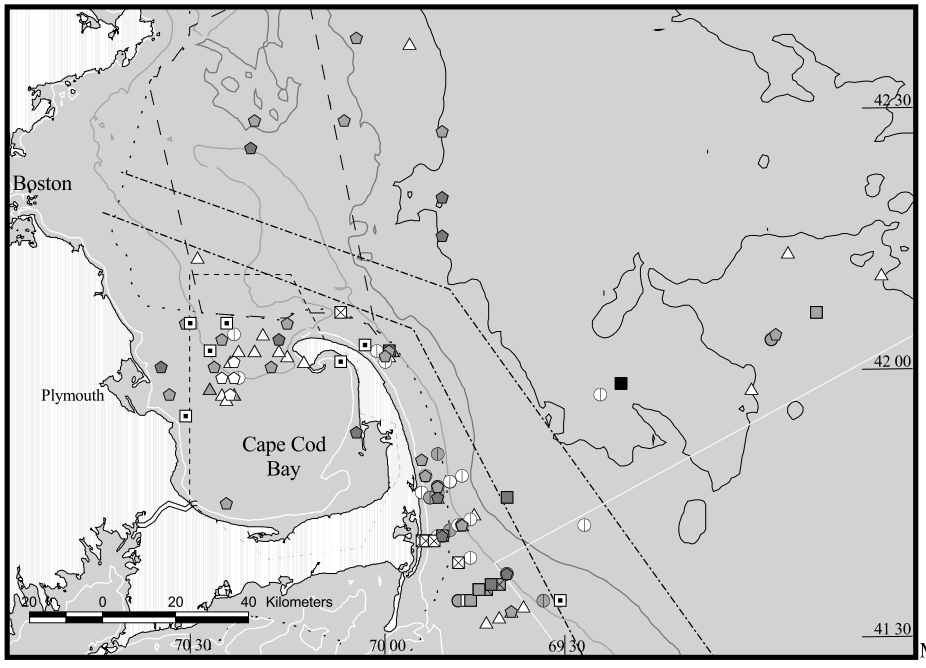
Sightings of other large whales and dolphins from aerial surveys in Cape Cod Bay, and adjacent waters March - May, 2003.



March, 2003.



April, 2003.



May, 2003.

Legend

Large Whales and Dolphins

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

Number of Animals Sighted

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

Bathymetry

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

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

Created by
J. Beaudin Ring
October, 2003
Map is Mercator Projection (central meridian = 69.5). Bathymetric and Coastal data obtained from http://woodshole.er.usgs.gov.

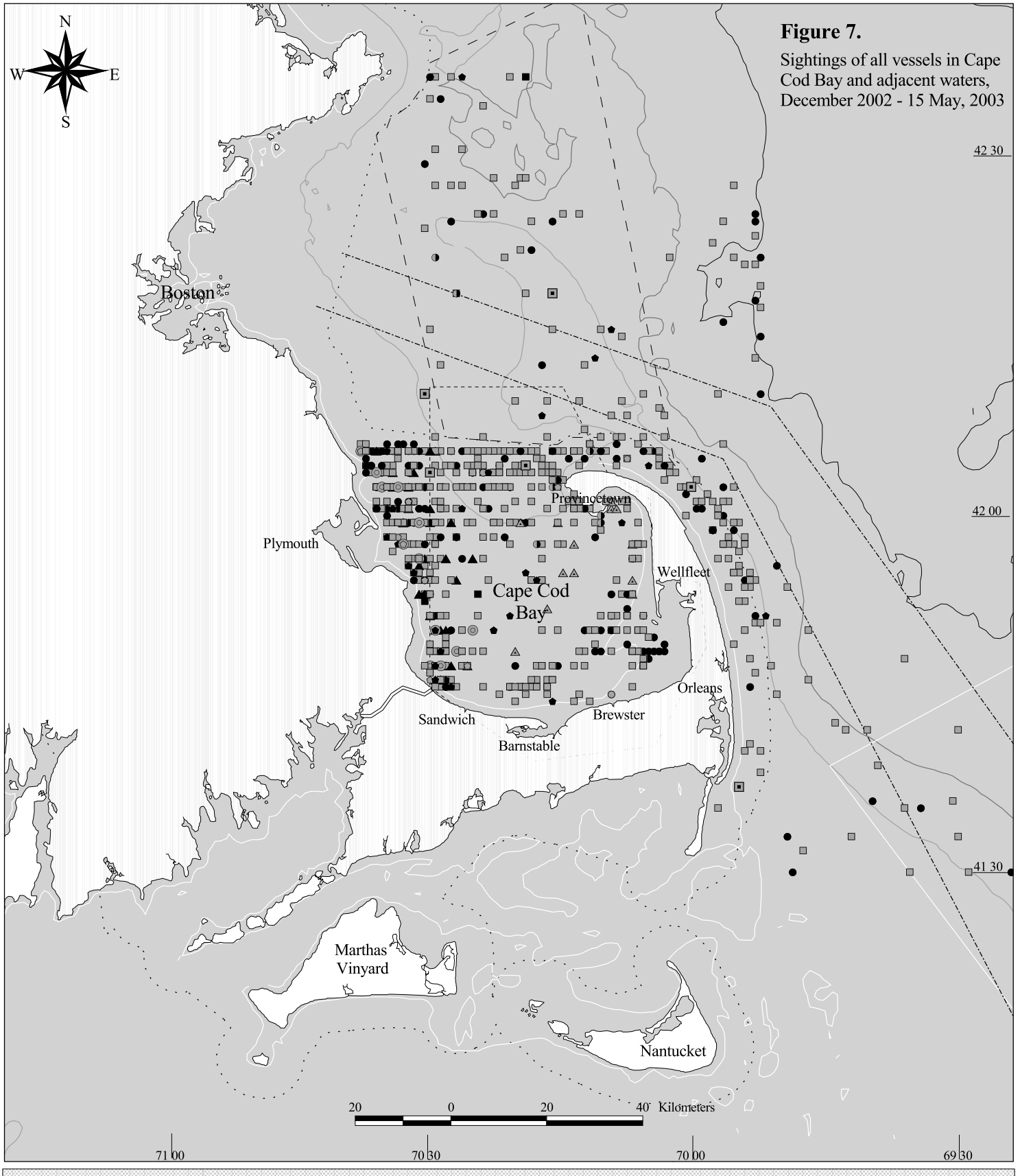


Figure 7.

Sightings of all vessels in Cape Cod Bay and adjacent waters, December 2002 - 15 May, 2003

Vessels Sighted

- Single Large Merchant Vessel
- Single Recreational Vessel
- Multiple Recreational Vessels
- Single Commercial Fishing Vessel
- Several Commercial Fishing Vessels
- Unidentified Fishin Vessel
- Tug and Barge
- Whale Watch Vessel
- Research Activity
- Single Sailing Vessel
- Sport Fishing Vessel

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

Bathymetry

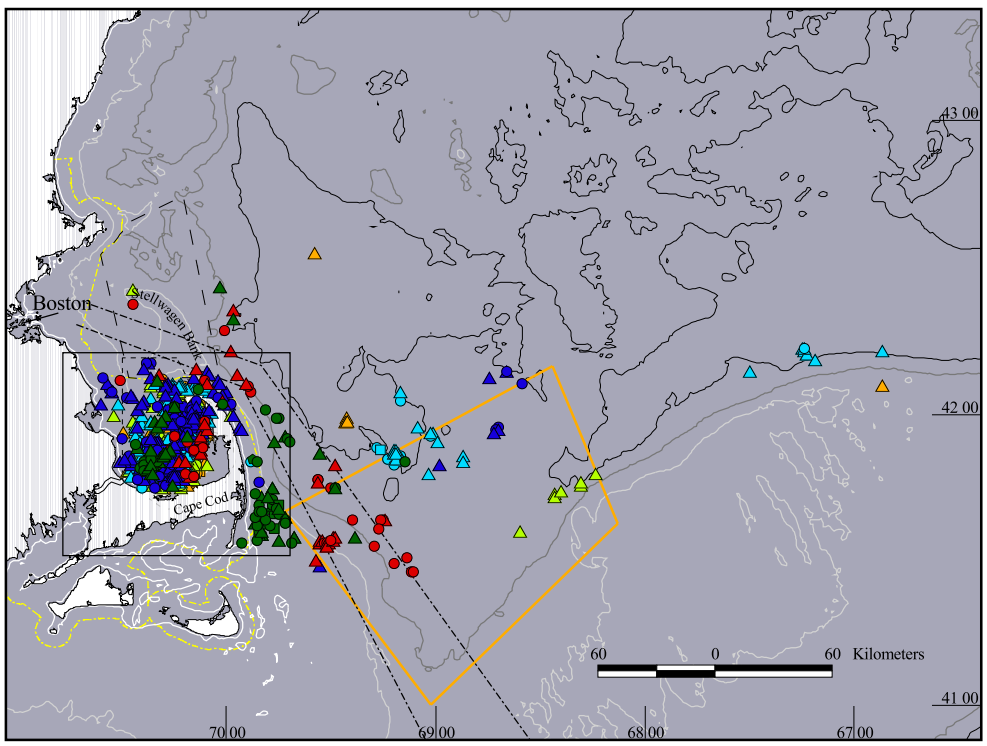
- 10 Meters
- 50 Meters
- 100 Meters
- 200 Meters

Shipping Lanes

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

Figure 8.
Sightings of right whales from aerial surveys in Cape Cod Bay and adjacent waters, 1998 - 2003 field seasons.

Created by
J. Beaudin Ring
October, 2003
Map is Mercator Projection (central meridian = 69.5). Bathymetric and Coastal data obtained from http://woodshole.er.usgs.gov.



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

Year Sighted
- 2003
- 2002
- 2001
- 2000
- 1999
- 1998

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

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

Sightings of right whales from aerial surveys in Cape Cod Bay, 1998 - 2003 field seasons.

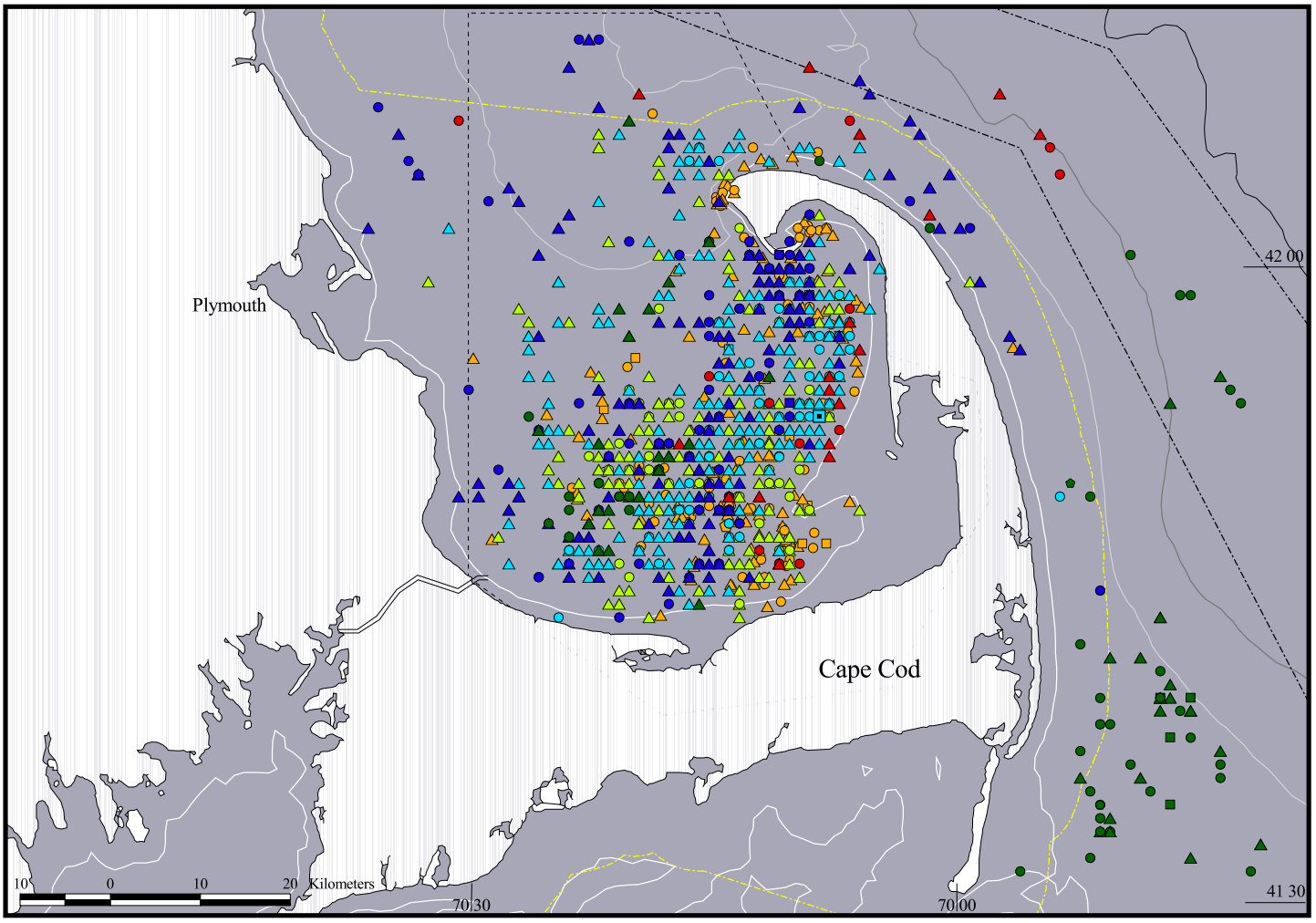
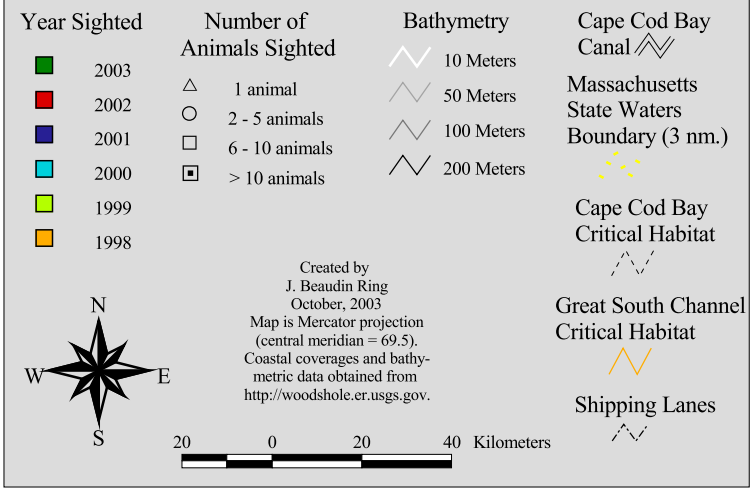
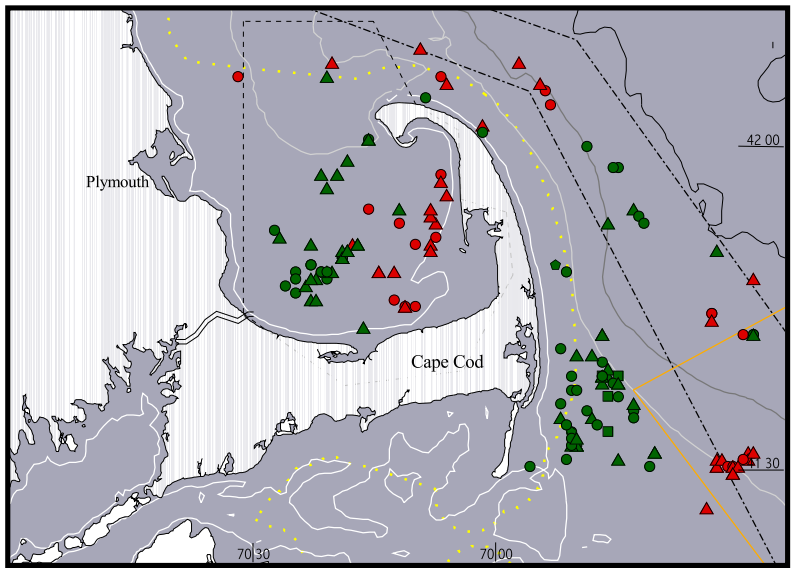
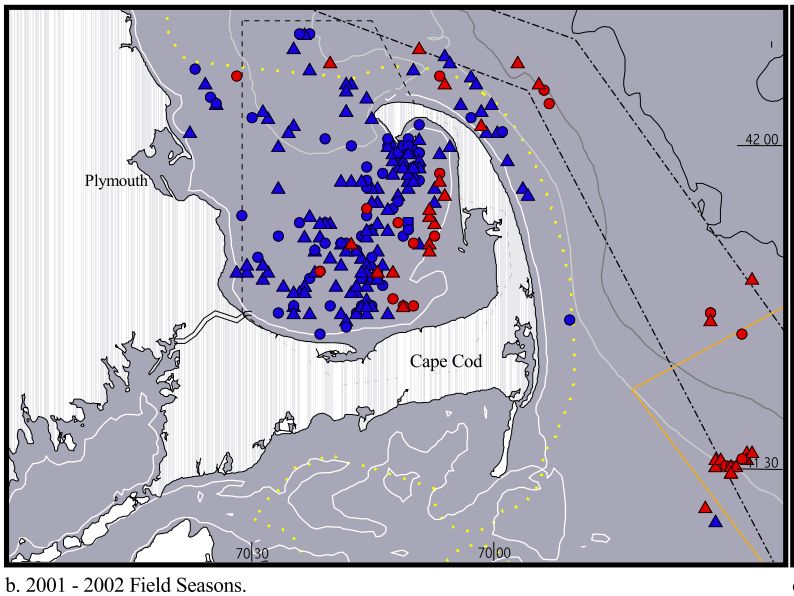


Figure 9.
Sightings (staggered by year) of right whales from aerial surveys in Cape Cod Bay and adjacent waters, 1998 - 2003 field seasons.

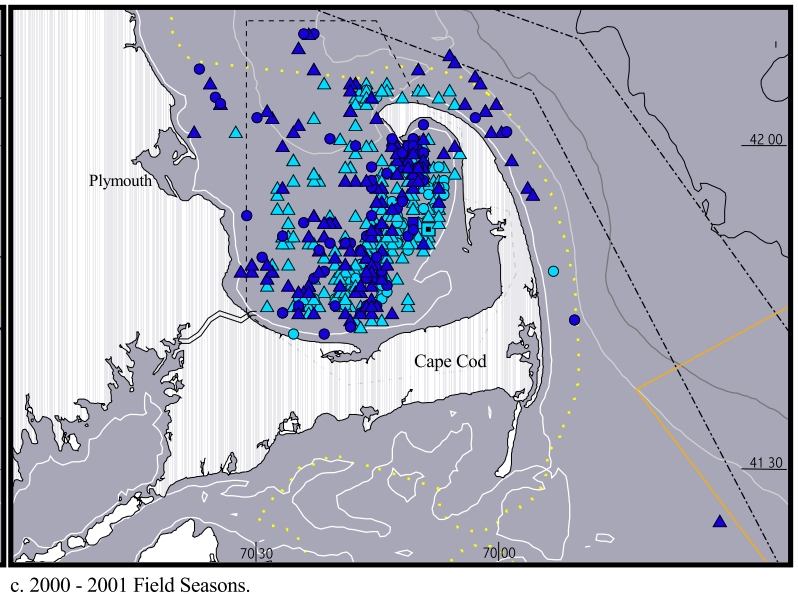




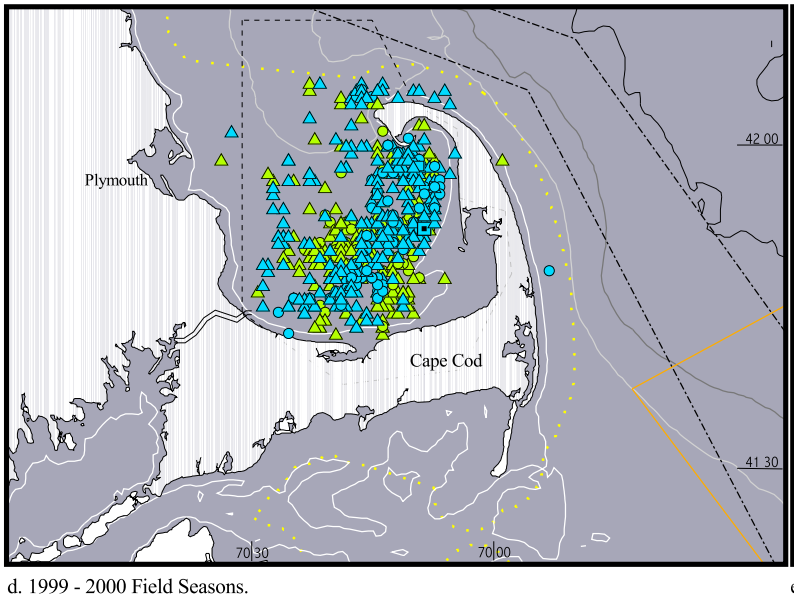
a. 2002 - 2003 Field Seasons.



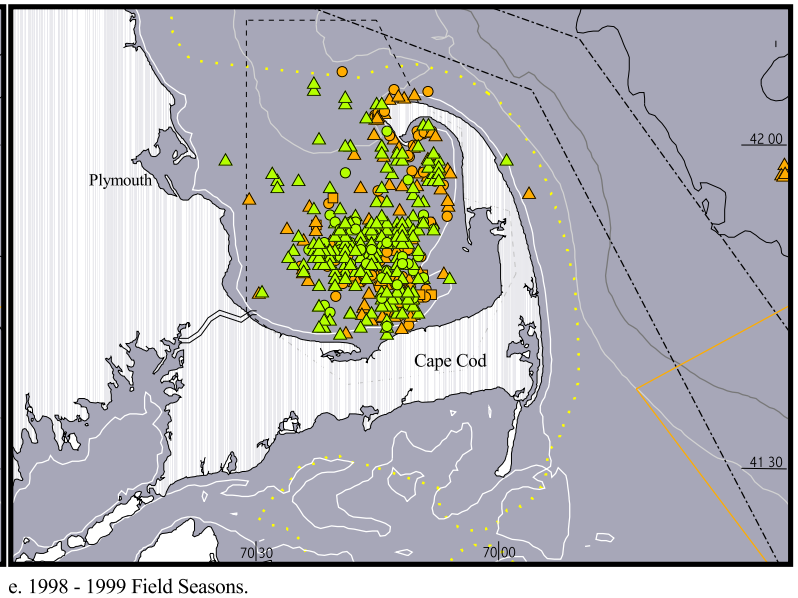
b. 2001 - 2002 Field Seasons.



c. 2000 - 2001 Field Seasons.



d. 1999 - 2000 Field Seasons.



e. 1998 - 1999 Field Seasons.

Appendix I

Confirmed right whale identifications in Cape Cod Bay and adjacent waters 1998-2003 and sighting histories. Abbreviations are listed at bottom of page.

EGNO	Sex	Y1980	Y1981	Y1982	Y1983	Y1984	Y1985	Y1986	Y1987	Y1988	Y1989	Y1990	Y1991	Y1992	Y1993	Y1994	Y1995	Y1996	Y1997	Y1998	Y1999	Y2000	Y2001	Y2002	Y2003
1004	F	OF					G		SMF		S	SFO			FS	S	M	S	SF	M		G	G		
1012	F				F	M	M	SF					S				M	SMGF				S	S	O (PH)	
1013	F	MF			M		SM				M					MJ		M	SM		M	M			
1014	F	MF		M	MOF					MGF	M	MS	SM				M	MS	M	M	M				
1019	M	F		GB			MF	M	B	G			M		F		MF	MGF	M	MGN	MG	S			
1027	F	F		BF	BF	SA	MG	MGBF	B	MBF	SMF	B	B		MF	F	MF	MF	MGF	MF	MF	MOF	MG	M	
1032	M	F		F	F			GF	F	GF	GF	F	F	F	F	F	F	F	MF	F	GF	OF	F	GF	G
1033	M		M	B			M	B	B	B					F	M	M	MF		M					
1036	M			B		G	G	B	MB	B	B			B											G
1039	F	O						B			M	MS		M		M	M	SM	M	MF	F	OS	S	M	
1042	U	GB	G		B			M	GB	B	GB		B					M	MO	MN	G				
1102	M	B	GO	B				B	G	B	B	B	B		F	F	MF	MF	F	MF			G		
1112	M	F	GF	BF	F	MJ	MO	B	F		FM	F		M	FJ	F	M	F	GF		F	MF	G		
1113	M		F	B		O		B	B	GB	B		B		M		M		B	N	F	M	S		
1114	F		GF		B	F		GB	MB			SM	M	M	M	M	MFS	SMF	F	M	F	MGF			
1121	M		GF	GB		MF			F	GF	GF	FB		F	F	MF	F	MFO	MF	M	F	F			
1130	M	GF	GF	F		M		B	B	GB	BJO	MF	B		F	F	FB	SMGF	MF	MF	MOF	M			
1131	M		GF	GF	GB	F	MG			B	F	F	B		F	F	F	MF	F	O	MGF	MOF	G		
1133	M		GF		B	BF	MG		B	GB	B			F	MF		M	F	F	AF	GN	M			M
1136	M		F	GF		F	G	B	B	GFB	B	F	MB	F	F	MFJ	F	MF	MF	F	M				
1140	F		GF	F				M	SMGF	G		SMFJ				SMF	M	M	M	M	M	MG	SAF		
1144	M	O	GF	G	B	BF		GBF	B	G	B			F	F	F	F	F	F		G		G		G
1145	F		F		G	MBF			S		SF		MF				S	S				G		M(STB)	
1146	M	B	GF		M	MBF			MF	MGB	MGBF			F	F	FJ	F	MF	F	M		MF			
1150	M	O	MF	B	M		MF	F	B	FB	F		MFB	F	F	MF	F	FO	MF	MF	MGF	MBF	MG		G
1152	M		F	F	GJ	J	GF	M	GF	GF	GJF	F		F	SF	F	F	SFO	F	F	GF	SOFB	G	F	G
1158	F		F	F		MF		M	G	G	SGF	M	F	M	F	F	MF	S	MFS	SAF	MGF	FS	SG		
1162	M	B	F										B			F	F		F	M	OF	F			
1167	M		F	F			G	MB	B	GB	B		B	F	SF	F	SGF	F	F	F	F	AMOF	MG		G
1170	M		F	F	MF	MGF	F	M		GF	F	F	B	F	F	F	F	FO	MF	MAF	MGF	GF	M		
1208	F		M				MG		G	GS	SAG	N	S				S	SF			M	O	M		SM
1209	F	M		M	B			B	F	F	SB	S	M		F	FJ	F	F	F	MF	GF	AOF	MG		M
1239	M		G	F				B	GB	GB	GB		B	M	F	F	F	MFO	F	G	MF				
1240	F			F			F			G	SB	S	F		F	F	F	F	SF	M	MF	MO	G	SG	
1241	F			F	MF	MF	F	GF		JF	SF	F	MFB	M	F	FS	SF	M	MF	MOF	F	MF	MG	S	G
1245	F			F	MF	F	MFO	A	F	F	F	F		F	OFS	SF	FS	SAMF	F	MF	F	MGF	O		
1246	F			F		G		S			SGJF										OF	GF	G	SG	
1249	M			OF	F	MG	M	MB	B	GB	B	B	BF		MF	F	MF	MFO	F	MF	MGF	MF	SGO		
1267	F			J	F			GBF	B	BF	GFB	FS	M		MF	MF	MF	SMF	MF	MF	MGF	GOF	MS	M	
1270	M	G		B		B				B	B	B								M					
1271	M			B	B			MF		GB	B	B	B			F	F	OF	F	M	GF	MGF	G	M (STB)	M (STB)
1276	M	GO		B	B	G			B	GB													G		G
1280	U			GB		G	MB	MB	MB	B			M	M	M	M			M	M	O	AM	G		
1281	F		G	B		SM	MA	SF		G	F		B	M	SF	F	MF	SF	F		F	OFS	SM		
1301	F				MF	AM		MB		BS	SF	M	B	BS		F	MF	MF	FS	SAF	MF	MGBS	SG	M	
1306	M				MF		F	G	M	GF	GF	B	B	F	F	F	F	SFO	F	F	GF	MGOF	GM	M (STB)	
1310	F				GF		G	MF				FJ		O				M	S	M			G	SM (STB)	
1311	M				GF		M	GB		GB	B		B	SB	F	MF	F		M		G	SMG	MG		
1317	M				SM	MBJ		GB	B	M	SB		B			OF	F	F	MF	F	MGF	MGF	MG		
1320	M	O	G		B		G	B	B	M	SB	B	B		F								G		G
1327	M			MG	M	G	M	MBF	M	MB	B	B	GB	F	MF	F	F	FO	F	F	MGF	MGOF	MG		M
1328	U				G					B	F	B	G	MBF	F	F	M	M	F		M	MG	M		M
1402	M					F		B	B	GB	GBF	B	B	F	F	F	F	SF	F		F	OF	G		G
1403	M					F		F		GB	B		B	MF		F	F	SM	F	F	GF	M	SO		

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

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EGNO	Sex	Y1980	Y1981	Y1982	Y1983	Y1984	Y1985	Y1986	Y1987	Y1988	Y1989	Y1990	Y1991	Y1992	Y1993	Y1994	Y1995	Y1996	Y1997	Y1998	Y1999	Y2000	Y2001	Y2002	Y2003
1405	F					SF	F			GF	F	F	F	F	F	F	F	SMF	SF	M	M				
1406	F					SMF	MOF			MB	FA		MF	MF	MFA	SMF	MF	M	MF	MF	MF	MOF			
1407	F	B	G	M		SF				F	SMF				SOAF	F			M	M	O	MOGS	S		
1408	F					AF	F	F	F	MF	B	F		F	FMS	SF	F	AF	F	F	GF	F	G		
1409	M					F		B	B	GB	B	B	B		SMF	F	MF	S				M	SG		
1411	M					SF		G		B	MB	B	B		F		F	F	MF	M		M	M		
1419	M					B		B		B	B		B	B		F	MF	M			F	G	OF	F	M
1424	M		M		B	B	S	M	G	GB	GB	M	B	M	MF	F	F	SMF	F	MAF	MF	GOF	MG	SM (STB)	M
1425	F			G		F	M		M	B	M	M		M	MFS	SGAF	MF	MF	F	A	M		SG		G
1427	M					F	JM		GB	GB	B	B	B	MF	MF	F	MF	FO	MGF	FM	MG	S	M		
1428	M		G			MGO	M	GB		MG	F	FB	B	F	F	F	MF	SMF	F	M		MOF	SM		
1429	M			G		M		MB	GB	GB	B	B	XF		M	F	F	FO	OF			GF	G		G
1430	F					M	M	MB	MB	MG	B			SM	F	MF	MF	MNS	S	MGN	MO	MO		S	
1503	F						F	M	M	MB		F		M	F	F	SFM	MF	BF	MG	MF	MOF	MG	M (STB)	SM
1505	M						MF	AM		GOB	B	B	MF		MSF	FJ	MF	SMF	MF	MOF	M				
1507	M						JOF	M	GMF	GOF	F	FB	MB	F	MF	F	F	MFO	MF	MGFJ	MGF	MOF	MG	M (STB)	
1509	F	GB				M	M	SM		B	SJM	M	M	SMJ		M	MN	MNS	SF	M	MG	MS	SA	M	
1511	M		G		B	G	M	MBF	B	B	B								F		M	MO	G		
1514	M						MG			MB	B	B	B				M			M		OF			
1601	F							SF	M	GF	F	F	MB		S	F	MF	F	SF	M	G	SO	S		
1602	F							SMF	MF	SMF	F		M	M	MFS	SF	MFS	SMFO	F	MF	GF	MGFS	SMG	M	
1603	M							SGJMF	M		B	S	M		SF	F	MF	F	F	M	GF	SMF	M		
1606	M							MF	G	F	B				F	F	F	SMF	F	M	MF	M			
1608	F							SM	GM		F	F	MF	MF	F	F	MF	MFO	F	MF	MGF	MF	MG	M	
1609	M							SM	F	F	F		B		F	F	F	SF			JMF	GFB	MG		G
1611	F							SM	SF	B	B		B			F	F	MFO	SF	MGF	MF	OFS	S		G
1613	M							SJM			FM	F			S	F	F	S	BF	F	F	SAGF	M		
1616	M							B	B	G	B	F	B	F	F	FJ	F	F	F	F	J		S		G
1622	F							M	M	GBS	S	M	SM				F	MS	SMO	M	MG	M	M	S	
1624	M							B		GB	GB				F	F			F		G	MG	G		
1625	M							B	GB	GB	GB		BF		F	F	F	FO	F	F	F	OGF	G	M	G
1627	M						G	B		GB	B		B		S				G	G			G		G
1630	U							B	B						F	F	F		F		F	MOG			
1632	F							B	G	GB												0		SF	G
1701	F								F	F	B	B	FB		FS	F	FS	SF	OF	MF	MGF	FS	SG		
1703	F								F		F	F			SF	SF	F	SF	MF	S	SGF	MOS	SMG		M
1704	F								SMGF	SMF	F	BM	MF	MF	MF	MF	MOF	MFOS	SMF	M	M				
1705	F								SMF	GF	GF	SF	F	OF	OFS	SFJ	FS	SF	F		GF	MOF	G		
1706	F								SMF	F	F	F	F		SMF	FJ	SF	MF	MFS	MF	MGF	ASGF	MG	M M(STB)	GM
1708	M								GB	B	B			M	M			M	F	F	MG	MGF	SM		G
1709	M								M	JB	B	B	B	M	SF	F	F	F	F	SMF					
1710	F								SM				JM					S				GS	SMG		
1711	F								SM	GB	MB						F	SMF	F	M	SMG	MS	SG		
1712	M								SAM		B	B	B			F	F	F	M		MF	S	SG		M
1716	M								B	B	B		B		F	F	F	F	F	G	MF	GF			
1802	F									MGF	MF	MF	MF	F	SMF	F	MF	MFS	F	MF	MGF	MGOFS	SGM		
1803	M									JF		F	F	S	SMF	F	F	M	OF	S	MGF	F	MG		
1804	M									GO	F	F	F	F	F	F	F	F	MF	SF	MGF	AMGF	MG		
1812	F									B	B		B		SF	F	F	S	F		MGF	MOGBF		S	
1817	F									B	SB		S	S	SF	SF	FS	SF	F	S	G	MFS	SMG		SMG
1820	U									B	B	B	B		M	F		SMF	MF	M	MF	MOF	MG		
1901	M										SGF		S	SF	SF	SF	SF	SMF	SMF	F	MGOF	SOFB	SGM	M (STB)	
1909	F										SJM	MJ	B	M	SMF	F	SF	F	MF	MF	SMOGF	GOF	G		
1911	F										F	M				F	MF	M	MF	MF	SMGF	MF	SG	M (STB)	

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

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EGNO	Sex	Y1980	Y1981	Y1982	Y1983	Y1984	Y1985	Y1986	Y1987	Y1988	Y1989	Y1990	Y1991	Y1992	Y1993	Y1994	Y1995	Y1996	Y1997	Y1998	Y1999	Y2000	Y2001	Y2002	Y2003
1934	F										SMO		B	M	SF	MF	MF	M	MF	MGF	MGF		G		GM
1946	F										SGJF	F		M	SF	F	F	FS	SMF	F	F	OF	M		
1960	M										B				F	F	F	SO	F	F	GF	G	G	M (STB)	G
1968	F										GF		B	B	S	F	F	OF	F	M	MF	MFS	SM	M (STB)	
1971	M										F	F		F	F	F	F	F	GF	F	GF	MSAOBF	GO	M (STB)	
1980	M										B							SM		M		SMG			M
1981	U										F	F			S	F	F	SOF	FS	F	MGF	F	G		
2010	M											FJ	M	M	S	F	F	SF	MF	SM	MGF	SMOB	MO		
2018	M											SF	FM	F	F	F	FS	F	F	A	F	F	G		SG
2027	M											MJF			F	F	F	MFO	F	M	F	MF	MG		
2040	F											MJF			F	F	F			O	G	MF	SG	S	
2048	M											F	F		F	F	MF	M	F	F	MF	SGOB	M	M	G
2050	F											M		M	SM		MF	SMF	MF	MGF	MGF	MGFS	SMGO		
2057	M											F				F	F	F	F				SG		G
2114	F											S	SB		M	F	MF		F	M	GF	FB			
2123	F												F	MF	SF	FS	FS	SMFO	SMF	SMAF	MGF	MF	SMG	M (STB)	
2135	M												MF	MF	SF	F	F	SMOF	GF	MF	MJOGF	SMF			
2140	M											S	F	F	S	MF	F	SMF	F	MF	MGF	GF	SMG		
2143	F												SF	F	F	F	F	FO	MF	F	GF	SMF	MG		G
2145	F												MF	F	MF	F	F	MOF	M	MF	MF	SMF	SMG	M	
2150	F												M			F							SMG		
2158	M												F	MF	F	F	MF	MF		SM	MF	MOF	M		
2201	M													SF	SMF	F	MF	SFO	F	SF	MF	GF	M		
2209	M													SMJ	M	F	MF	SMFO	F	AF	MGFS	MGOF	MG		SGM
2212	M													SJM	M		F	F	F	MF					
2215	M													SB	MF	F	MF	SMFO	MF	SMF	MGOF	MF	MOG		G
2223	F													F	F	F	F	O	F	MGF	MGFS	MF	MG	O	M
2240	F													SF	SF	F	F	SFO	F	MG	OGF	MOF	SG		
2271	M													SF	F	F	F	SMOF	F	M	MGF	AGOF	M		M
2303	M														SF	SMF	MF	SF	M	SAF	MGF	GF	G		SG
2304	M														M	F	F	MF	F	F	MOF	MGO	M		
2310	M														F	F	F	F	FS		F	F	MG		
2320	F														S	F	F	SF	SMF	S	GF	MOBFS	MG	M (STB)	GM
2330	F														M		F	F	F	SF	F	GF	SMG	S	
2340	M														F	F	M	F	F		MGF	MGF	M		
2350	U														F	F	MF		F		MGF		SMG	M (STB)	M
2406	U														A	SMF	M	F	F	MF	MGF	MGOF	MG		SGM
2425	F															SGAF	MF			MF	MGF	SMGF	MG	M	
2427	M															M	F	MFO	F	F	GF	MF	MOG		G
2430	F															F	MF	F	F	F	MGFS	MF	M		
2460	F															F	MF	F			GF	MOF	MG		
2470	U															F	F	MF	F	MF	MGF	MGF	S		
2479	U															F	F	MF	MF	MF	MGF	MF	M		
2503	F																SFM	F	F	MF	F	MF	MG		
2510	U																M			MN		G	SG		
2540	M																F	F	F	F	F	MOF	MG		GM
2602	M																	SMFOA	F	F	F	MF	MG		G
2605	F																	SF	F	MF	F	F	G		
2608	M																	AF	F	F	F	MF			G
2611	F																	SF	F	AF	F	F	GF	F	AG
2614	F																	SMF		M	GF		G		
2615	M																	SF	F	AF	F	OF	GF	F	G
2617	U																	SF	SF	F	F	MF	MO		
2630	U																	F	F	MAF	MF	GF	G		

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

Appendix I

Confirmed right whale identifications in Cape Cod Bay and adjacent waters 1998-2003 and sighting histories. Abbreviations are listed at bottom of page.

EGNO	Sex	Y1980	Y1981	Y1982	Y1983	Y1984	Y1985	Y1986	Y1987	Y1988	Y1989	Y1990	Y1991	Y1992	Y1993	Y1994	Y1995	Y1996	Y1997	Y1998	Y1999	Y2000	Y2001	Y2002	Y2003
2645	F																	SAMF	SMF	F	MS	MF	MG	M	
2681	M																	SF			G	O	O		G
2701	F																		SF	SMF	F	A			
2704	M																	S	SMF	MF					
2705	U																		SF	SMF	F	F	MG		
2709	M																		SF	SF	F	MF	MG	M (STB)	
2710	U																	S	SF	F	MF	F	G		
2720	U																		F	MF		MF	MG		
2740	M																		SF	F	MF	F	MG	S	GM
2746	F																	S	SMF	F	F	F	M	S	
2750	M																		SF	F	MGF	MF	MG	M	M
2753	F																		SF	F	F	GF	GF	G	SM
2760	U																		F	GFM	MOF	MF	G		G
2770	M																	S	F		F	S	F		M
2810	M																		S	SG	G	F	G		G
2820	M																			SF	F	F	G	M (STB)	
2830	U																			AF	F	MF	MF	F	G
2910	U																				M	F	G		G
2920	U																				SMG	MG	MG		
3020	F																								G
3102	U																						M	M	
3103	U																						M	M (Canal)	G
3109	M																								SG
3110	U																						M	S	
3123	U																								G
3139	U																							M	
3150	M																						M		
3160	U																						M	SM	
3180	U																						M		G
3181	U																						M		
3240	F																							G	
1145ca																								M (STB)	
1246ca																								G	
1310ca																								M (STB)	
1503ca																									SM
1817ca																									SMG
98-443																				M			M		
99-342																					M				G
01-03																							M		G
01-178																						F	M		
01-185																							M		
01-401																							M		
02-120																								M	G

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

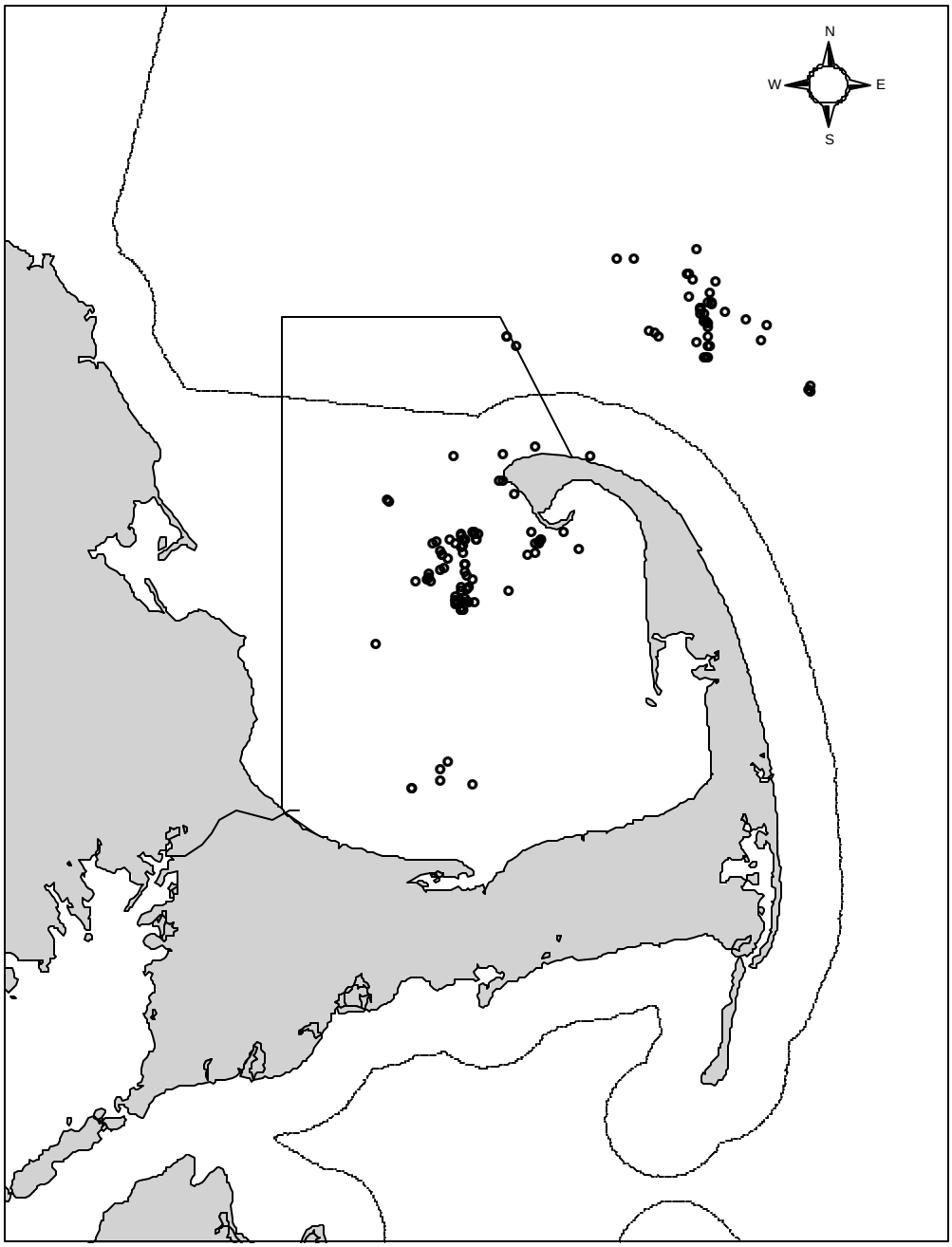
Appendix II. Sighting records of identified right whales seen in **Cape Cod Bay** and adjacent waters, December 2002 to mid-May 2003. F (female), M (male), A (adult), J (juvenile), U (unknown), Y (yearling).
"X" denotes the day on which the animal was seen, **X** in bold type shows animals seen in CCB, lower case "x" is used for animals seen outside CCB. * denotes an entangled whale
In id# column, four digit number is actual right whale individual identification, five digit or hyphenated number is annual sighting number of new whales that do not yet have an identification number.

Id #	Sex	Age	2002 10-Dec	2002 13-Dec	2003 6-Jan	19-Jan	25-Jan	26-Jan	6-Feb	10-Feb	20-Feb	21-Feb	27-Feb	1-Mar	4-Mar	8-Mar	15-Mar	20-Mar	23-Mar	24-Mar	27-Mar	28-Mar	7-Apr	9-Apr	10-Apr	13-Apr	14-Apr	19-Apr	21-Apr	23-Apr	25-Apr	28-Apr	30-Apr	4-May	5-May	9-May	15-May	# days sighted
2750	M	6					**X**													x	x																	3
1133	M	A							**X**																													1
1271	M	A											x																									1
1276	M	A																x	x																			2
1611	F	17																x																				1
2740	M	6																x	x										**X**									3
1708	M	16																x																				1
1152	M	A																x																				1
2810	M	5																x			x																	2
2602	M	7																x																				1
2611	F	7																x	x	x	x																	4
2406	M	9																x			x											**X**	**X**				x	5
2615	M	7																x																				1
99-342	U	U																x																				1
01-03	U	U																x			x																	2
2215	M	11																x			x																	2
1167	M	A																x																				1
1032	M	A																x			x																	2
2057	M	13																x																				1
1616	M	A																x																				1
1960	M	A																	x																			1
1627	M	A																	x																			1
1320	M	A																	x	x	x																	3
1036	M	A																	x		x																	2
1429	M	21																	x	x																		2
1150	M	A																	x																			1
1934	F	14																	x		x											**X**	**X**					4
2018	M	13																	x		x																	2
1632	F	A																	x							x												2
1144	M	A																	x																			1
2608	M	7																	x							x												2
2760	M	U																	x																			1
1241	F	21																		x																		1
2540	M	A																		x	x				**X**													3
2320*	F	A																		x*												**X***						2
1625	M	A																			x																	1
2303	M	10																			x																	1
3180	U	2																			x																	1
2910	U	U																			x																	1
2427	M	9																			x																	1
1609	M	17																			x																	1
2209	M	11																			x								**X**									2
2681	M	7																			x																	1
3109	M	2																			x																	1
2048	M	13																			x																	1
1402	M	19																			x																	1
3123	U	2																			x																	1
2143	F	12																			x																	1
1706	F	16																			x											**X**	**X**					3
02-120	U	U																				x																1
1209	F	A																					**X**															1
1503	F	18																					**X**												x			2
1503C	U	calf																					**X**												x			2
2271	M	11																					**X**		**X**				**X**									3
1980	M	A																						**X**	**X**		**X**											3
2350	U	A																							**X**													1
1419	M	A																							**X**													1
1703	F	16																							**X**													1
1712	M	16																							**X**				**X**			**X**	**X**					4
2830	U	U																								x												1
1425	F	A																								x												1
3020	F	U																								x												1
1424*	M	A																									X*											1
1208	F	A																										**X**										1
2753	F	6																											**X**									1
2770	M	U																											**X**									1
1327	M	A																											**X**									1
1817	F	A																												**X**							x	2
1817C	U	calf																												**X**							x	2
2223	F	11																													**X**							1
1328	M	A																													**X**							1
3103	U	2																																			x	1
Daily totals			0	0	0	0	1	0	1	0	0	0	1	0	0	0	0	17	15	7	26	1	4	1	7	5	2	1	7	2	2	5	4	0	2	0	4	115

Appendix III

Right whale sightings from Dolphin Fleet whale watch vessels with CCS naturalists on board April - July 2003 (Data courtesy of Jooke Robbins)

A total of 526 trips were conducted, resulting in a minimum of 185 right whale sightings. It is impossible to determine the number of individually identified right whales (only 64 sighting events were photographed; the photographic data have not yet been submitted to NEAq).



Appendix III. Right whale sightings from Dolphin Fleet whale watch vessels with CCS naturalists on board April - July 2003 (Data courtesy of Jooke Robbins).

DATE	SPECIES	LOW_NO	HI_NO	START_TIM	END_TIME	LAT_DEG	LAT_MIN	LONG_DEG	LONG_MIN
03.04.13	EG	5	5	1459	1536	41	59.90	70	17.65
03.04.13	EG	2	2	1511	1551	42	00.41	70	18.14
03.04.14	EG	1	1	1136	1136	42	00.25	70	17.83
03.04.14	EG	1	1	1116	1129	41	59.31	70	17.52
03.04.14	EG	1	1	1107	1116	41	59.39	70	17.57
03.04.14	EG	2	2	1102	1116	41	58.17	70	17.82
03.04.14	EG	1	1	1057	1057	41	58.93	70	17.56
03.04.14	EG	2	2	1048	1057	41	58.57	70	17.02
03.04.14	EG	1	1	1051	1051	41	58.75	70	17.39
03.04.14	EG	2	2	1125	1129	41	59.33	70	17.45
03.04.14	EG	2	2	1602	1607	42	00.57	70	17.62
03.04.14	EG	1	1	1535	1535	41	59.86	70	19.07
03.04.14	EG	1	1	1539	1542	42	00.02	70	19.28
03.04.14	EG	1	1	1545	1549	42	00.40	70	19.74
03.04.14	EG	1	1	1549	1552	42	00.53	70	19.50
03.04.14	EG	1	1	1555	1555	42	00.63	70	18.57
03.04.14	EG	1	1	1600	1602	42	00.57	70	17.52
03.04.14	EG	1	1	1535	1538	41	59.86	70	19.07
03.04.14	EG	1	1	1523	1530	41	48.77	70	19.26
03.04.14	EG	1	1	1519	1519	41	59.00	70	19.17
03.04.14	EG	1	1	1505	1505	41	59.14	70	18.99
03.04.14	EG	2	2	1505	1519	41	59.65	70	18.68
03.04.14	EG	1	1	1458	1458	42	00.37	70	17.61
03.04.14	EG	1	1	1454	1457	42	00.78	70	17.85
03.04.14	EG	2	2	1448	1448	42	00.92	70	17.79
03.04.14	EG	2	3	1439	1439	42	01.04	70	17.05
03.04.14	EG	1	1	1428	1428	42	00.98	70	16.89
03.04.14	EG	1	1	1425	1443	42	00.93	70	16.84
03.04.14	EG	1	1	1424	1443	42	00.91	70	16.80
03.04.14	EG	1	1	1411	1411	42	00.92	70	16.62
03.04.14	EG	1	1	1410	1425	42	00.67	70	16.75
03.04.14	EG	1	1	1409	1409	42	00.62	70	16.68
03.04.14	EG	1	1	1455	1457	42	00.62	70	17.52
03.04.15	EG	1	1	1110	1134	41	57.36	70	17.30
03.04.15	EG	1	1	1043	1058	41	48.05	70	17.09
03.04.15	EG	1	1	1121	1204	41	57.44	70	16.76
03.04.15	EG	1	1	1048	1048	41	58.16	70	17.34
03.04.15	EG	1	1	1057	1108	41	57.98	70	17.69
03.04.15	EG	1	1	1110	1110	41	57.39	70	17.48
03.04.15	EG	1	1	1438	1438	41	58.70	70	19.98

Appendix III. Right whale sightings from Dolphin Fleet whale watch vessels with CCS naturalists on board April - July 2003 (Data courtesy of Jooke Robbins).

DATE	SPECIES	LOW_NO	HI_NO	START_TIM	END_TIME	LAT_DEG	LAT_MIN	LONG_DEG	LONG_MIN
03.04.15	EG	1	1	1452	1524	41	58.85	70	19.96
03.04.15	EG	1	1	1509	1509	41	58.53	70	19.83
03.04.15	EG	1	1	1536	1547	41	58.57	70	20.22
03.04.16	EG	1	1	1447	1456	41	57.51	70	18.16
03.04.16	EG	1	1	1517	1539	41	57.03	70	17.63
03.04.16	EG	2	2	1516	1539	41	57.03	70	17.64
03.04.16	EG	1	1	1514	1539	41	57.02	70	17.69
03.04.16	EG	1	1	1510	1539	41	57.05	70	17.70
03.04.16	EG	1	1	1510	1539	41	57.05	70	17.70
03.04.16	EG	2	2	1504	1510	41	57.13	70	17.70
03.04.16	EG	1	1	1454	1504	41	57.34	70	18.14
03.04.16	EG	2	2	1420	1424	41	58.07	70	17.43
03.04.16	EG	1	1	1445	1445	41	57.67	70	18.16
03.04.16	EG	1	1	1440	1445	41	57.60	70	17.56
03.04.16	EG	2	2	1435	1440	41	57.46	70	17.50
03.04.16	EG	2	2	1435	1440	41	57.46	70	17.50
03.04.16	EG	2	2	1428	1435	41	57.98	70	14.50
03.04.16	EG	2	2	1424	1432	41	58.08	70	17.38
03.04.16	EG	1	1	1447	1504	41	57.51	70	18.16
03.04.16	EG	2	2	1459	1459	41	57.38	70	17.95
03.04.18	EG	2	2	1547	1605	41	55.24	70	23.61
03.04.18	EG	1	1	1508	1521	41	58.44	70	20.91
03.04.19	EG	1	1	1538	1546	42	05.01	70	14.89
03.04.20	EG	1	1	1354	1417	42	01.03	70	10.81
03.04.20	EG	1	1	1449	1450	42	02.90	70	14.16
03.04.21	EG	3	4	1514	1538	41	47.85	70	21.15
03.04.21	EG	1	2	1506	1506	41	48.22	70	19.18
03.04.21	EG	1	1	1514	1538	41	47.85	70	21.15
03.04.21	EG	1	1	1443	1503	41	49.26	70	18.65
03.04.22	EG	1	1	1525	1554	42	04.85	70	08.98
03.04.23	EG	3	3	1436	1436	42	00.65	70	12.29
03.04.23	EG	2	2	1358	1413	42	00.44	70	12.37
03.04.23	EG	1	1	1405	1436	42	00.41	70	12.65
03.04.23	EG	1	1	1413	1436	42	00.52	70	12.40
03.04.23	EG	2	2	1420	1436	42	00.65	70	12.29
03.04.24	EG	2	2	1203	1212	41	59.92	70	12.69
03.04.27	EG	1	1	1410	1443	41	59.86	70	13.28
03.04.27	EG	2	2	1443	1550	42	00.14	70	09.72
03.04.28	EG	1	1	1359	1423	42	01.07	70	12.93
03.04.29	EG	1	1	1057	1125	42		70	

Appendix III. Right whale sightings from Dolphin Fleet whale watch vessels with CCS naturalists on board April - July 2003 (Data courtesy of Jooke Robbins).

DATE	SPECIES	LOW_NO	HI_NO	START_TIM	END_TIME	LAT_DEG	LAT_MIN	LONG_DEG	LONG_MIN
03.04.30	EG	2	2	1427	1500	42	02.54	70	22.75
03.04.30	EG	2	2	1500	1539	42	02.59	70	22.80
03.05.02	EG	1	1	1045	1105	42	03.64	70	15.18
03.05.02	EG	1	1	1138	1158	42	04.88	70	18.28
03.05.05	EG	1	1	1417	1425	42	05.41	70	12.74
03.07.02	EG	1	2	1920	1928	42	03.53	69	43.67
03.07.04	EG	2	2	1948	1952	42	08.29	70	54.18
03.07.04	EG	1	1	1939	1943	42	08.13	69	53.82
03.07.04	EG	3	3	1920	1939	42	08.28	69	54.02
03.07.04	EG	4	4	1920	1935	42	08.52	69	53.89
03.07.17	EG	2	2	1407	1424	42	15.03	70	05.91
03.07.17	EG	2	2	1524	1528	42	14.91	70	07.07
03.07.18	EG	2	2	1117	1125	42	12.30	69	59.70
03.07.18	EG	2	2	1603	1615	42	03.63	70	14.93
03.07.18	EG	1	1	1459	1509	42	13.88	70	01.97
03.07.18	EG	1	1	1544	1548	42	14.26	70	02.08
03.07.18	EG	2	2	1757	1818	42	10.99	70	04.29
03.07.18	EG	2	2	1919	1923	42	11.31	70	04.87
03.07.18	EG	2	2	1840	1847	42	11.25	70	04.49
03.07.19	EG	1	1	1030	1037	42	11.79	70	01.02
03.07.19	EG	1	1	1030	1037	42	11.79	70	01.02
03.07.19	EG	1	1	1004	1013	42	10.45	70	00.75
03.07.19	EG	1	1	1013	1033	42	11.02	70	00.81
03.07.19	EG	1	1	1053	1113	42	12.45	70	01.35
03.07.19	EG	2	2	1036	1048	42	11.70	70	00.79
03.07.19	EG	1	1	1053	1113	42	12.45	70	01.35
03.07.19	EG	2	2	1053	1104	42	11.49	70	00.90
03.07.19	EG	1	1	1111	1128	42	12.35	70	01.30
03.07.19	EG	2	2	1130	1142	42	13.01	70	02.08
03.07.19	EG	1	1	1424	1430	42	12.60	70	00.56
03.07.19	EG	1	1	1435	1439	42	13.27	70	00.74
03.07.19	EG	1	1	1449	1449	42	15.51	70	01.62
03.07.19	EG	1	1	1430	1445	42	12.73	70	00.67
03.07.19	EG	1	1	1512	1544	42	12.71	70	00.91
03.07.19	EG	1	1	1828	1834	42	11.73	70	01.21
03.07.19	EG	1	1	1828	1834	42	11.73	70	01.21
03.07.19	EG	1	1	1842	1842	42	11.75	70	01.11
03.07.19	EG	1	1	1923	1923	42	10.65	70	01.62
03.07.19	EG	1	1	1913	1921	42	09.95	70	01.18
03.07.20	EG	2	2	1105	1118	42	10.77	69	57.19

Appendix III. Right whale sightings from Dolphin Fleet whale watch vessels with CCS naturalists on board April - July 2003 (Data courtesy of Jooke Robbins).

DATE	SPECIES	LOW_NO	HI_NO	START_TIM	END_TIME	LAT_DEG	LAT_MIN	LONG_DEG	LONG_MIN
03.07.20	EG	2	2	1041	1051	42	11.94	69	58.21
03.07.20	EG	2	2	1116	1118	42	11.52	69	56.85
03.07.20	EG	1	1	1852	1910	42	09.95	70	00.93
03.07.20	EG	1	1	1819	1830	42	10.54	70	00.95
03.07.20	EG	1	1	1919	1936	42	09.99	70	01.03
03.07.21	EG	1	1	1115	1119	42	13.81	70	00.34
03.07.21	EG	1	1	1116	1116	42	14.16	70	02.34
03.07.21	EG	1	1	1509	1516	42	12.19	70	01.44
03.07.21	EG	1	1	1502	1515	42	12.17	70	01.19
03.07.27	EG	2	2	1000	1004	42	10.56	70	14.00
03.07.27	EG	2	2	1758	1802	42	11.03	70	14.60
03.07.27	EG	2	2	1758	1802	42	11.03	70	14.60

Appendix IV

Acoustic Detections of Northern Right Whales in Cape Cod Bay, Sampled 21 November 2002 - 21 May 2003

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

There is good evidence from previous studies to support the assumption that passive acoustic methods can provide an effective mechanism for detecting and estimating the number of right whales. Preliminary research to evaluate this working assumption was first initiated in late spring 2000 in the Great South Channel, then again in 2001 and 2002 in Cape Cod Bay and the Great South Channel using autonomous acoustic recorders referred to as "pop-ups". The results have been very encouraging. In all three seasons and in both locales right whale sounds have been detected, and there has been a positive association between the presence of whales, as sighted from aircraft, and the number of whale sounds as detected on pop-ups.

For Cape Cod Bay, this applied research continued in 2003 in collaboration with the Center for Coastal Studies[1]. The primary hypothesis is that there is a statistically reliable relationship between the number of right whales in an area and the number of right whale sounds produced. A second hypothesis is that there is a statistically reliable relationship between the activities of right whales and the types of sounds produced.

Starting in the fall of 2002 and through spring 2003, the Cornell Bioacoustics Research Program deployed multiple sets of pop-ups in Cape Cod Bay. The first set of three pop-ups was deployed off Race Point, off Sandwich near the "fingers" and 5 nautical miles (nmi) south of Wood End in the same locations as in previous years. This configuration of three units collected data continuously from 21 November 2002 to 18 January 2003 at a sampling rate of 2000 Hz for an effective frequency range of 10 - 1000Hz. From 18 January 2003 to 21 May 2003, six pop-ups were deployed with three of the six being in the same locations as during the 21 November 2002 to 18 January 2003 period. The additional three pop-ups were configured with the unit south of Wood End to form a diamond array. These six pop-ups recorded continuously at a sampling rate of 2000Hz. Pop-up positions are shown in Figure 1. All acoustic data from the pop-ups have been processed for right whale sounds. Array data from only the deployment covering April and May have been processed for right whale sounds. Processing of the array data for acoustic locations is in progress.

Figure 2 shows daily counts of right whale calls for the processed data. The first right whale call was heard on the Sandwich pop-up on 23 November 2002. Very low numbers (1-15) of right whale calls were heard intermittently throughout November and December at all three pop-up locales. The first obvious increase in vocal activity occurred during the second half of January. This was followed by a long period of modest, but highly variable levels of vocal activity that continued until mid April. On 14 April there was a distinct increase in calling that lasted until the end of April. No right whale calls were detected for the 5-21 May period.

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

Figure 1. Positions of pop-ups deployed in Cape Cod Bay and used to detect the calls of northern right whales during the 2002-2003 season.

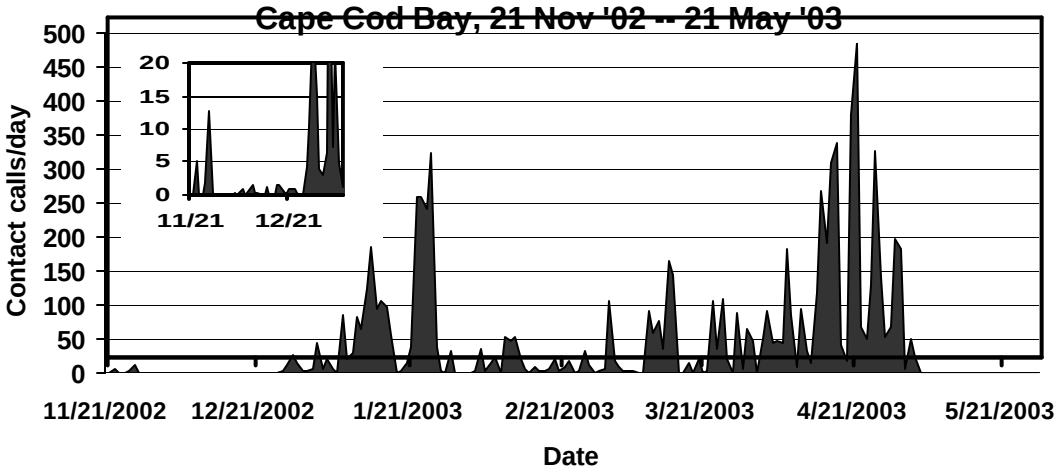


Figure 2. Histogram showing the number of northern right whale contact calls detected each day from 21 November 2002 through 21 May 2003. The inset expands the calls/day scale for the 21 November 2002 through 7 January 2003 period to reveal the burst of call activity during the last weeks of November.

Using Zooplankton Enumeration to Manage the Cape Cod Bay Right Whale Critical Habitat - 2003

Final Report
Chapter Two

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October 31, 2003

Introduction

As in past years, this chapter of the report compliments the aircraft survey studies described in the earlier chapter. Also as in past reports, we present in appendices the observations from oceanographic sampling of the Cape Cod Bay system. These observations add to the baseline data on the qualities of the system that supports right whale aggregation in the Massachusetts and Cape Cod Bays.

In addition to the 2003 oceanographic conditions summarized here are results of an innovative study intended to test the value of zooplankton enumeration as a tool for the management of anthropogenic activities that impact right whales. This directed management effort was undertaken throughout the usual season of right whale residency in 2003 and reported on a cruise-by-cruise basis to the Division of Marine Fisheries (DMF), Commonwealth of Massachusetts, for use in the management of fixed fishing gear activities. The 2003 habitat reports and predictions were sent to DMF and to interested parties at federal, state, and private institutions by email usually within 24 hours of a sampling cruise. Because we were interested in reporting the data and our interpretation to managers in a very rapid fashion, we set as a goal the quick enumeration and reporting of the results.

The zooplankton assessments of the 2003 season comprised near-real-time reports and predictions. Here we present, in Appendix II, the results of the tests of the assessment and reporting methods as copies of the original assessment forms and comments.

Methods and Materials

Sampling methods, both at stations and in the vicinity of right whales, for the purposes of describing the Cape Cod Bay system have been explained in previous reports (Mayo et al., 2001; Mayo et al., 2002). In 2003 oceanographic and biological conditions found in Cape Cod Bay were described from collections taken on 21 cruises funded by DMF. An overview of these cruises and the collections made is presented in Table 1.

Zooplankton samples were collected using standard 333 μ mesh conical nets 30cm or 60cm in diameter and fitted with a General Oceanics helical flow meter. Net tows were taken at stations and in the vicinity of right whales both at the surface and by oblique sampling to a depth of 19 meters. Vertical samples were obtained from a pump sampler deployed in a CTD frame. Zooplankton samples collected by pump were filtered through a 333 μ mesh and the volume of the water sampled was recorded with a 1" water meter. Field samples were chilled or preserved in isopropyl alcohol and counted within 48 hours of collection and the results of the zooplankton observations were expressed in organisms/m^3.

CTD casts were made at all zooplankton stations. Data from the CTD were downloaded to an on-board computer and represented graphically using the Seasoft graphics programs. The data collected from the CTD is archived and made available to DMF and other interested parties.

During the 2001 – 2002 seasons, in support of ongoing DMF efforts to manage the Cape Cod Bay fixed gear fisheries with respect to potential gear entanglements, we reported to DMF by email the general characteristics of Cape Cod Bay from rough estimates of zooplankton density. These first efforts to produce post-cruise briefing documents included very general information on the plankton densities that control whale distribution, physical conditions of the water column, and identification of regions of the bay where dense fields of fixed fishing gear were observed. In 2001 and 2002 these

reports were delivered to DMF to give the agency a quick image of the factors controlling the whales' distribution and occurrence and to identify areas potentially needing DMF management action. In 2003 our efforts evolved toward the collection of precise information that could be used in a transparent evaluation process similar to that which managers might use to make decisions depending on the potential for Cape Cod Bay to support aggregations of whales in areas where whale – industrial conflicts were possible. The analysis we employed for this first effort was to define the conditions in the bay from samples taken at fixed stations in all four quadrants of the bay and to rapidly present the results to interested parties using an emailed template developed for the purpose. The methods used for evaluating the collections are similarly described in the preamble to the cruise reporting system (Appendix II) and help describe the foundation philosophy.

To use this habitat evaluation tool most effectively, it is essential to understand the conditions that govern the movement and aggregation of whales. Such an understanding must relate to the scale at which right whales make decisions. This initial effort to evaluate Cape Cod Bay incorporated the simple understanding that whales, during foraging activities, make decisions, probably continuously, that lead to the aggregations typical of the species. Similarly, the behavior that places whales at the greatest risk for lethal entanglement and collision, that of feeding, is based on simple decisions that can be predicted from an analysis of the food resource compared with benchmark values that describe the whales' responses to the habitat.

The evaluation of Cape Cod Bay benefits from long term baseline studies against which the conditions observed might be measured. Though the details of the Cape Cod Bay resource that supports right whale aggregation and feeding, or lack thereof, may be specific to the bay, benchmark values (e.g. feeding threshold) may nevertheless be of considerable use in evaluating other habitats not studied in equal depth. The use of this method to assist in management decisions in other habitats requires some baseline study, however it is likely that food resources generally influence the whales' aggregative behavior wherever the whales are found in high latitudes. Thus, this method's application to areas of potential fisheries and shipping risk, while requiring some baseline study, can be projected throughout the feeding range of the species. In particular, we suggest that areas being considered for or being subject to regulation of industry activities could be assessed and the results used to predict aggregation, dispersion, or continued residency of whales, substantially improving the sensitivity and timing of management decisions.

Principals

The goal of this assessment form presented in a report template is to display in timely fashion information that is useful for evaluating the food resource conditions influencing right whale aggregative behavior. Because this is the first effort to develop such an evaluation instrument, the structure of this method will likely evolve and its accuracy will improve. Below the elements of the evaluation and some of the underpinnings of the approach we have taken are described.

The assessment forms are completed and distributed between 36- 48 hours after each cruise, thus the techniques used to produce it have been streamlined and automated to permit the required rapid assessment

- The details of the zooplankton collection, counting, and analysis are available on request.
- Several "benchmark" values (e.g. feeding threshold zooplankton density) are presented below to place the observations in context. Many of these benchmarks are part of an evolving understanding of the factors that control the coalescence and durability of whale aggregations.

- The text interpretations of the observations are attached to the assessment form in order to add to the reader's understanding of how the information may be used to predict the attractiveness of Cape Cod Bay to right whales.

Details of the Draft Assessment Template

1. The assessment form is created in Microsoft Excel and disseminated in a .pdf file.

2. Julian Day (JD) is used throughout to aid in plotting. JD is counted continuously from 1 January through the year.

3. Table (upper left corner of form) presenting sampling detail and the four estimated measures:

   Collection Technique: techniques for collection are surface or oblique conical metered net, vertical pump, or transect sampler. The mesh of all samplers used in the assessment work is standardized at 333μ to approximate right whale baleen filtration (Mayo, Letcher, and Scott, 2001).

   Station: The stations listed are the fixed locations from which samples of zooplankton are and have been collected in Cape Cod Bay. Additional stations are occasionally added in areas of whale aggregation or at locations in which there is special interest. Collections at special stations are noted as such and not used in general characterization of the bay system.

   Total Zooplankton/m^3: This value is a particle count, an estimation of the number of zooplankters that a right whale would filter from one cubic meter of seawater. For comparison with a benchmark, we have estimated the right whale feeding threshold at 3,750 org/m^3. The threshold measure is useful because it gives a value, against which one may compare any calculated density, that describes a quality of the environment likely important in the foraging strategies of the feeding animal.

   Settled Volume/m^3: Settlement of metered samples gives a measure of the bulk of zooplankton available to a feeding right whale. At present we do not have a benchmark against which we can compare the observations. However, this measure may be particularly instructive if right whales' decision-making processes are based on near-real-time evaluation of the bulk of the zooplankton harvested or on gut fullness.

   Total Calories/m^3: The caloric value of the taxa of zooplankton collected in Cape Cod Bay is estimated from the literature. This value is calculated from species counts (with coarse staging of the principal taxa) to give an approximation of the caloric density of the capturable zooplankton resource. The benchmarks against which this value may be compared are 690 cal/ m^3, the estimated caloric density of the feeding threshold, and 2,430 cal/ m^3**,** the mean caloric density in feeding areas of Cape Cod Bay 1984-1999. These values permit a comparison with right whale requirements suggesting the suitability of the environment may influence decision-making based on energy capture, and possibly reflected in the whale's fitness. Depending on how a whale might assess the intake of energy, this measure may be reflected either in short- (minutes and meters) or medium- (days/weeks and 1000's of km) term decisions involving feeding and movement. We anticipate that information from Amy DeLorenzo's doctoral thesis (URI, with E. Durbin) will improve this estimate.

Total Dry Weight/m^3: This value is of use for assessment of nutritional intake. No benchmark comparator is available at present.

We assume that taxa that are known to support observed feeding in Cape Cod Bay, *Calanus, Pseudocalanus, Temora*, and *Centropages*, are suitable to lead to aggregative behavior and provide the cues required for feeding. At present a zooplankton resource containing those species is considered acceptable in composition. It should be noted that all measures of *Pseudocalanus* in text and graphics refer to a complex of taxa of similar character composed of species of *Pseudocalanus, Paracalanus,* and *Clausocalanus.*

At the bottom of the framework form, two rows of simple graphs place the observations of a cruise in context. These show the trends of the four assessment measures described above for all samples of Cape Cod Bay (upper row of graphs with a linear regression plotted) and for the four quadrants of the bay (lower row with fitted curves plotted). This display shows the overall trends in the data for the bay and for portions of the bay and offers context for the observations of the individual cruise.

* Note: The patterns of the four assessment measures are similar, offering like pictures of the environment encountered by a searching right whale. The similarity in trends will continue as long as the taxonomic and stage composition of the samples remains the same. We observed that the similarity in relationship between the measures was disrupted by an influx of *Calanus finmarchicus* during March. The *Calanus* – rich resource displayed a higher settled volume, caloric density, and dry weight per organism density than seen with the early-winter samples, a reflection of the greater value of late stage *Calanus* with respect to the measures.

Results

The results of the 2003 study of the Cape Cod Bay habitat are presented in two appendices. General observations of habitat conditions and those closely associated with right whale presence, including assessment of conditions in the vicinity of feeding whales, and inter-annual comparisons, are found in Appendix I. The daily assessment reports and associated text interpretations as distributed after each cruise are bound in Appendix II. Together these reports represent a description of the conditions that influenced right whale presence in Cape Cod Bay in 2003 and add to the baseline understanding of the conditions that provide for a good feeding environment.

Discussion

The descriptions of Cape Cod Bay contained in Appendix I demonstrate that the system was comparatively unproductive with respect to midwater copepod resources during the usual early and middle period of right whale residency season, with comparatively low *Centropages* spp. and *Pseudocalanus* complex densities found during January and February. The low copepod biomass during these months mimicked conditions that were observed during 2001 and 2002 and were, as shown in Appendix II and in the aircraft survey chapter of this report, reflected in low right whale densities during the mid-winter months when, in the period 1984 – 1999, whales were commonly found in the bay. As in past years, changes in whale density in 2003 appeared to be a response to variations in zooplanktonic food density.

The cause of the low early-season zooplankton densities cannot be ascribed to specific conditions within the system or adjacent waters, however the fundamental controlling influence of the zooplankton resource on the residency of whales is clearly demonstrated.

In March, around Julian Day 100, the first indications of an impulse of zooplankton biomass were seen, first as increasing density of *Pseudocalanus* and *Calanus* in samples from oblique net collections. This observation suggests, as shown in Appendix I data, that the calanoid resource entered the bay through advective processes and likely radiated throughout the water column thereafter. Thus, by JD 113 the peak seen in the mid – waters was observed in surface samples. As this pulse of zooplankton developed it resolved into a patch dominated by *Calanus,* while the *Pseudocalanus* resource declined in density. The initial pattern of enrichment, while generally similar to that seen in past seasons, was not, as is the usual case, followed by a period of several weeks of high surface and mid-water resource, but instead was followed immediately by a sharp decline in resource densities that reached low values on JD 120.

The responses of whales to the aforementioned changes in resource are contained in the air survey portion of this report and in Appendix II. These assessment forms in Appendix II present a weekly tracking of changes in the fundamental characteristics of the system that lead to the patterns of residency by right whales that are of interest to DMF. While the forms presented here have already been submitted to DMF and incorporated in their management actions, an evaluation of the effectiveness of such system should be made.

The initial effort to develop a new tool for documenting and predicting the occurrence of right whales in the Cape Cod Bay habitat has proven successful. In combination with the cruise reports, the plot of whale density index against estimated zooplankton density (see Appendix II) demonstrates the association between the two variables and the value of zooplankton density assessment for determining the potential of the bay to cause the aggregation and residency of right whales. Because the assessment protocol we undertook in 2003 was built on a variety of analytical and interpretative methods structured specifically to test the use of zooplankton assessment as a management tool, improvements in the method can be proposed for use during the 2004 season. Changes in the methods are expected to increase the certainty of the predictions in 2004 and thereby improve the ability of DMF to use the assessments to manage the Cape Cod Bay system.

We propose the following additions and improvements for incorporation in 2004 assessment studies:

1. The number of samples on which the individual cruise analyses are based be increased, as possible, to a minimum of 8 stations (2 per quadrant of the bay).

2. Collections made at predetermined stations selected from the suite used in 2003. These fixed stations should be selected based on their representative characteristics.

3. Continue sampling using oblique net techniques to reach depths of 19 m, where water depth permits, to test the hypothesis that deep zooplankton resources are important predictors of future enrichment.

4. An automated method for analysis of zooplankton (either an Optical Plankton Counter or Video Plankton Recorder) be incorporated into the assessment protocols. An automated system of analysis will substantially increase both the speed and the detail of the assessment while offering the synoptic view of the system needed by DMF for time/area management of fixed fishing gear.

Literature Cited

Mayo, C., M. Brown, A. DeLorenzo, and M. Bessinger. 2001. Using Food Density to Predict Right Whale Occurrence and Movements in Cape Cod Bay: 2001. Final Report submitted to Division of Marine Fisheries, Commonwealth of Massachusetts and Massachusetts Environmental Trust, 31 October 2001.

Mayo, C.A., B.H. Letcher and S. Scott. 2001. Zooplankton filtering efficiency of the baleen of a North Atlantic right whale, *Eubalaena glacialis*. J. Cetacean Res. Manage. (Special Issue 2): 225-229

Mayo, C., M. Bessinger, and M. Brown. 2002. Right Whale Occurrence and Habitat Measures in Cape Cod Bay: during a year of change 2002. Final Report submitted to Division of Marine Fisheries, Commonwealth of Massachusetts, September 2002.

CTD CASTS								PLANKTON SAMPLES: Zooplankton (Phytoplankton)					
Cruise	**Date**	**On Station**	**Off Station**	**Pump Casts**	**Transects**	**Vertical Casts**	**Total**	**On Station Surface Tows (Bucket Samples)**	**Off Station Suface Tows (Bucket Samples)**	**Pump Samples**	**Transect Samples**	**Oblique Tows**	**Total**
SW306	9-Jan	1	.	.	.	1	1	2 (2)	.	.	.	.	2 (2)
SW308	19-Jan	6	.	.	.	6	6	6 (6)	.	9 (3)	.	.	15 (9)
SW309	25-Jan	7	.	.	.	7	7	7 (7)	.	.	.	.	7 (7)
SW310	29-Jan	9	.	.	.	9	9	9 (9)	.	18 (6)	.	.	27 (15)
SW311	7-Feb	7	.	.	.	7	7	7 (7)	.	12 (5)	.	.	19 (12)
SW312	10-Feb	8	.	.	.	8	8	8 (8)	.	14 (6)	.	.	22 (14)
SW314	20-Feb	10	.	.	.	10	10	10 (10)	.	20 (10)	.	.	30 (20)
SW315	21-Feb	8	.	.	.	8	8	8 (8)	.	17 (7)	.	.	25 (15)
SW316	27-Feb	8	.	.	.	8	8	8 (8)	.	15 (5)	.	.	23 (13)
SW318	7-Mar	6	.	.	.	6	6	6 (6)	.	6 (2)	.	6	18 (8)
SW319	13-Mar	7	.	.	.	7	7	7 (7)	.	.	.	7	14 (7)
SW320	17-Mar	5	.	.	.	5	5	5 (5)	.	12 (5)	24 (8)	5	46 (18)
SW321	23-Mar	.	.	.	.	CTD in for repairs		7 (7)	.	14 (5)	.	7	28 (12)
SW322	24-Mar	.	.	.	.	CTD in for repairs		2 (2)	.	.	.	3	5 (2)
SW323	2-Apr	.	.	.	.	CTD in for repairs		7 (7)	.	10 (4)	.	7	24 (11)
SW325	9-Apr	.	.	.	.	CTD in for repairs		1 (1)	1 (1)	7 (3)	.	2	11 (5)
SH001*	15-Apr	.	.	.	.	.	.	(3)	.	.	.	3	3 (3)
SW328	19-Apr	5	1	.	.	6	6	6 (6)	.	7 (4)	.	7	20 (10)
SW330	23-Apr	8	.	1	.	7	8	7 (7)	.	9 (2)	.	7	23 (9)
SW333	30-Apr	5	1	.	.	6	6	5 (5)	(1)	.	.	6	11 (6)
SW334	4-May	7	.	.	.	7	7	7 (7)	.	16 (7)	.	7	30 (14)
SW336	10-May	7	.	.	.	7	7	7 (7)	.	.	.	7	14 (7)
SW338	14-May	2	.	.	.	2	2	2 (2)	.	11 (9)	.	2	15 (11)
							118	**134 (137)**	**1 (2)**	**197 (83)**	**24 (8)**	**76**	**432 (230)**

**SH001 provided 3 opportunistic samples collected in CCB by a collaborator from the University of Rhode Island*

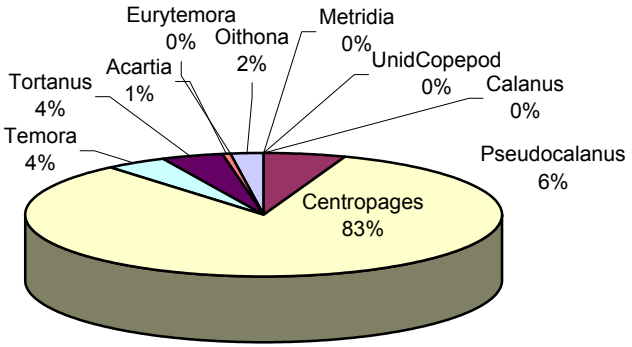
Table 1. **2003 Cape Cod Bay Habitat Cruises and Collected Samples.**

Appendix I

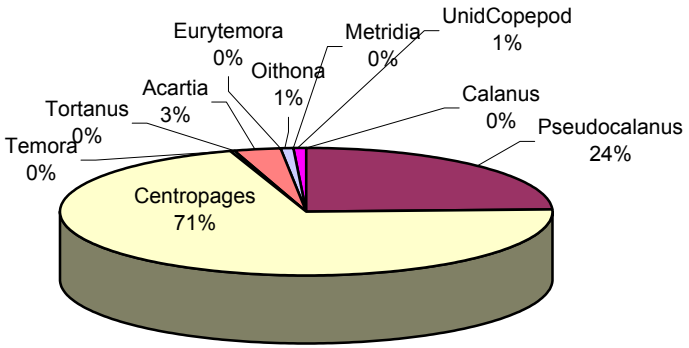
System Data Record with Inter-annual Comparisons - 2003

Cape Cod Bay surface layer copepod composition averaged for the month of January, 1999-2003.

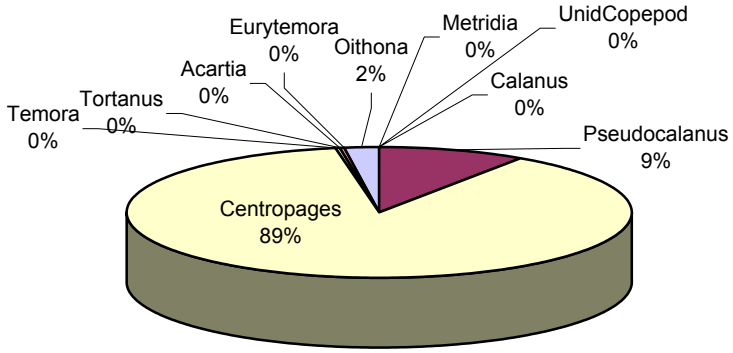
1999



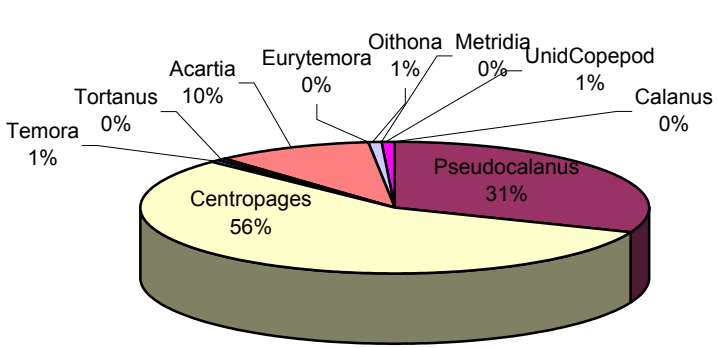
2000



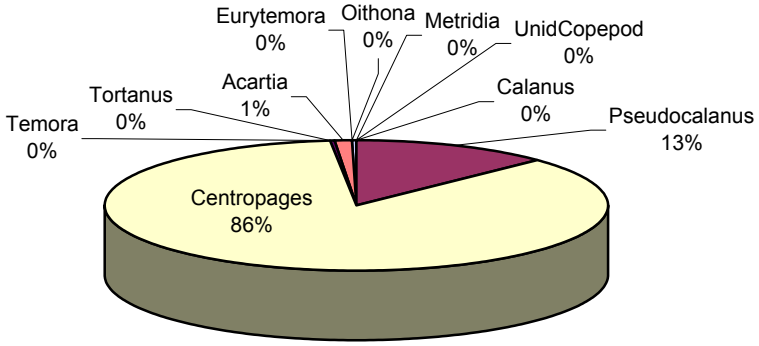
2001



2002

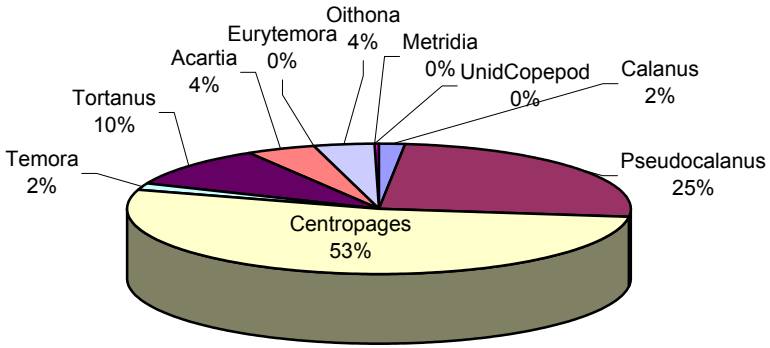


2003

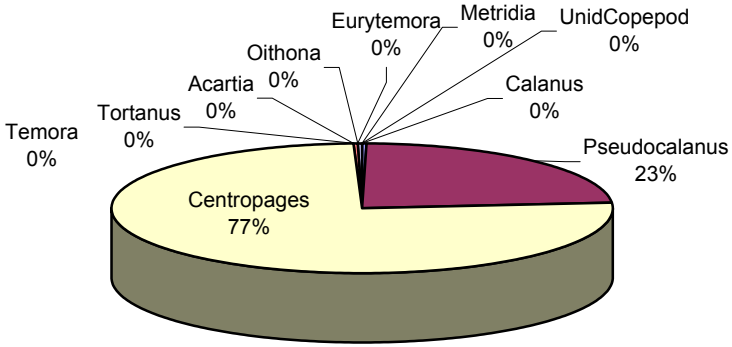


Cape Cod Bay surface layer copepod composition averaged for the month of February, 1999-2003.

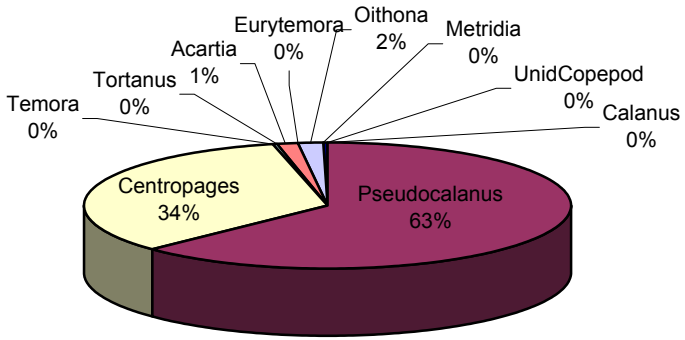
1999



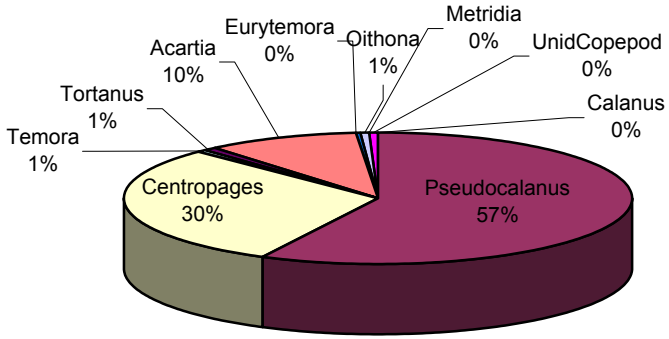
2000



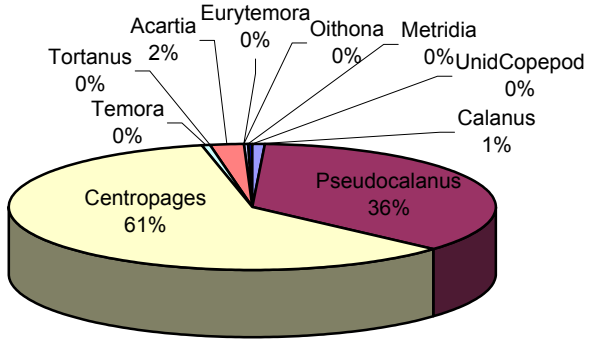
2001



2002

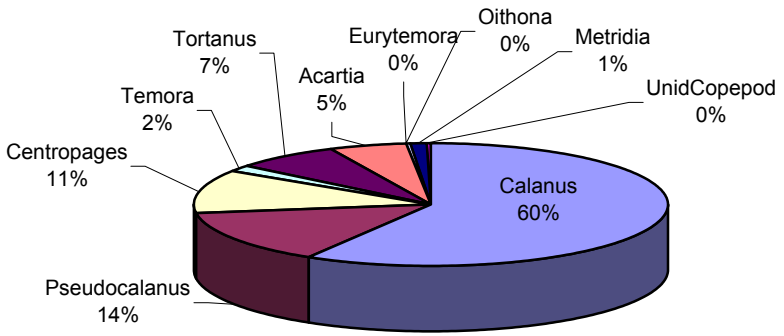


2003

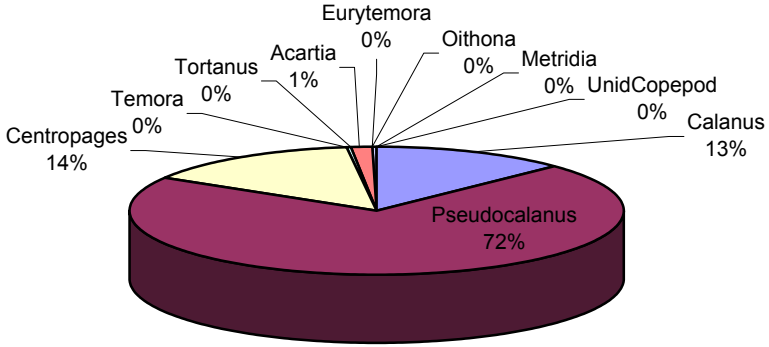


Cape Cod Bay surface layer copepod composition averaged for the month of March, 1999-2003.

1999



2000



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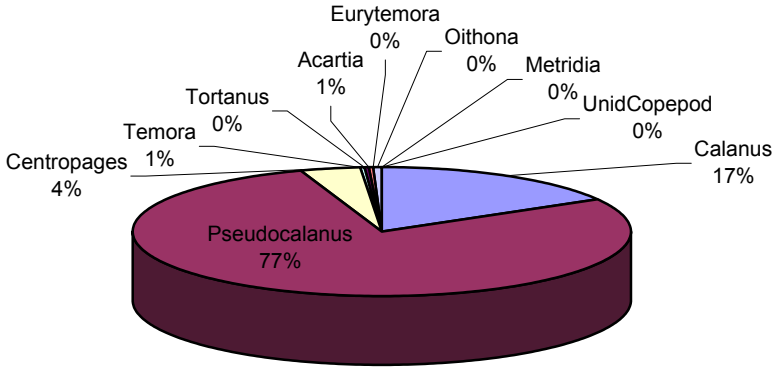

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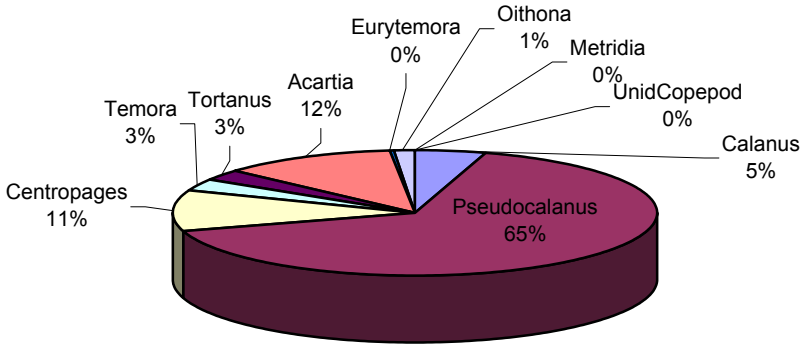
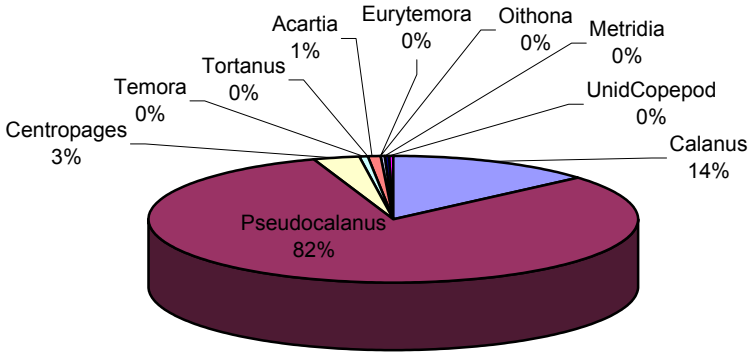
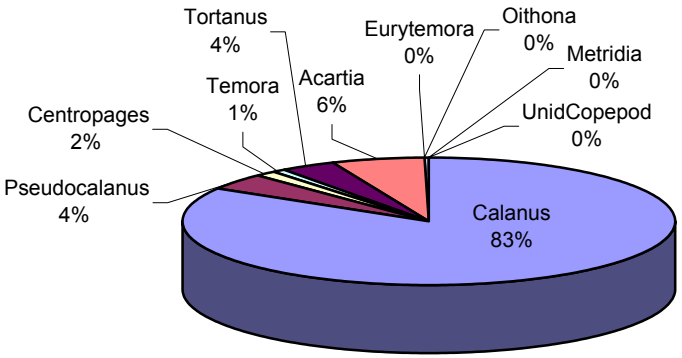


2003



Cape Cod Bay surface layer copepod composition averaged for the month of April, 1999-2003.

1999



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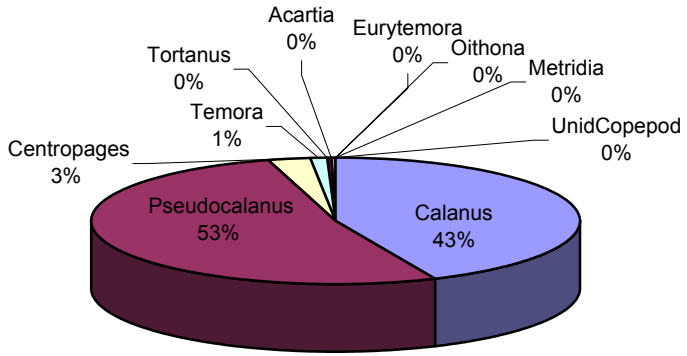

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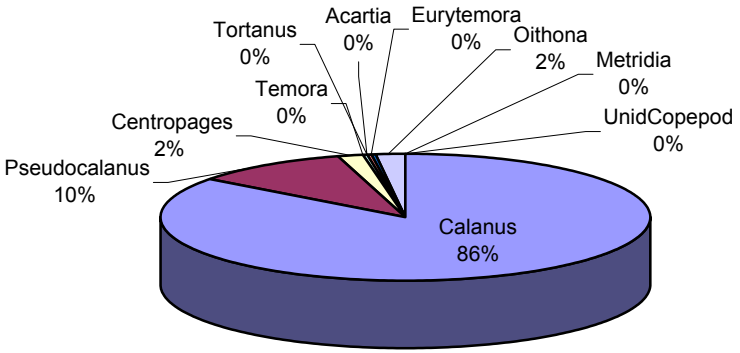

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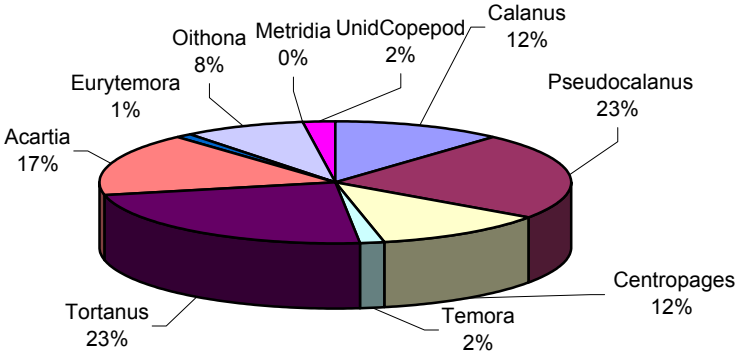

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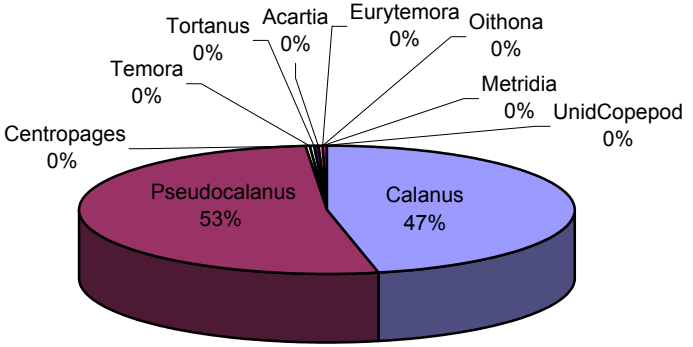
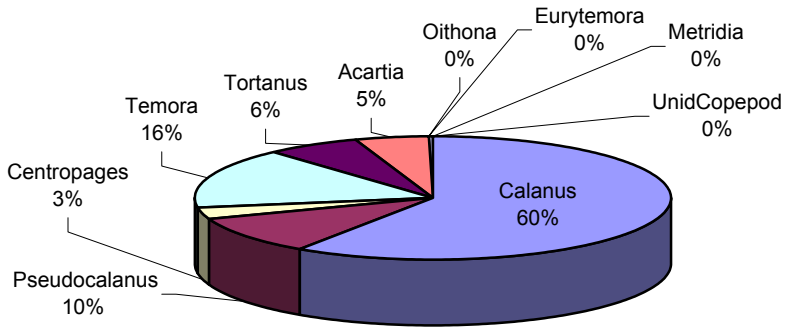


Cape Cod Bay surface layer copepod composition averaged for the month of May, 1999-2003.

1999



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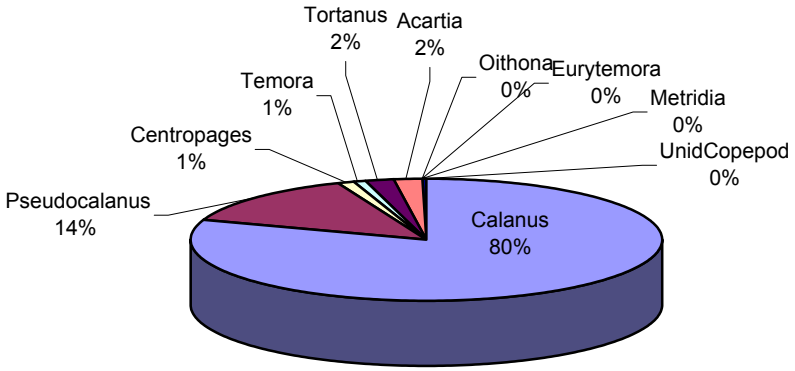

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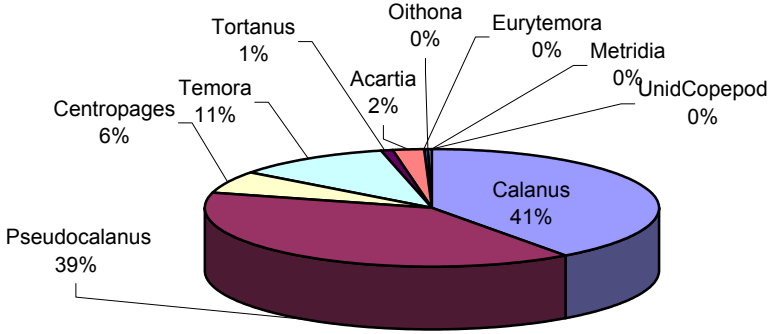

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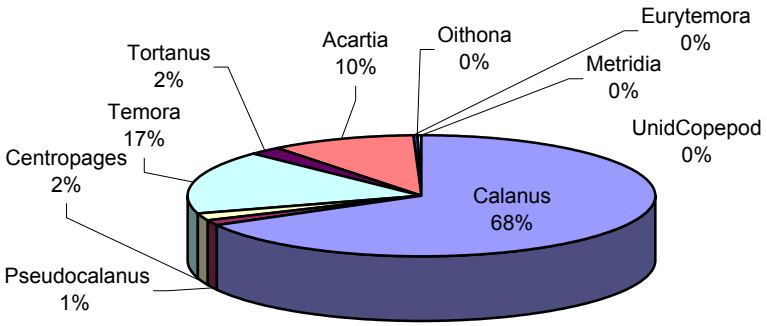
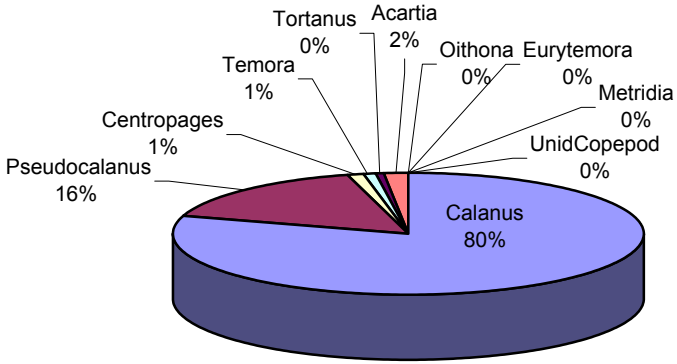
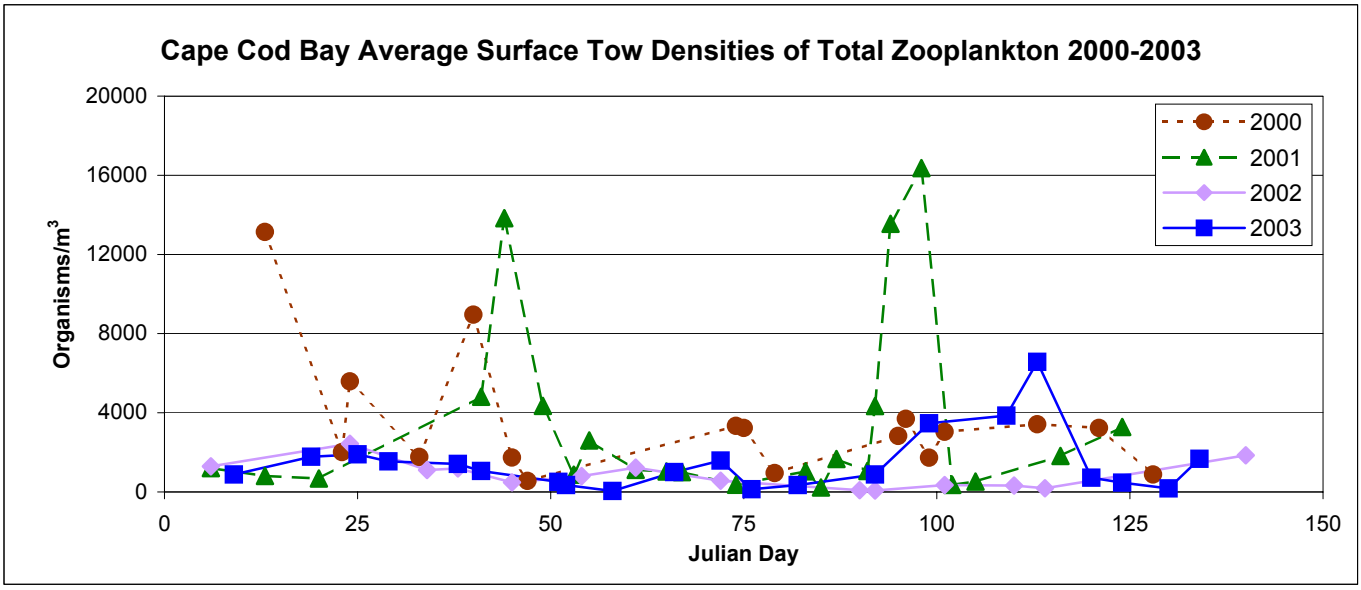
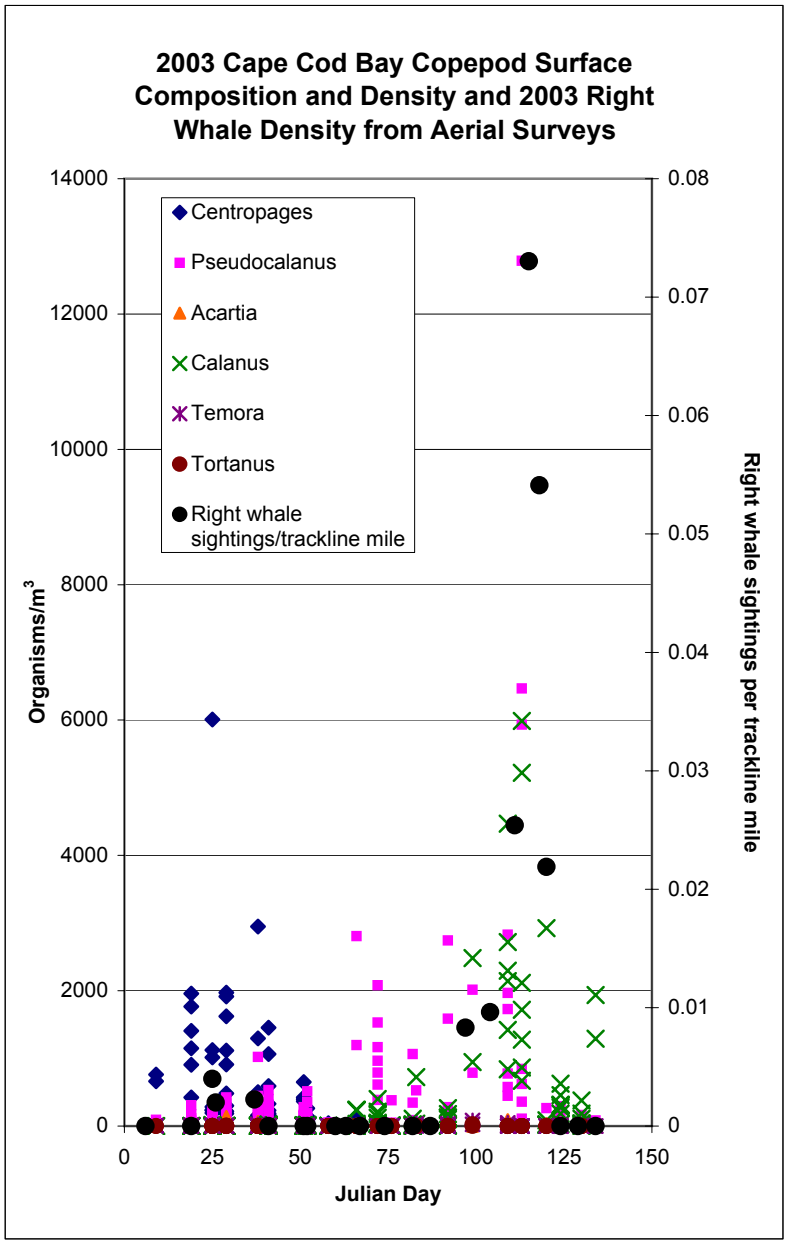


2003

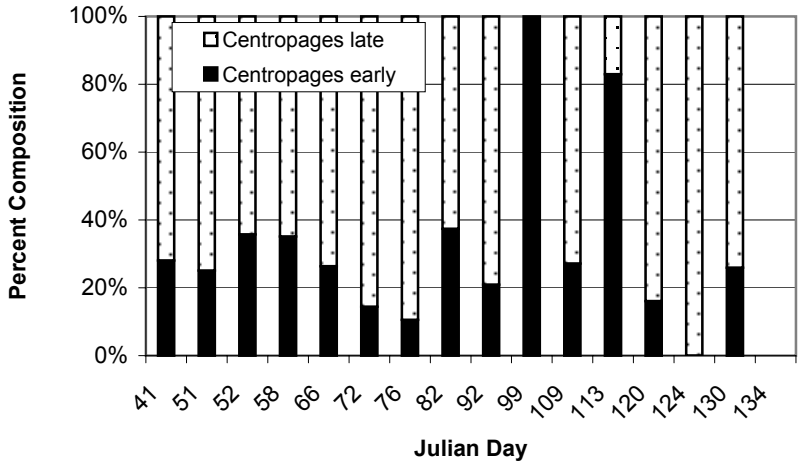



Cape Cod Bay Average Surface Tow Densities of Total Zooplankton 2000-2003
Organisms/m3
20000
16000
12000
8000
4000
0
0
25
50
75
100
125
150
Julian Day
2000
2001
2002
2003

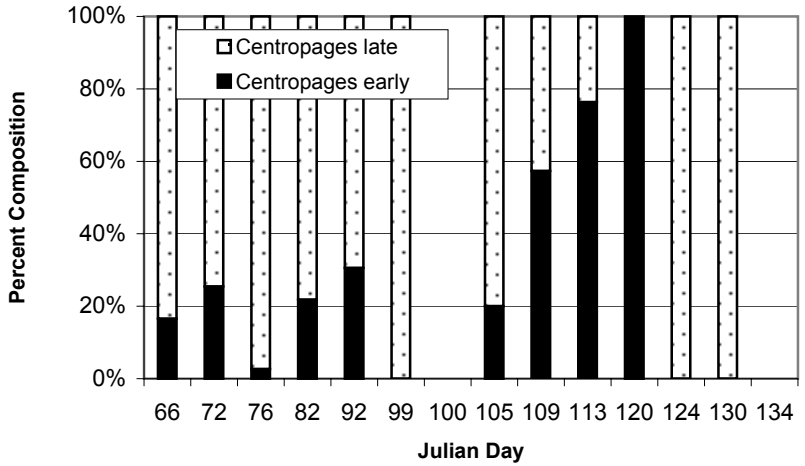

2003 Cape Cod Bay Copepod Surface Composition and Density and 2003 Right Whale Density from Aerial Surveys
Organisms/m3
14000
12000
10000
8000
6000
4000
2000
0
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
Right whale sightings per trackline mile
0
25
50
75
100
125
150
Julian Day
Centropages
Pseudocalanus
Acartia
Calanus
Temora
Tortanus
Right whale sightings/trackline mile

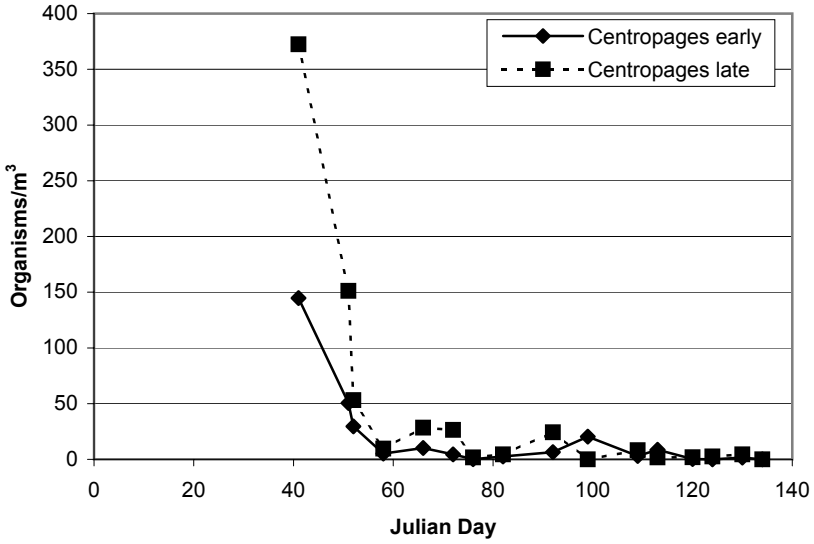
Cape Cod Bay 2003 Average Zooplankton Density Graphs for early and late-stage *Centropages* spp.

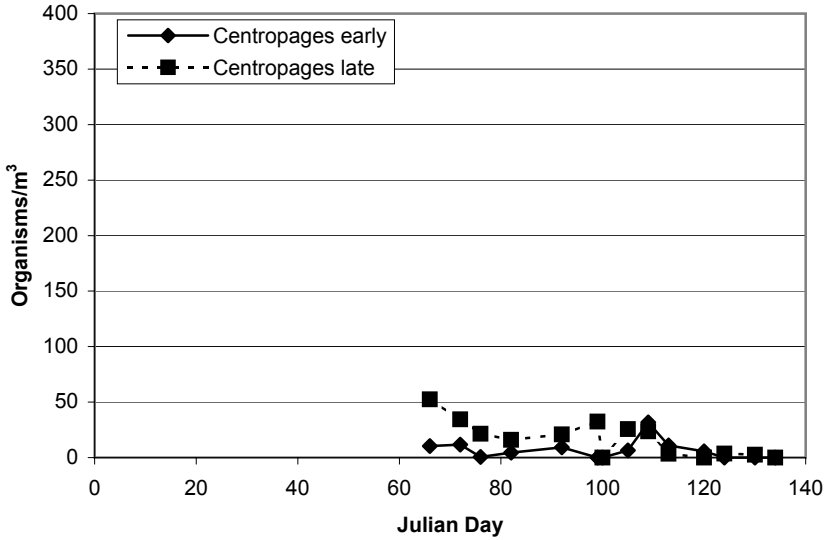
Surface Samples



Oblique Samples

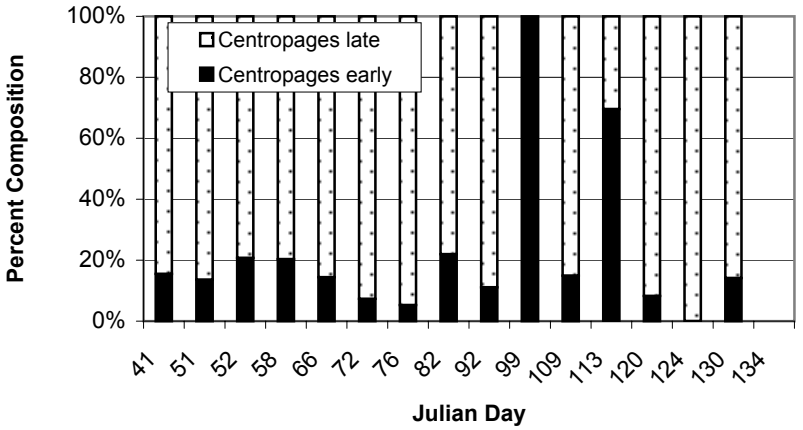




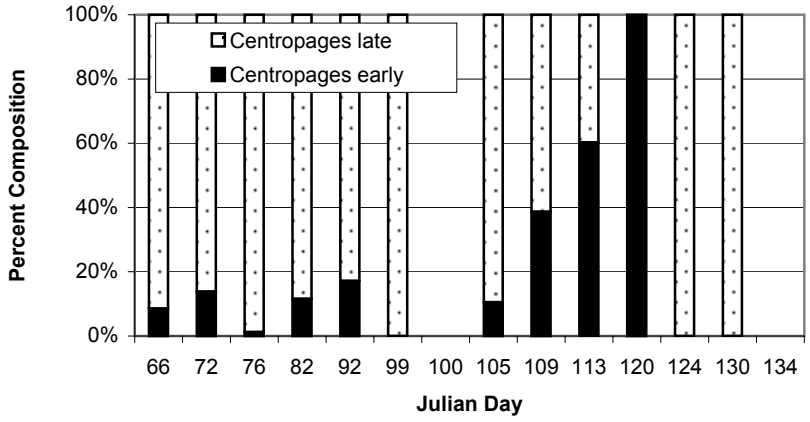


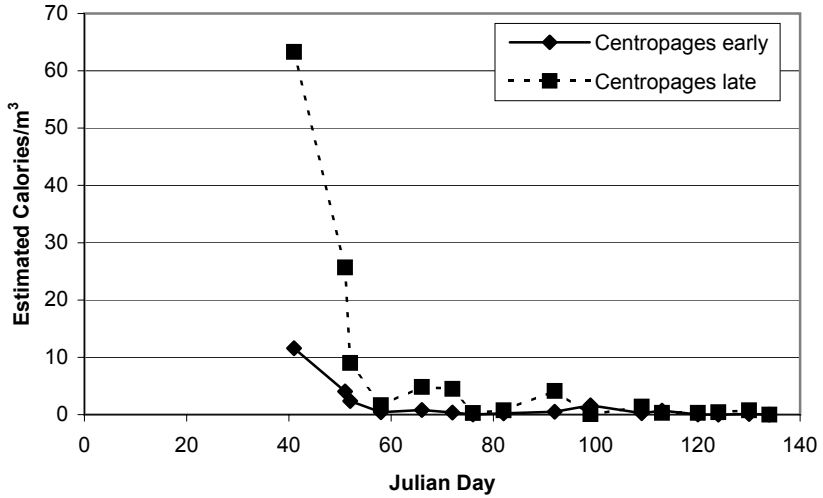
Cape Cod Bay 2003 Estimated Caloric Density Graphs for early and late-stage *Centropages* spp.

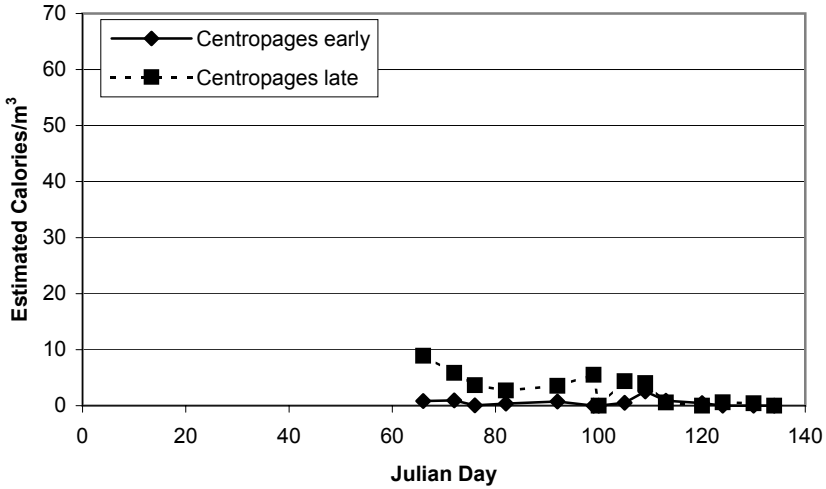
Surface Samples



Oblique Samples

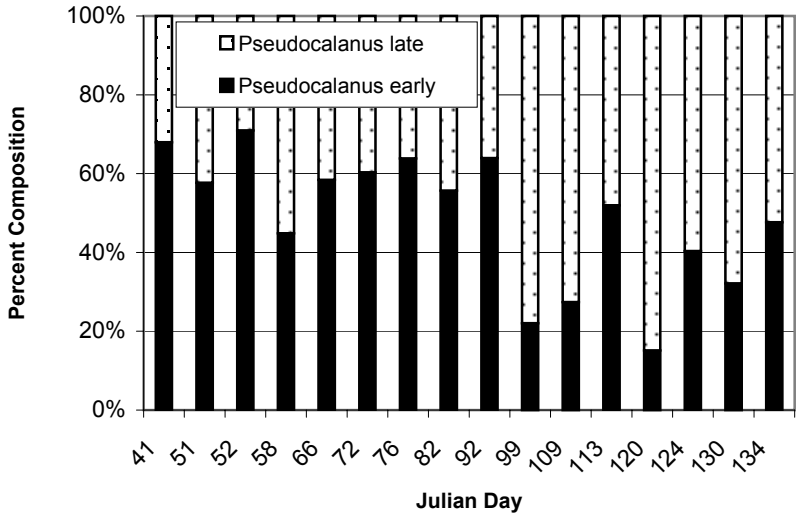




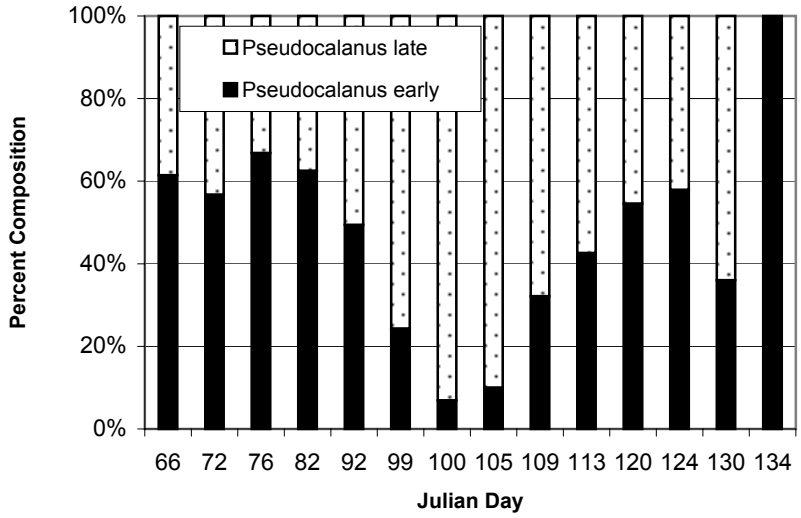


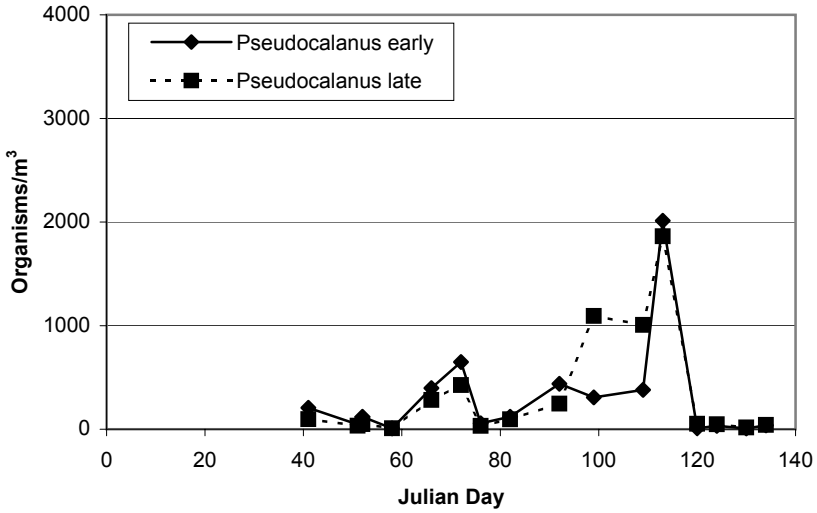
Cape Cod Bay 2003 Average Zooplankton Density Graphs for early and late-stage *Pseudocalanus* spp.

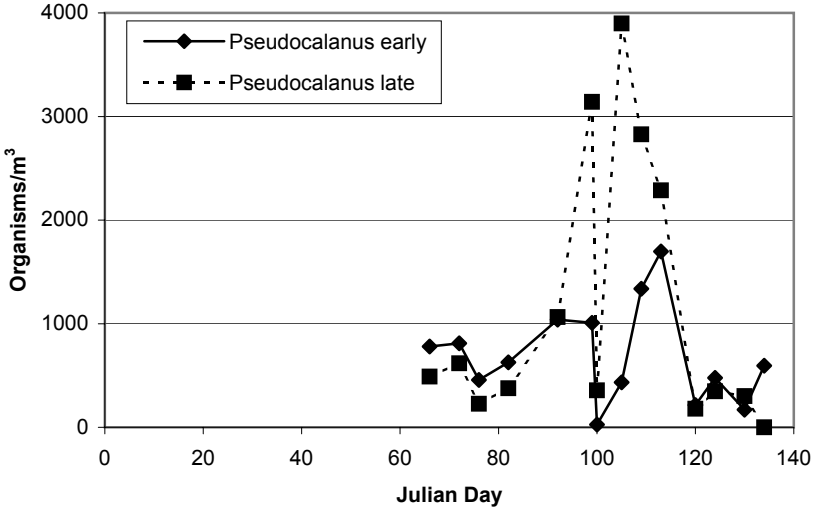
Surface Samples



Oblique Samples

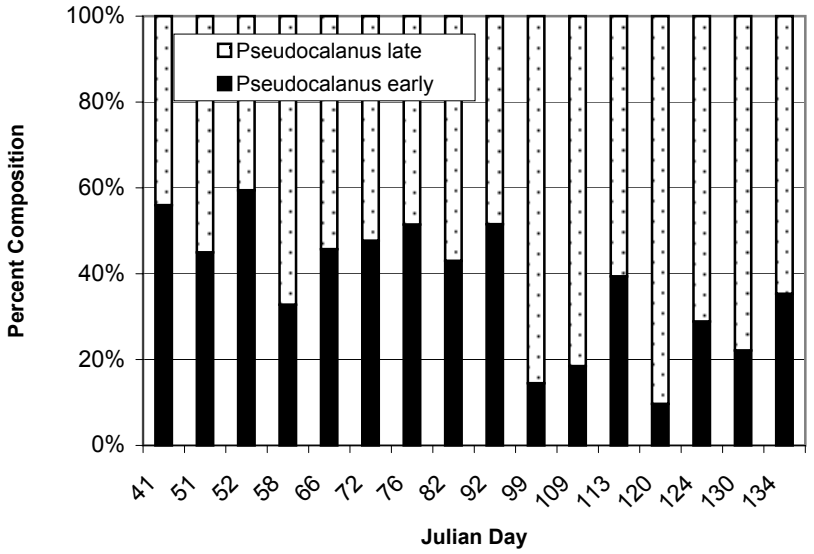




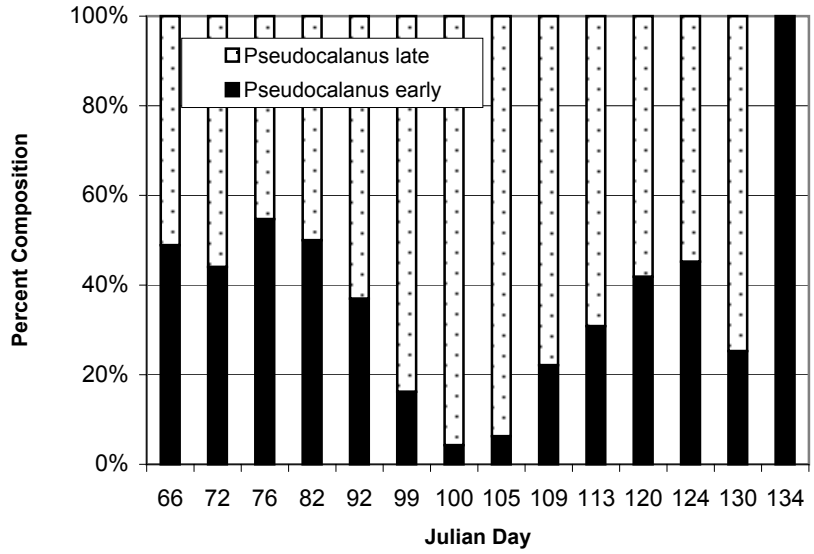


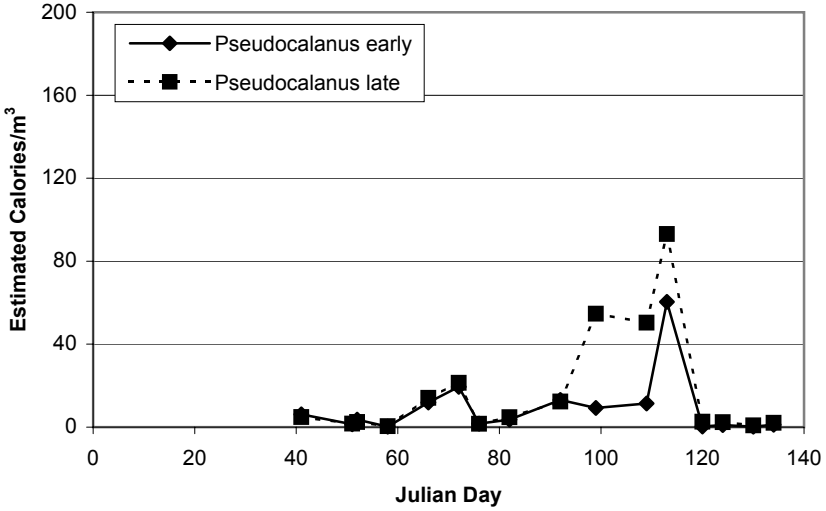
Cape Cod Bay 2003 Estimated Caloric Density Graphs for early and late-stage *Pseudocalanus* spp.

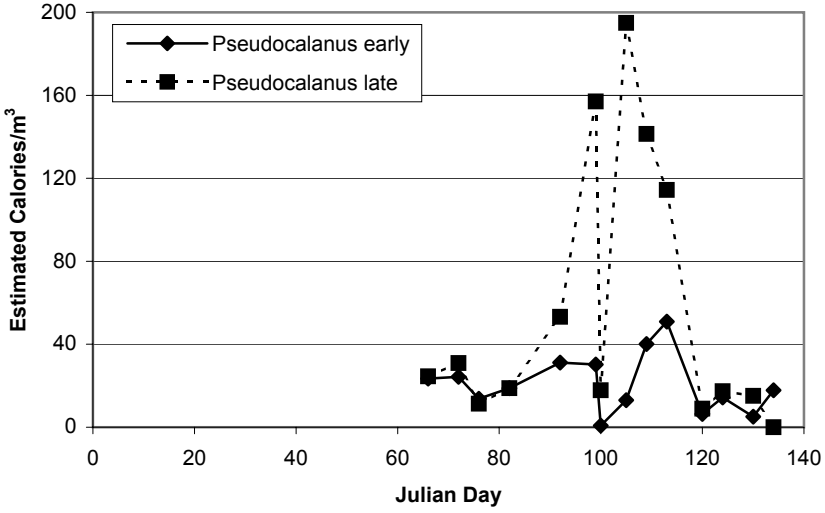
Surface Samples



Oblique Samples

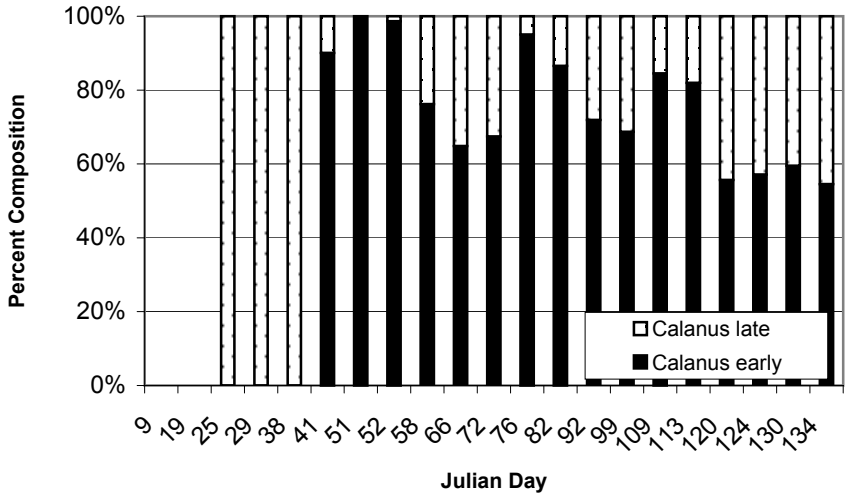




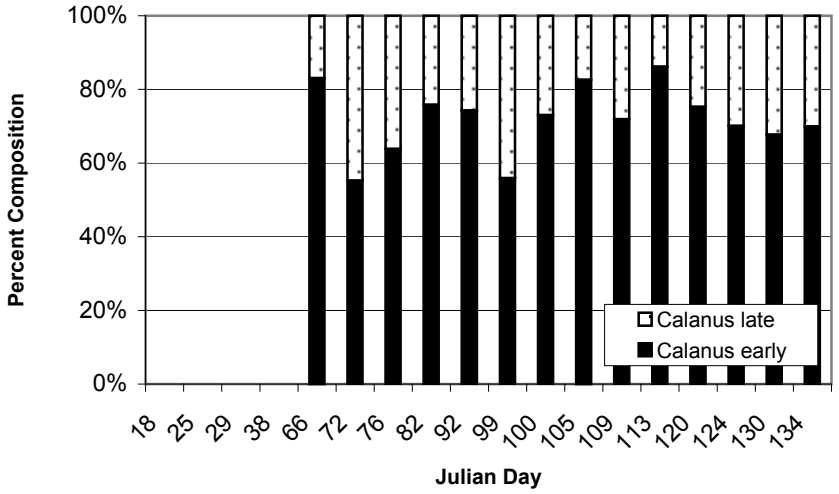


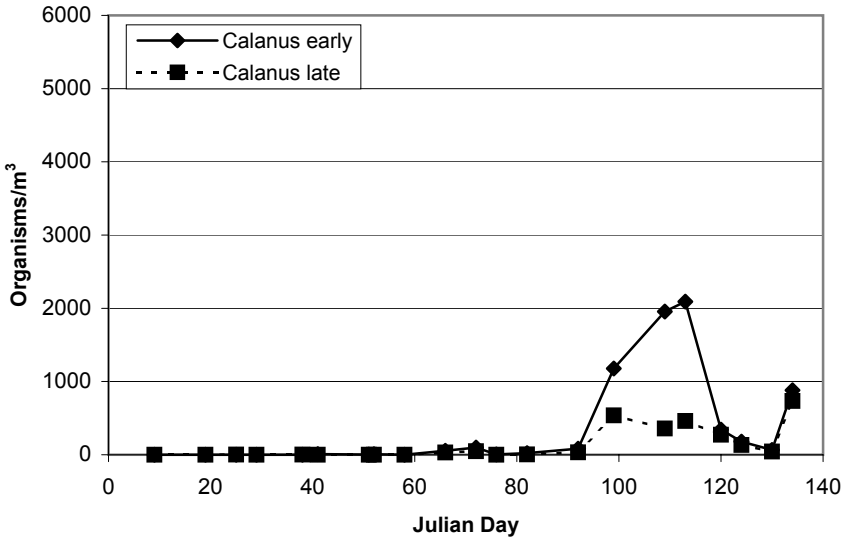
Cape Cod Bay 2003 Average Zooplankton Density Graphs for early (I-IV) and late stage (V-VI) *Calanus finmarchicus*

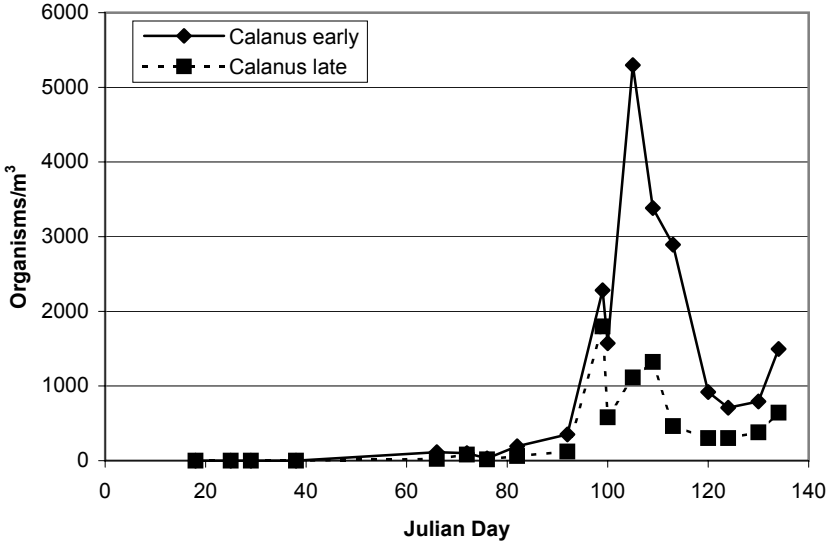
Surface Samples



Oblique Samples

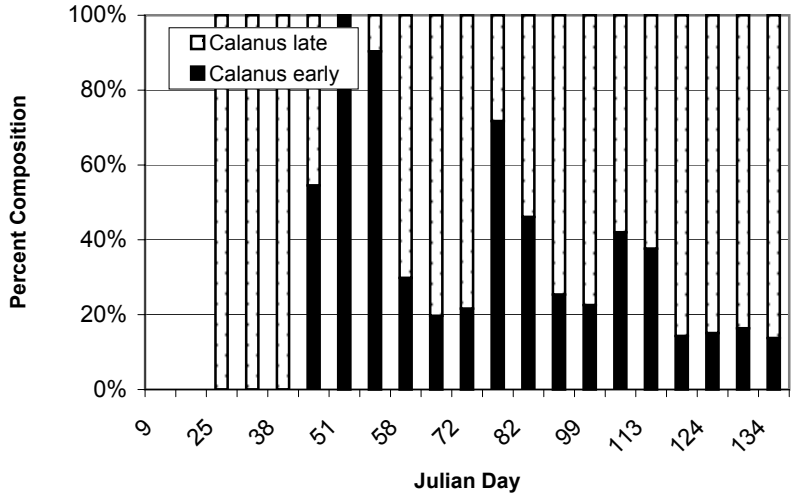




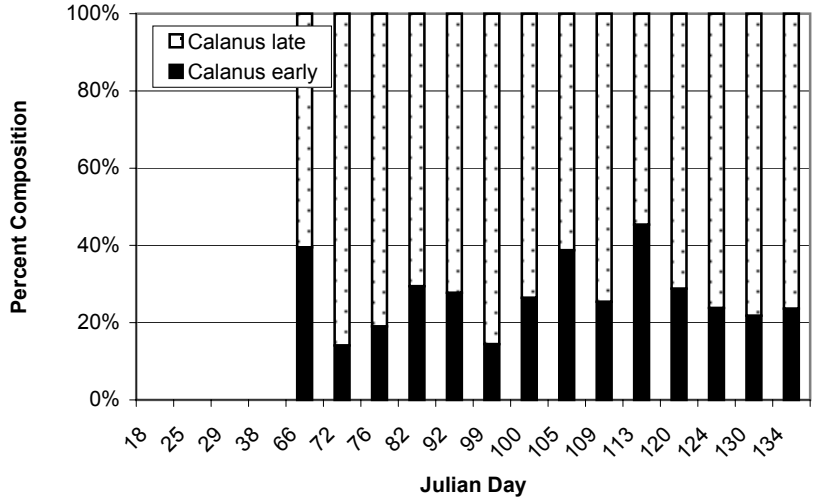


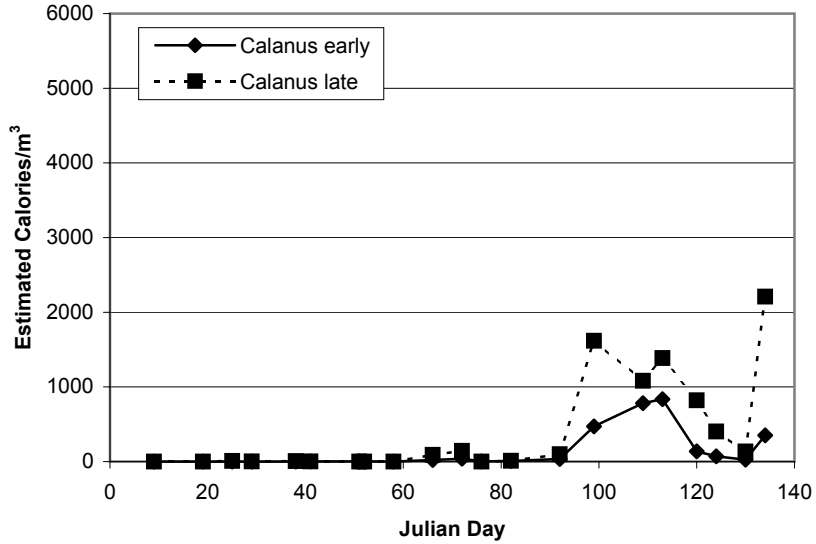
Cape Cod Bay 2003 Estimated Caloric Density Graphs for early stage (I-IV) and late stage (V-VI) *Calanus finmarchicus*

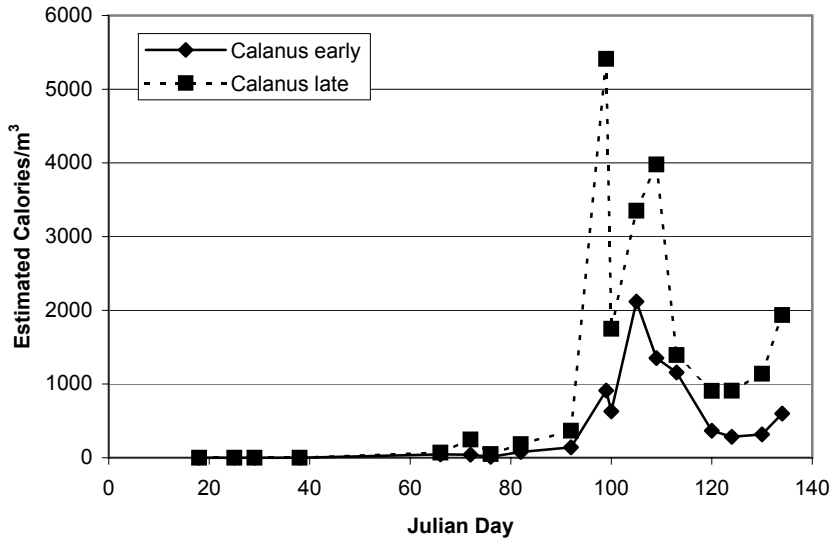
Surface Samples



Oblique Samples

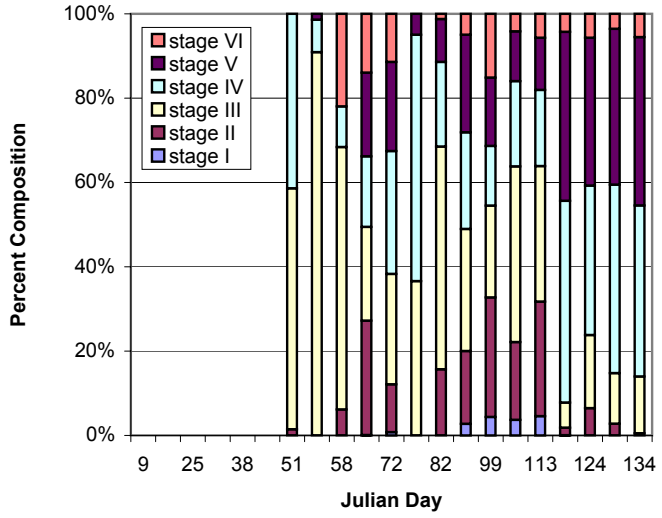




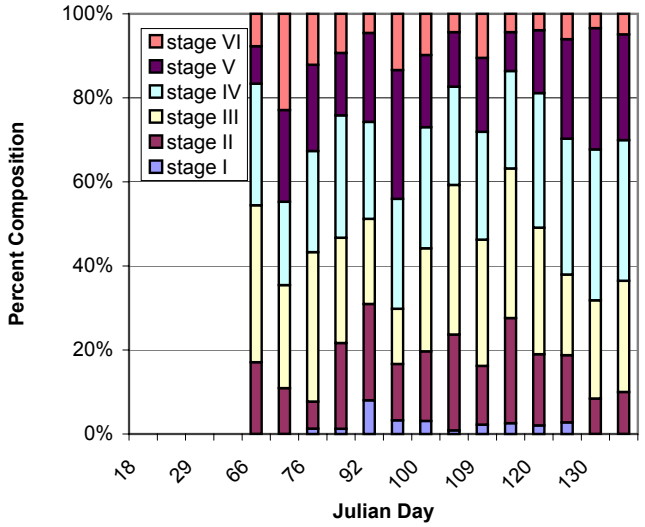


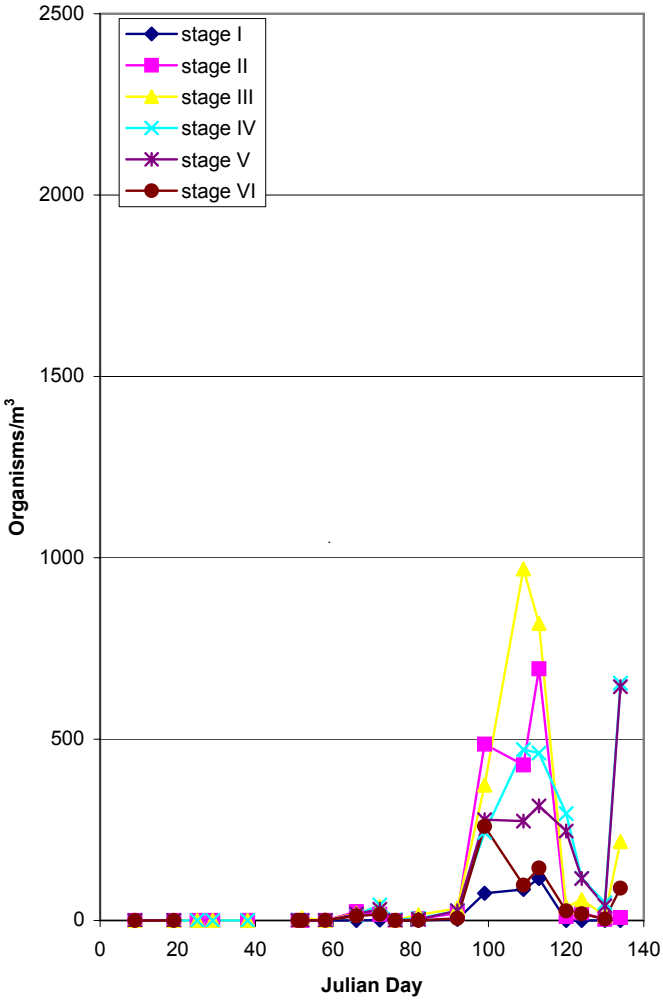
Cape Cod Bay 2003 Average Zooplankton Density Graphs for individual stage *Calanus finmarchicus*

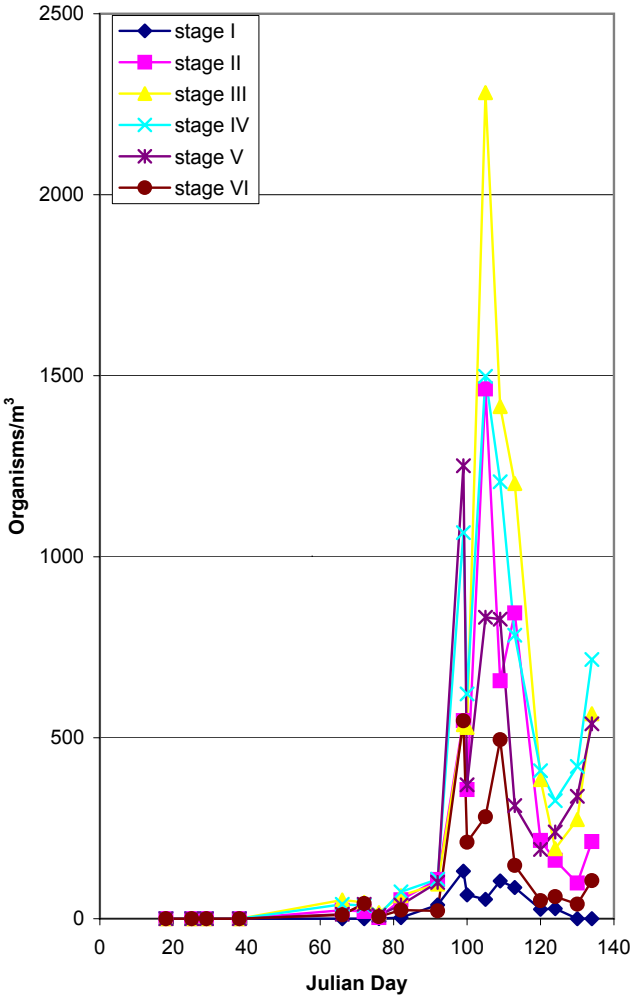
Surface Samples



Oblique Samples

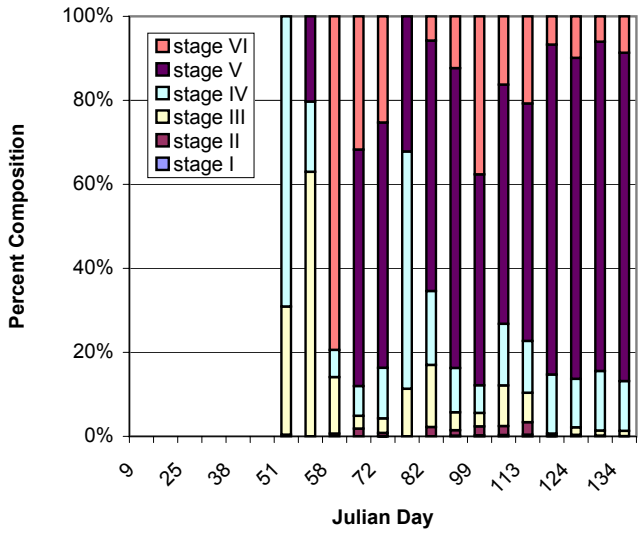




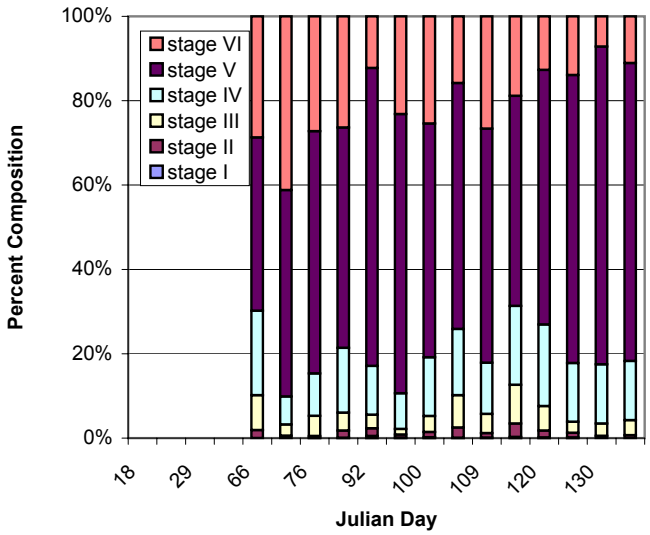


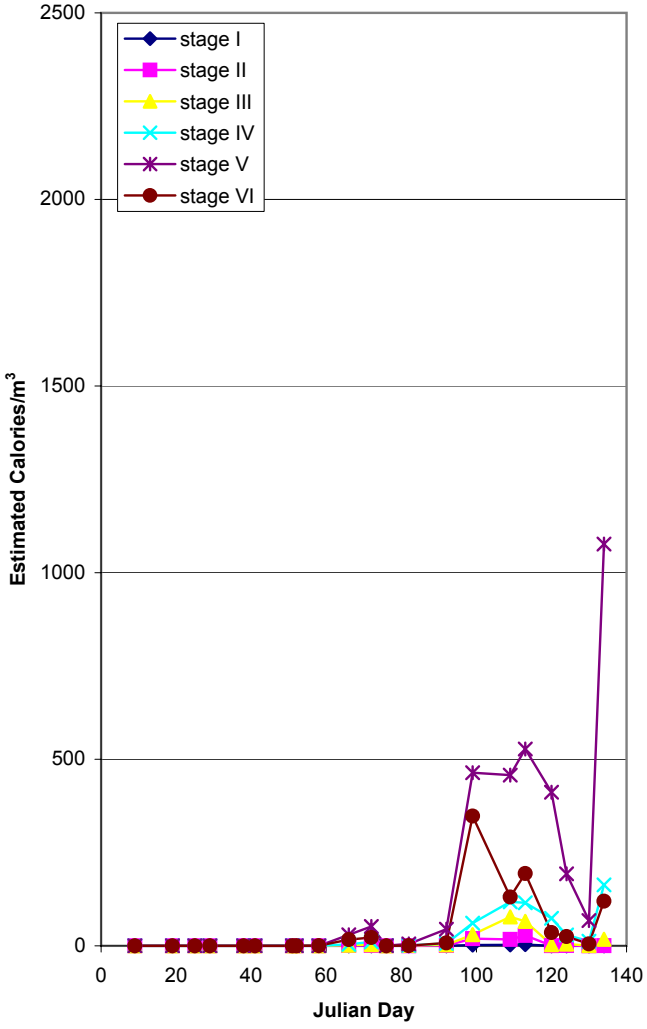
Cape Cod Bay 2003 Estimated Caloric Density Graphs for individual stage *Calanus finmarchicus*

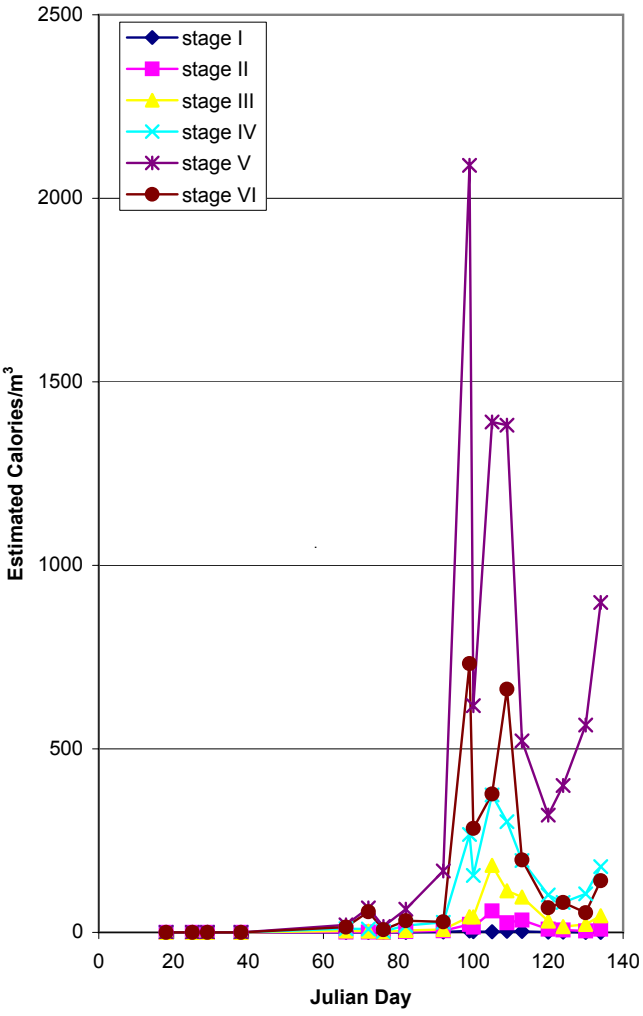
Surface Samples



Oblique Samples







Appendix II

System Assessment and Prediction - 2003

Assessment Description

Introduction

The continuing alarm over right whale mortalities caused by ship strike and entanglement has placed increasing pressure on managers and conservationists to develop new and more accurate methods for reducing risk to the whales. The most difficult problem presently encountered by management agencies is that of locating right whale aggregations and tracking the changes in the temporal and spatial characteristics of the aggregations (e.g. dispersion, behavior, and movement). The dynamic characteristics of right whale aggregations and the great geographic range of the species in the New England waters makes real-time management based on surveillance efforts difficult and desired prediction nearly impossible. It is apparent that new and more precise tools, added to existing methods of management - the use of DAMs and SAMs, the alteration of shipping activities, early warning surveys, and modification of fishing gear in target habitats – are needed to refine and perhaps predict the locations where management actions are needed. It has long been known that the dynamic nature of the aggregations of right whales and the wide region and dispersion of the whales has confounded efforts to reduce mortality caused by fisheries and shipping activities.

For several years we have presented to the Division of Marine Fisheries narrative assessments of the food resource conditions in Cape Cod Bay to aid managers in assessing the potential of the bay to attract and support whale aggregations. In our previous presentations to DMF we drew on baseline data amassed during 18 years of continuous study of the association of whales with the food resources of the bay. Recently, working with Dr. Moira Brown's survey data, we demonstrated that this assessment method could be refined to permit numeric evaluation of the conditions and to allow near-real-time assessment and, probably, prediction. This approach offered a potential new tool for use by managers who are charged with the difficult task of regulating industry activities that may threaten right whales. In 2003, supported by funds from DMF, we have undertaken an effort to improve the use of food resource data for assessment of the habitat for management purposes. The approach we have recently taken involves a simple updatable excel graph set to put the assessment into context and attached to an interpretation sheet. We also have put out (below) some of the benchmark values that may help in reading the graphs.

The following information is intended to introduce you to the use of food quality assessment as a method for managers to evaluate the potential that a feeding habitat has for developing an aggregation of right whales. The conceptual basis of this assessment method is the widely accepted view that right whale aggregations in higher latitudes develop in areas favorable to feeding. Here we propose that the quality of the food resource when properly evaluated can be used to predict both the aggregation and the dominant behavior of the whales, behavior that may or may not place the individuals at high risk. Thus, a well developed assessment of the kind we present here may be a useful tool for managers to predict aggregation and the occasion of risky behaviors that together

may, along with other traditional assessment methods (e.g., aircraft surveillance), suggest or aid in the development of management action.

Taken together, as an indicator of aggregation and feeding potential, we hope that this assessment method can be refined and applied in combination with other management tools to aid managers in determining the development and timing of management action.

To use this tool, it is essential to understand the conditions that govern the movement and aggregation of whales. This understanding must relate to the scale at which right whales make decisions. This initial effort to evaluate Cape Cod Bay incorporates a simple understanding that whales, during foraging activities, make decisions, probably continuously, that lead to the aggregations typical of the species. Similarly, the behavior that places whales at the greatest risk of lethal entanglement and collision, that of feeding, is based on simple decisions that can be predicted from an analysis of the food resource compared with benchmark values that describe the whales' responses to the habitat.

The evaluation of Cape Cod Bay benefits from long term baseline studies against which the observed conditions may be measured. Though the details of the Cape Cod Bay resource that supports right whale aggregation and feeding, or lack thereof, may be specific to the bay, benchmark values (e.g. feeding threshold) may nevertheless be of considerable use in evaluating other habitats not studied in equal depth. The use of this method to assist in management decisions in other habitats will require some baseline study, however it is likely that food resources generally influence the whales' aggregative behavior. Thus this method's application to areas of potential fisheries and shipping risk, while requiring some baseline study, can be projected throughout the feeding range of the species. In particular, we suggest that areas being considered for or being subject to regulation of industry activities could be assessed and the results used to predict aggregation, dispersion, or continued residency of whales, substantially improving the sensitivity and timing of management decisions.

Principals

The goal of this assessment form is to display in a timely fashion information that will be useful for evaluating the food resource conditions that influence right whale aggregative behavior. Because this is the first effort to develop such an evaluation instrument, the structure of this method will likely evolve and its accuracy will improve. Below we describe the elements of the evaluation and some of the underpinnings of the approach we have taken to get it off the ground.

- We anticipate completing the assessment form and distributing it within 24 hours of each cruise, thus the techniques used to produce it have been streamlined and automated to permit the required rapid assessment. Our initial efforts will be produced just a bit more slowly due to an ongoing effort to work out the methods we need to use to best display the information.

- The details of the zooplankton collection, counting, and analysis are available on request.

- Several "benchmark" values (e.g. feeding threshold zooplankton density) are presented below to place the observations in context. Many of these benchmarks are part of an evolving understanding of the factors that control the coalescence and durability of whale aggregations.

- The initial assessment form presents values estimated from surface collections. We regularly collect both vertical and oblique profiles of the zooplankton resource. We anticipate providing our analysis of the zooplankton in the water column in future cruise reports and to thus considerably improve our ability to predict aggregation and dispersion.

- The text interpretations will be attached to the assessment form in order to add to the reader's understanding of how the information may be used to predict the attractiveness of Cape Cod Bay. The reference to whale densities in the bay has been made available for our use by the air survey observer program at Center for Coastal Studies (Moira Brown, P.I.). The air survey work is supported by the Division of Marine Fisheries, Commonwealth of Massachusetts.

Details of the Draft Form

1. The assessment form is made in Excel. In the future we would hope to put it in a .pdf for ease of distribution.

2. Julian Day is used throughout to aid in plotting. JD is counted continuously from 1 January through the year.

3. Table presenting the four estimated measures:

MEASURES:

Technique	Station	Total Zpl/m3	Settled Vol/m3	Total Calories/m3	Total Dry Wt./m3
surface tow	6N	53.49	0.04	4.72	7.91E-04
surface tow	6M	26.91	0.05	1.68	3.45E-04
surface tow	7N	55.52	0.10	5.34	9.96E-04
surface tow	5S	23.14	0.02	1.79	3.53E-04
surface tow	6S	12.88	0.02	0.64	1.29E-04
surface tow	7S	48.13	0.04	3.61	7.03E-04
surface tow	8M	42.73	0.09	4.28	7.99E-04
surface tow	LP	127.74	0.11	11.36	2.18E-03
Cruise Average:		**48.82**	**0.06**	**4.18**	**7.87E-04**

Collection Technique: may be surface conical metered net, vertical pump, transect sampler, or oblique tow. The mesh of all samplers used in the assessment work is standardized at 333μ to approximate right whale baleen filtration (Mayo, Letcher, and Scott, 2001).

Station: The stations listed are the fixed locations from which samples of zooplankton are and have been collected in Cape Cod Bay. Additional stations are occasionally added in areas of whale aggregation or at locations in which there is special interest. Collections at special stations will be noted as such.

Total Zooplankton/m^3: This value is a particle count, an estimation of the number of zooplankters that a right whale would filter from one cubic meter of seawater. For comparison with a benchmark, we have estimated the right whale feeding threshold at **3,750 org/m^3**. This measure is of importance because it gives a value (against which one may compare any calculated density) that may capture one of the whale's empirical sources of information, which would be available to a feeding right whale using visual or tactile senses.

Settled Volume/m^3: Settlement of metered samples gives a measure of the bulk of zooplankton available to a feeding right whale. At present we do not have a benchmark against which we can compare the observations. This measure may be particularly instructive if right whales' decision-making processes are based on near-real-time evaluation of the bulk of the zooplankton harvested or of gut fullness.

Total Calories/m^3: The caloric value of the taxa of zooplankton collected in Cape Cod Bay estimated from the literature. This value is calculated from species counts (with coarse staging of the principal taxa) to give an approximation of the caloric density of the capturable zooplankton resource. The benchmarks against which this value may be compared are **690 cal/ m^3**, the estimated caloric density of the feeding threshold, and **2,430 cal/ m^3,** the mean caloric density in feeding areas of Cape Cod Bay 1984-1999. These values permit a comparison with right whale feeding requirements suggesting the suitability of the environment may influence decision- making based on energy capture, and potentially reflected in the whale's fitness. Depending on how a whale might assess the intake of energy, this measure may be reflected either in short- (minutes and meters) or medium- (days/weeks and 1000's of km) term decisions involving feeding and movement. We anticipate that information from Amy DeLorenzo's doctoral thesis (URI, with E. Durbin) will improve this estimate.

Total Dry Weight/m^3: This value will be of use for assessment of nutritional intake. No benchmark comparator is available at present.

To the right of the cruise synopsis table a pie chart displays the average species composition of the samples summarized in the table. For each sample individual composition is available, however for the purposes of this assessment we have used the mean composition for the entire cruise.

We assume that taxa that are known to have supported observed feeding, *Calanus, Pseudocalanus, Temora*, and *Centropages*, are suitable to lead to aggregative behavior and provide the cues required for feeding. At present a zooplankton resource containing those species is considered acceptable in composition. It should be noted that all measures of *Pseudocalanus* in text and graphics refer to a complex of taxa of similar character composed of species of *Pseudocalanus*, *Paracalanus*, and *Clausocalanus*.This benchmark of resource composition containing those taxa is not considered exclusive. Observations and reanalysis of existing data could increase the value of taxonomic composition in assessment of habitat.

At the bottom of the assessment form, two rows of simple graphs place the observations of a cruise in context. These show the trends of the four evaluation measures described above for all samples of Cape Cod Bay (upper row of graphs with a linear regression plotted) and for the four quadrants of the bay (lower row with fitted curves plotted). This display shows the overall trends in the data for the bay and for portions of the bay and offers context for the observations of the individual cruise.

* Note: The patterns of the four assessment measures are similar, offering like pictures of the environment encountered by a searching right whale. The similarity in trends will continue as long as the taxonomic and stage composition of the samples remains the same. We anticipate that the similarity in relationship between the measures will be disrupted by an influx of *Calanus finmarchicus.* A *Calanus* – rich resource should display a higher settled volume, caloric density, and dry weight per organism density than seen with the early-winter samples.

Interpretation of Zooplankton Assessment: SW 316 Cruise Date: 2/27/03 J.D.: 58

In reference to the assessment form, conditions in Cape Cod Bay suggest an extremely low available surface food resource, lower than previously observed in study of the region. The SW316 samples demonstrate that the Cape Cod Bay system, which until 2002 supported a substantial number of right whales, does not have and this winter has not to date had a zooplankton biomass, caloric or particle density capable of supporting right whale aggregation and feeding. The mean bay-wide zooplankton density from the SW 316 cruise is generally an order of magnitude lower than that considered a feeding threshold while average caloric density is more than 15 times lower than the estimated threshold.

The trends observations (lower graphs) show clearly that the Cape Cod Bay averages of all measures has declined, with the values collected on SW316 the lowest of the 2003 season for all average values both through out the bay and in all four of its quadrants. While both average particle and caloric densities in the northeastern quadrant of the bay approached acceptable values in late January, subsequent sampling revealed declines paralleling those in other portions of the bay. By JD 58, the day of this report, all quadrants had declined to extremely impoverished levels.

The possibility that the SW316 report is not representative of a rich subsurface resource is addressed by a synoptic comparison of subsurface samples (which will, in future reports, be included in the body of the reporting form) from 2000-2003 (see attached graphic of 4 years comparisons). This treatment with linear regression lines for the four years supports the observations of the surface synopses and the observations of SW316, that zooplankton densities are exceedingly low and declining. For comparison in the vertical resource graph, 2000-2001 were years in which comparatively high numbers were recorded throughout the January – February period, while 2002 was unique among years since 1984 in the lack of whales present in the bay. Through to the reporting of SW316, the 2003 season appears to offer an even less favorable condition than 2002.

The presence of low concentrations of *Calanus* seen in the assessment pie graph is the only suggestion that an improvement in the conditions in the bay may be indicated. The low *Calanus* signal is typical for the period of early march and late February and offers the possibility that increased food resource could reverse the presently bleak outlook.

On the whole these observations suggest that any whales seen in the area are likely on searching patterns, certainly not individuals that will establish resident aggregations.

<u>Interpreted likelihood (1-10) of</u> Aggregation: very low (2)
Residency: very low (2)
Near-Surface feeding: extremely low (1)
Feeding in the water column: low (3)
Trend in Above: stable or improving (it can't go lower and *Calanus* is usually arriving in mid March)
Quadrant Quality/Attractiveness: NE low 3, NW low 3, SE very low 2, SW extremely low 1

Interpretation of Zooplankton Assessment: SW 318 Cruise Date: 3/7/03 J.D.: 66

This interpretation is in reference to the accompanying assessment form for SW 318.

Observations from SW318 prepared by Moriah and Jenny show that the system is responding in a somewhat more typical way than the previous observations. Instead of the extremely low concentrations of zooplankters seen in all quadrants of the bay, elevated values of all measures, due to *Pseudocalanus* and *Paracalanus,* at stations in the central and north central parts of the bay (6M and 7N) suggest some potential for enrichment. Further, the increasing *Calanus* signal and an indication that a right whale may have been associated with 7N (sighting, not confirmed as a right whale) all suggest increased potential for right whale aggregation. At this time much of the bay is still impoverished and the lack of resource in the SE quadrant continues to suggest that this potential, while increased, is still low. In past years, the discovery of a small area of acceptable conditions, usually represented by one station with elevated estimated caloric density, and coupled with the increase in *Calanus* during this, the usual period for increase in that species, has been followed by rapid increases in resource.

The species composition absent the quantitative information suggests a reasonably balanced calanoid composition, though we should soon expect to see *Calanus* become dominant and *Pseudocalanus* become subdominant if the productivity of the system is to again look "normal". The key to the system becoming acceptable to right whale residency and subject to feeding aggregations, therefore, is probably the development of both a strong and dominant *Calanus* resource, which resource was absent during the key period of late March of 2002.

The data from SW 318, however, continue to suggest poor feeding conditions.

On the whole these observations suggest that any whales seen in the area will be on searching patterns with brief stops to feed, and, unless further enrichment is seen, will not aggregate.

<u>Interpreted likelihood (1-10) of</u>
Aggregation: low (3)
Residency: low (3)
Near-Surface feeding: low (3) most likely in small areas and intermittent
Feeding in the water column: low (3)
Trend in above: improving (due to slightly increased resource and stronger *Calanus* signal)
Quadrant Quality/Attractiveness: NE low (3), NW low (4), SE very low (2), SW extremely low (1)

We will be looking to see (1) a clear increase in Calanus approaching dominance and (2) a more widespread increase in resource measures, exceeding approx. 4000-5000 orgs/m^3 or an estimated caloric density of approx. 700-800 calories/m^3. Should those conditions appear we would expect that aggregation might follow (depending of course on competition from other quality habitats). We wait to see what future cruise collections show.

Interpretation of Zooplankton Assessment: SW319 Cruise Date: 3/13/03 J.D.: 72

This interpretation references the accompanying zooplankton assessment form for SW319.

Zooplankton samples collected during SW319 were noticeably thicker even before any counting was completed. Total zooplankton densities at all stations, except one, in Cape Cod Bay have increased substantially since our last cruise (J.D. 66, SW318), bringing the average for the bay up to 1584 organisms/m^3. The central and north central parts of the bay (stations 6N, 7N, 6M) contained the highest densities, and the SE quadrant (5S) was again the lowest. Even though the total zooplankton value of 1584 organisms/m^3 represents less than half of the number needed to reach the right whale approximated feeding threshold (3750 organisms/m^3), the consistent increase from the last two cruises (49 organisms/m^3, and 1005 organisms/m^3) suggests that the resource in Cape Cod Bay may be beginning to rebound to comparable levels of previous years. Quadrant data also show this increase in all zooplankton parameters, with the one exception being a slight decrease in total zooplankton density in the NW quadrant. It should be noted, however, that on SW319 this "average" value is the result of only one station (7N), and that even though total density decreased, the caloric density increased (a result of a stronger presence of the calorie- rich species *Calanus finmarchicus* and adult *Pseudocalanus spp.*, see below).

The "copepod species average percent composition" pie chart displays the increasing dominance of *Pseudocalanus spp.* and *Paracalanus/ Clausocalanus spp*. (84% combined) as well as the gradual increase in *Calanus finmarchicus* (12%, as compared to 10% last cruise), which is to be expected for Cape Cod Bay during this period. By late March, we would expect the traditional seasonal progression to produce a dominance of *Calanus finmarchicus* and make the bay more attractive to resident, feeding right whales. Not evident in this chart is the variability among species percentage compositions at different stations. For example, *Calanus finmarchicus* made up nearly 28% of the total copepod species percentage at station 7N, but only 3% at Long Point, and resulted in an average of 12% (7 stations). Due to differing caloric contribution values and body structure among species, we include such parameters as caloric density and settled volume in addition to total zooplankton density when attempting to judge patch attractiveness for right whales.

Although there was some enrichment in the zooplankton resource in Cape Cod Bay during SW319, we do not expect resident aggregations of right whales to establish unless further enrichment is seen.

Final Note: SW319 was conducted during a snowstorm that limited visibility in Cape Cod Bay to less than 2 km. Therefore, no aerial surveys were flown, and not surprisingly, no marine mammals were sighted by observers on the R/V *Shearwater*.

<u>Interpreted Likelihood (1-10) of</u>

Aggregation:	**low (4)**
Residency:	**low (4)**
Near-Surface Feeding:	**low (4)**
Feeding in the Water Column:	**low (4)**
Trend in Above:	**improving (steady among stations)**
Quadrant Quality/Attractiveness:	**NE: low (4)**
	NW: low (4)
	SE: low (3)
	SW: low (3)

Will Right Whales Aggregate in Cape Cod Bay?
Interpretation of Zooplankton: SW 320
Cruise Date: 3/17/03
J.D.: 76

In reference to the assessment form, zooplankton collections from Cape Cod Bay suggest an extremely low available surface food resource. After some elevation of the assessment measures in collections taken on SW319 3/13/03, observed conditions in the bay have again declined to extremely low levels. All measures for which previously established benchmarks (see the circulated introduction materials) are at least an order of magnitude lower than the minima proposed for defining a habitat that will support feeding and aggregation of right whales.

By JD 76, the day of this report, all quadrants have again declined to impoverished levels within the set of surface samples (see lower graphs in the assessment instrument). In addition to the surface measures presented, two surface zooplankton transects and two vertical water column characterizations involving more than 30 additional samples were collected in order to produce a more synoptic view of the system. Though at present we do not include the observations from the transects or surface to bottom water column stations (we anticipate developing a method for presenting them in future assessment documents) the observations can be summarized:

Midwater Pump Profiles

- 6S: densities ranged from 63- 1948 orgs/ m^3 with lowest at surface and progressive increase from 5-19 m (highest at 19 m) and then slight drop at 23 m (bottom). At 19m, 1697 orgs/m^3 were nauplii, a resource not considered an important component of right whale forage. *Calanus* was in low density except for a layer of modest density at 5m (94-orgs/ m^3). Resource at 19m moderate but not dense enough to support feeding.

- 7S: 346-1320 orgs/m^3. Lowest at sfc, highest at 5m, followed by 10m, 25m, 20m, 15m (last 3 depths all very close) 300-500 nauplii orgs/m3 at all depths. Copepods again mostly *Pseudocalanus-Paracalanus* and *Centropages*. Resource at 5m moderate but not dense enough to support feeding.

Transects

- T1: 12 miles straight line from 5N to beyond 8N, sampling one-mile segments. Densities ranged from 0- 7 orgs/m3, highest near 5N. Food resource extremely low throughout, not great enough to support any surface feeding or aggregation.
- T2: 12 miles straight line from 8N to beyond 6S, sampling one-mile segments. Densities ranged from 0-9 orgs/m3, highest at miles 8 and 9. Food resource extremely low throughout, not great enough to support any surface feeding or aggregation.

The composition of the zooplankton resource collected on SW320 suggests a reversion to the unusual conditions observed in 2002. The *Calanus* signal noted for SW319 as an indication of the possible development of conditions favorable to aggregation and feeding in Cape Cod Bay has failed to materialize. In addition to the decline in *Calanus*, we note that there has been an increase in the relative abundance of *Acartia*, an estuarine taxon that in 2002 showed mounting relative abundance starting in mid March. Further it should be noted that the strongest *Acartia* signal was found at station 8N on this cruise (39% of collected organisms), a location that arguably may be the gateway for advection of zooplankton resource into Cape Cod Bay.

The observations of SW320 suggest that any whales seen in Cape Cod Bay are likely on searching patterns, and will not establish resident aggregations. Until increases in caloric density and zooplankton concentration are observed, the bay will likely remain as it has this winter, unacceptable to whale aggregation. The parallel of resource measures in 2003 with those of 2002 is obvious and the parallel consequence, the absence of right whales, is to be expected. Only either a strong increase in the *Calanus* resource which remains still possible or the rare influx of other late winter/early spring copepods (including *Temora longicornis* or *Tortanus* sp.) can now reverse the trend and lead to conditions that are favorable to whale residency and feeding in 2003. Enrichment of the mid waters coupled with the formation of ephemeral thermoclines on calm days now seems the most likely place where improvement of the conditions will be seen. We anticipate increasing out sampling of that horizon using oblique and vertical pump samplers.

Interpreted likelihood (1-10) of
Aggregation: very low (2)
Residency: very low (2)
Near-Surface feeding: extremely low (1)
Feeding in the water column: low (4)
Trend in above: stable or improving (as earlier in our assessment reports, conditions can't go much lower)
Quadrant Quality/Attractiveness: NE very low (2), NW very low (2), SE low (4) due to a mid-water layer, SW low (3)

Interpretation of Zooplankton: SW321 and SW322
Cruise Dates: 3/23/03 and 3/24/03
J.D.: 82 and 83

SW321

In reference to the assessment form, zooplankton collections from Cape Cod Bay continue to suggest an extremely low available surface food resource. There were only slight increases in average densities for all quadrants, resulting in a total average of 344 organisms/m^3 (up from 140 organisms/m^3 on the last cruise). Our oblique tows (collected at all 7 stations) and vertical pump samples (collected at 7S and 6N) also show this trend of low surface densities. Densities at 5m or deeper were on average 7 times as great as samples taken at 1m. Densities at 6N were between 1000-2000 organisms/m^3 and at 7S were ~700 organisms/m^3, with no evident "peaks" at any depth. This is consistent with observations from previous cruises.

Once again, there was great variety in both zpl surface densities and species composition among stations. Station densities ranged from 22 organisms/m^3 - 1400 organisms/m^3 with a general trend of increase geographically from south to north. We continue to closely monitor the *Calanus* signal as an indicator of the likelihood of right whale residency, and SW321 did not show much of an increase. The strongest signal remains in the northern edges of the bay (6N and 8N) where *Calanus* composed between 41%-53% of all copepod species. This is in sharp contrast to the SE and NE quadrants (1%-2%). As a result, we would predict right whales to spend more time feeding in the northern bay, but with these low densities, they would not stay long. It is worth noting that the stronger *Acartia* signal mentioned in the last interpretation for SW320 was not observed on SW321.

Current zooplankton conditions continue to suggest that right whales will not aggregate in any part of Cape Cod Bay unless increases in densities occur.

Interpreted likelihood (1-10) of
Aggregation: very low (2)
Residency: very low (2)
Near-Surface feeding: extremely low (1)
Feeding in the water column: low (4)
Trend in above: stable or improving
Quadrant Quality/Attractiveness:
NE low (4), NW low (3), SE low (3) SW very low (2)

SW322

The intention of this cruise was to thoroughly document the zooplankton resource in the region (east of Chatham) where right whales were seen aggregating and subsurface feeding during a CCS aerial survey on 3/23. We intended to collect surface and oblique tows in areas near feeding whales, and at measured distances away from them for the purposes of comparison. Also, we planned to conduct a long transect connecting CCB to this region to obtain a view of the changes in zpl density at 1 meter depth. As it turned out, our first and last right whale sighting of the day was #2320 "Piper", a known entangled whale. All habitat and photoID/biopsy efforts were suspended as R/V *Shearwater* and later R/V *Gannet* (with the CCS disentanglement team aboard) tried unsuccessfully to attach a VHF/satellite telemetry tag to this whale. HOWEVER, we did manage to collect a few zpl samples: surface and oblique tows approx. 5 miles E of Highland Light (station HL), and 4-5 miles east of Nauset Inlet (station NI), where an aggregation of right whales (some subsurface feeding) was seen the previous day. We also took an oblique tow in the presence of #2320, who was not observed to be feeding. Zpl densities and pie charts of the copepod species composition are displayed on the accompanying assessment form for SW322. Neither NI nor HL had densities high enough to support a residency period for feeding right whales, however the relative percentage of *Calanus finmarchicus* was significantly higher than anything we have yet to see in CCB. The fact that there is *Calanus* present, but at below- threshold densities, supports observations that Eg's would be attracted to feed in the area, but would not stay too long. We hope to soon make another attempt at completing the objectives of SW322.

Interpretation of Zooplankton: SW323
Cruise Date: 4/2/03
J.D.: 92

Surface Layer Assessment:

The attached assessment form displays a surface tow density range of 77-2900 organisms/m^3, with an average of 884 organisms/m^3, for the 7 stations sampled in CCB on 4/2/03. Although the average value did increase by 344 organisms/m^3 when compared to cruise SW321, zooplankton density generally remains very low, and densities among stations are typically variable (= patchy). We continue to await the influx of *Calanus finmarchicus*, usually underway by this time. The *Calanus* average percent composition has remained under 15% for the past few cruises, but like overall density, it is highly variable among stations. In analysis of SW323 we saw some stations (6N, 5S) with less than 5% *Calanus* and others with as much as 53% (8M). Data from surface tows collected in the northern reaches of the bay (stations 6N and 8N) reveal a surprising dominance of *Centropages hamatus* (males), and higher numbers of *Acartia* spp. than other stations. The increase in *Centropages* and *Acartia* was not observed during our previous cruise (3/23/03). In fact the northern (8N, 7N, 6N) region has supported the highest percentage of *Calanus* for the past 2 weeks. By 4/2/03 is appears that this patch of low-density/high relative percentage *Calanus finmarchicus* had moved ~3nm to the south to 8M, as would be predicted by surface transport models.

The other measures of the assessment of surface condition, while generally following the organism densities, do not track the changes in amplitude. In particular, caloric and dry weight density for SW323 surface tows have not responded (see the SE Quadrant of the bay) because of the lower estimated per-organism values of the earlier stages identified at a number of stations. Caloric density remains very low at all stations and in all quadrants.

Generally, the surface observations suggest enrichment of some portions of the bay, but, with *Calanus* still in low abundance, none of the summary assessment measures suggest that the area will support whale aggregations. Several stations are rich enough to potentially encourage feeding for a brief time, however residency is not likely.

Oblique (surface - 19m) Assessment:

Oblique tows were taken at each station immediately following the 5 min. surface tow. As seen previously, overall densities for obliques are considerably higher than in the surface layer, (range 1740 – 6200 organisms/m^3 and average 2975 organisms/m^3), however copepod species composition was roughly the same as the surface layer (see pie charts). There is great variability among the stations for both total zpl density and *Calanus finmarchicus* relative percent composition. We did not observe the higher densities of *Centropages hamatus* and *Acartia* spp. seen in the northern bay in surface tows.

Although zooplankton densities in the oblique tows suggest the possibility of enrichment to levels that, at some stations, exceed estimated thresholds (6M and 5S) caloric density remains low (below the 690 caloric benchmark and well below the 2400 cal/m^3 average feeding caloric density observed over the past years) and patchy. As in the surface evaluations, the region continues to be characterized by low caloric and dry weight density with some layers in the mid water that might elicit feeding but which would not likely lead to aggregation and long-term residency.

Vertical Pump Profile:

We conducted discreet depth sampling at station 8N, one of our deepest stations and the one that has the greatest potential for advection of new zooplankton resources into the bay. Preliminary results show a very high percentage of *Pseudocalanus* spp., (higher than the 79% average for all stations), and a steady increase in total zpl density from surface to bottom (45m = 34,0000 organisms/m^3, by far the highest value we have seen anywhere all season). Vertical pumps can be extremely useful for gathering information on the zpl resource below the reach of our 19m oblique tows.

The vertical pump profile suggests that, at least at 8N, bottom feeding would be well supported by a zooplankton resource composed of acceptable species and that, if this condition persists with all measures above the estimated feeding thresholds, whales in the area would both feed and aggregate. Since this sample described only the deepest station of our sampling grid and because the extent of the rich resource is not clear, further sampling using vertical pumps would be necessary to fully assess the potential that this signal at the deepest location in the entrance to Cape Cod Bay has to propagate through the system and change the otherwise bleak outlook for aggregation and feeding in Cape Cod Bay. Our "likelihood" assessment below takes the vertical pump sample analysis into account but does not place as much weight on it, because of uncertainty of the extent of the layer.

Some Details:

- Station 5S had the highest total zpl densities for both net tow methods, (yet caloric analysis reveals continued relative low values). This was a complete turnaround from the last cruise, when this area in the SE quadrant showed the lowest densities. It appears that advective or aggregation processes have begun to influence this southern region.

- Station 8N clearly exhibits the patchiness and complexity of zpl layers:
  Surface Layer: very low overall densities and average % of *Calanus*
  Mid Layer (to 19m): average densities and very high % of C*alanus*
  Deep Layer (19-45m): VERY high densities and VERY low % of *Calanus*

Combined results from surface and oblique tows and vertical pump samples clearly reveal that CCB is in a complicated and rapidly changing phase. These preliminary attempts at assessing the influence of the dynamics of the mid water system are obviously incomplete and will continue to evolve. At this time, we do not predict an aggregation or residency period of feeding right whales in CCB, though enrichment of the mid and bottom layers may increase to levels that might support right whale feeding and aggregation. However, the vexing absence of *Calanus* and the likelihood of the usual *Pseudocalanus* decline (seen around this time each year) continue to argue against the aggregation scenario. In the end, with measures giving an increasingly mixed picture we believe that *Calanus* will, as in 2002, remain absent from the system in its usual densities and that whale aggregation and residency is unlikely.

Interpreted likelihood (1-10) of
Aggregation: low (4)
Residency: low (4)
Near-Surface feeding: extremely low (2)
Feeding in the water column: fair (5)
Trend in above: improving
Quadrant Quality/Attractiveness:
NE low (4), NW low (3), SE fair (5) SW very low (2)

Interpretation of Zooplankton: SW325
Cruise Date: 4/9/03
J.D.: 99

The past week has brought consistently strong winds to Cape Cod Bay, a pattern that is expected to persist for the next several days. Therefore, when a very short marginally-good weather window suddenly opened up on 4/9 we took advantage of it to target the NW quadrant of the bay where we had seen the very dense near-bottom *Pseudocalanus* resource on our last cruise (SW323, 4/2/03). We hoped to assess the extent and composition of this layer to see if it could support feeding by the small group of right whales observed near Herring Cove (in the eastern portion of the NW quadrant) on 4/6 – 4/10. The residual swell, Beaufort 4 sea conditions, and driving rain/hail/snow mixture forced us to be expedient and conservative in our sampling goals. We did find 3-5 right whales approximately 5 nm WSW of Herring Cove, as we were headed out to station 8N. The whales were on 5-10 minute dives, with occasional fluking, and traveling in a random fashion. We did not observe any surface or near-surface feeding, but did see defecation twice. In this report station "A" is in the region of the whale aggregation.

Surface Layer Assessment:

Surface samples at both reported stations showed an increase in zooplankton concentration as compared with surface tows from this quadrant collected from SW323. All assessment measures exceed those for which benchmarks have been established. Although the surface is not unusually high in estimated caloric density, we predict that surface feeding will be supported and that, though probably patchy, would likely be acceptable for aggregation. Further enrichment of the surface resource from lower biomass (see below) is likely to occur occasionally.

The *Calanus* signal, clearly seen in surface samples, suggests a late but important influx of that species. The presence of a strong (and probably strengthening) *Calanus* resource does support the view that, at least in the presently limited area of the NW quadrant the surface resource is likely to remain significant for a period, perhaps not exceeding a week or 10 days, in the present location. It is apparent as seen in past years that the richer mid-deep resource is presently attracting the attention of the whales, and their behavior, typical of midwater feeding, supports this observation.

Oblique (surface - 19m) Assessment:

Samples from oblique tows demonstrate a pattern similar to that seen in comparable samples from SW323. There appears also a similarity, reflected in surface collections, between the two stations sampled. These observations further support the view that the north end of the NW quadrant underwent a significant change over the last week, with continuing increases in all measures and in the representations of *Calanus* in the samples. Midwater oblique sampling does not identify layers, thus if, as is the case, measures of acceptability are exceeded in these samples it can be assumed that particularly dense layers may be found by whales feeding at depth. Hence, conditions for feeding in the

midwater are considered good and the maintenance of the present aggregation and possibly increases in numbers may be expected.

Vertical Pump Profile: A deep vertical zooplankton collecting station established at station A in the presence of 3-5 whales, yet to be counted, suggested that the greatest resource densities are to be found below 30 meters, with very high densities at 45 meters, near the bottom. This deep resource continues to be dominated by the acceptable but less calorically/settled volume valuable *Pseudocalanus.*

General: The conditions found in the north end of quadrant NW suggest conditions that have significently improved over the past week to levels that are acceptable to aggregation and feeding through much of the water column. Vertical sampling does point to the potential for formation of ultra-dense near-surface layers because the total water column biomass is very high, if not yet concentrated in a discreet layer. It is difficult to predict the movement of this resource or the potential for its further enrichment because of the present location of the patch. Such bodies of rich mid- and surface resources may move over significant areas, advected into or exiting the bay. The future of this aggregation of whales, and its potential increase in numbers, will be governed by competition from adjacent areas high in food resources, graze – down rates, and the vagaries of current transport. Though many of these processes are not being monitored, it seems likely that the aggregation presently foraging in the north end of quadrant NW will soon move. We anticipate:

- that numbers of whales in the aggregation will remain the same or increase
- residency will not be maintained in quadrant NW for more than several more days and movement into Cape Cod Bay is possible
- surface feeding (and associated vulnerability) will occur, probably within the last days of the present aggregation location and most likely in morning or evening

Interpreted likelihood (1-10) of
Aggregation: medium-high (7)
Residency: medium (5)
Near-Surface feeding: medium (5)
Feeding in the water column: high (8)
Trend in above: improving
Quadrant Quality/Attractiveness:
NE ?, NW high (8), SE ?, SW ?

Interpretation of Zooplankton: SH001
Cruise Date: 4/15/03
J.D.: 105

This is a supplementary assessment of zooplankton collected by Amy DeLorenzo in Cape Cod Bay. This assessment adds to information on the midwater food resource last collected on cruise SW325, JD99, 4/9/03. The collections were made in the southeastern part of the bay (station 5S), in east central Cape Cod Bay (6M), and at the entrance to Provincetown Harbor (LP) using oblique net tows with baleen-corrected mesh to a depth of 10- 19 meters.

Surface Layer Assessment:

No samples available.

Midwater Resource Assessment:

Data from midwater/oblique nets in the south and central part of the bay show a continuing influx of *Calanus finmarchicus* and further enrichment. These observations combined with observations from the previous cruise suggest that, of the possible scenarios, advection and enrichment of the resource in the less dynamic (and hence less changeable) parts of the bay has occurred. Further, as described for the SW325 report, the available biomass appears to be very rich, at least throughout the upper layer, leading to the continued likelihood that calm days and thermal stratification will lead to the formation of ultra-dense surface layers and bouts of surface skim feeding. The composition of the zooplankton at the stations sampled furthers the view that the bay, at least the eastern portions that have been sampled recently, is enriching to caloric/particle densities and taxonomic composition that may be considered supportive of right whale aggregation.

General: The collections reported here, while limited in extent, support the view that the region, particularly the deep and eastern parts of the bay, contains both a composition and available biomass that will release foraging behavior. Caloric and particle densities estimated from collections on cruise SH001 all substantially surpass the benchmark values and allow us to predict that the bay, through at least the eastern extent, will support residency, increased aggregation, and probably some bouts of skim feeding. We continue to predict that the present locus of right whale aggregation will move, and it is increasingly likely that this movement will bring whales deep into Cape Cod Bay. The durability of patches of the richness we are seeing has not been studied, however it seems likely that, absent strong winds that seem to affect transport processes, the favorable conditions that are developing may continue for at least many days. The influence of strong winds and spring tidal currents will likely have some effect (most particularly on the portion of the patch presently being foraged in the NW quadrant), however transport processes along the eastern portions of the bay where the resource measures are increasing appear less influenced by advection and may anchor the whale aggregation for some greater period of time if whales choose to enter and forage there.

We continue to anticipate:

- that numbers of whales in the aggregation will remain the same or increase
- residency will not be maintained in quadrant NW for more than several more days and movement by some or all of the aggregation into Cape Cod Bay is increasingly likely
- surface feeding (and associated vulnerability) will occur

<u>Interpreted likelihood (1-10) of</u>
Aggregation: high (8)
Residency: medium-high (7)
Near-Surface feeding: medium-high (7)
Feeding in the water column: high (8)
Trend in above: improving
Quadrant Quality/Attractiveness: NE ?, NW high (8), SE high (8), SW ?

Interpretation of Zooplankton: SW328
Cruise Date: 4/19/03
J.D.: 109

This assessment relates to the above cruise conducted on Easter weekend. Collections were made in all quadrants of the bay to permit a more nearly synoptic assessment of the conditions that are influencing the whales that have moved south from quadrant NW to occupy an area along the south central and SW portions of the bay. An additional station (A) approximately 2 km. south of east central station 6M and in the vicinity of subsurface feeding whales is also included in the summary.

Surface Layer Assessment:

Samples reflect a general and rapid enrichment of the bay, with most surface collections showing elevated organism and caloric densities exceeding the proposed benchmarks. The average surface layer values for these measures have continued to climb over the last 2 weeks and suggest conditions very favorable to right whale aggregation and feeding with a trend that suggests further enrichment and maintenance or increased aggregation of whales. The rise of *Calanus finmarchicus* at most stations further supports the premise that Cape Cod Bay is approaching a prime condition to support feeding whales, only the lateness of the season argues against an ongoing residency in the bay.

Midwater Resource Assessment:

The data from midwater/oblique nets collected at stations throughout the bay show a continuing influx of *Calanus finmarchicus* and widespread and continuing enrichment of the zooplankton. Both organism density and estimated caloric measures at all stations are at levels above or considerably above benchmarks and reflect a very rich total biomass. The oblique samples, integrative as they are, suggest the likelihood that the zooplankton resources of the bay are dominated by a subsurface layer of particularly dense zooplankton. A single vertical sample in the vicinity of right whales demonstrated high caloric density to a depth of 30 m. with all values exceeding the benchmarks and with *Calanus* found abundantly throughout the water column. The greatest zooplankton densities were found in a broad layer between 10 and 20 m deep. Cape Cod Bay presents a very rich, late-season food resource that suggests several aspects favorable to maintain or, more likely, increase aggregation of whales. Following previous scenarios, it is most likely that this subsurface resource whose enrichment is clearly indicated in the graphic tracking of the measures, will coalesce and intensify and that bouts of skim feeding may be expected during periods of calm, particularly in the evenings and mornings. This condition further suggests that at all depths, but certainly in the upper 20 m of the water column, whales will feed nearly continuously, presenting increased potential for vessel collision or entanglement in gear. Since near surface feeding that our measures clearly predict may be particularly associated with increased risk of collision (because of low visibility, insensitivity of whales to external stimuli, and the "mouth-sea anchor" effect) great caution by vessel operators in the entire area of Cape Cod Bay is warranted.

General:

The widespread enrichment of Cape Cod Bay and the occurrence of a very deep layer composed of taxa known to release feeding behavior in right whales suggests that the bay will continue to support residency and aggregation, quite possibly by increased numbers of whales, and surface or near-surface feeding. All measures used in our assessment are the highest seen this year and in many cases exceed identified thresholds by several times. Prediction of the movement of the resource and estimation of its durability are possible based on previous observations, however we cannot, of course, predict the lure of adjacent known feeding areas that we are not presently assessing. Nevertheless we anticipate:

- increased density of whales in occasionally dense feeding aggregations surpassing the perhaps 15+ whales observed in the SW quadrant

- movement of the feeding area to the east along the south shore of the bay, into quadrant SE

- in the absence of major transport events, residency of perhaps as much as several more weeks generally moving east and north from the present location

- caloric density and total available biomass will not decline appreciably over a span of days to a week due to grazing, thus only advection should influence the next days or weeks of the whales residency

- apparent movement of the aggregation may be slow and fluctuate with tidal cycles, some potential for movement into the shallows of the south bay, south of stations 5 and 6 S seems likely given the overall biomass

- for the near term, subsurface feeding will dominate the activities in the aggregation and residency areas, however skim feeding will occasionally be supported

- when surface ultra-dense layers are formed (we might expect that to occur in the next week) several days of skim feeding may be anticipated

Interpreted likelihood (1-10) of
Aggregation: high (9)
Residency: medium-high (7)
Near-Surface feeding: high (8)
Feeding in the water column: high (8)
Trend in above: improving
Quadrant Quality/Attractiveness: NE medium-high (7), NW high (8), SE high (8), SW high (8)

Interpretation of Zooplankton: SW330
Cruise Date: 4/23/03
J.D.: 113

This assessment relates to the above cruise conducted on a windless, foggy day. Visibility improved throughout the course of the day, but was limited to 1-2 km for most of the cruise. This dense fog likely explains, at least in part, why only 2 right whales were sighted. Collections were made in all quadrants of the bay to again permit a nearly synoptic assessment of the conditions that are influencing the movements of the right whales in CCB. We targeted the southern bay in response to recent sightings in this area and to increasing zooplankton densities (see the recent interpretation from SW228). An additional station (A) approximately 3 km. NW of southwestern station 7SX and in the vicinity of a mother calf pair is also included in the summary. The cow was observed once with her mouth closing at the surface and her behavior indicated subsurface feeding, although she traveled nearly 2 km in the time we spent with her and didn't seem to be working a discrete patch.

Surface Layer Assessment:

Samples reflect a continuing general enrichment of the bay, with most surface collections showing elevated organism and caloric densities exceeding the proposed benchmarks. The eastern bay (stations LP, 5S, 5SX, and 6S), showed exceptional elevation of all measures and continues to be an area of likely future whale aggregation. *Calanus finmarchicus* remains at all stations, although there was extreme variation of its relative species composition (9%-94%). We noted a general trend in which the stations with the highest percentage of *Calanus* had some of the lowest overall zooplankton densities. The majority of this resource is still supported by *Pseudocalanus* spp. (see below in General section).

Midwater Resource Assessment:

The data from midwater/oblique nets collected at stations throughout the bay show a steady presence of *Calanus finmarchicus* and widespread and continuing enrichment of the zooplankton. We again found great variation among stations in the percentage of *Calanus finmarchicus* (12%-79%). As with surface tows, a high percentage of *Calanus finmarchicus* did not lead to great overall densities, these high densities are mainly supported by a very rich biomass of *Pseudocalanus* spp. The area near stations 7M and special station A (whales present) had the highest percentage of *Calanus finmarchicus*. Although it seems the whales do target this species when feeding, the incredibly dense resource of *Pseudocalanus* spp is certainly an acceptable food source for right whales, (see caloric density graphs). Both organism density and estimated caloric measures at all stations remain at levels above or considerably above benchmarks and reflect a very rich total biomass. The oblique and vertical samples continue to suggest the likelihood that the zooplankton resources of the bay are dominated by a subsurface layer of particularly dense zooplankton.

General:

All measures used in our assessment continue to indicate a high likelihood of whale aggregation and residency. The dense zooplankton resource could continue to support near-surface and, at times, surface feeding by steady or increasing numbers of whales. The associated risk of vessel collisions or entanglement in gear urges great caution by vessel operators in the entire area of Cape Cod Bay .The continued presence of large areas of high density *Pseudocalanus* spp. is worth noting, as normally we would have expected this resource to decline by this late in the season. In 2003 CCB has seen an unusually strong and long-lasting occurrence of *Pseudocalanus* spp., with densities throughout the bay significantly higher than at this time in previous years. This resource in large part is supporting the feeding and residency of right whales in the bay. We can continue to predict the movement of the resource and estimate its durability, but we still have no way of assessing adjacent know feeding areas. Nevertheless, we repeat some of our earlier predictions:

- in the absence of major transport events, residency of perhaps as much as several more weeks generally moving east and north from the present location

- caloric density and total available biomass will not decline appreciably over a span of days to a week due to grazing, thus only advection should influence the next days or weeks of the whales residency

- apparent movement of the aggregation may be slow and fluctuate with tidal cycles, some potential for movement into the shallows of the south bay seems likely given the overall biomass

- for the near term, subsurface feeding will dominate the activities in the aggregation and residency areas, however skim feeding will occasionally be supported if layering occurs

Interpreted likelihood (1-10) of
Aggregation: high (9)
Residency: medium-high (7)
Near-Surface feeding: high (8)
Feeding in the water column: high (8)
Trend in above: improving
Quadrant Quality/Attractiveness: NE medium-high (7), NW high (8), SE high (8), SW high (8)

Interpretation of Zooplankton: SW333
Cruise Date: 4/30/03
J.D.: 120

SW333 was conducted in CCB under sunny skies and calm seas, with sightings of minke, humpback and right whales, as well as harbor porpoise and seals. We were able to travel to all quadrants of the bay for zooplankton sampling, but only encountered one right whale, approximately 3 km north of station 7SX, in the southwestern portion of the bay. This is the same area where right whales have been resident in numbers of at least 10-15 animals for the past few weeks. This animal showed no evidence of feeding, either surface or subsurface, and we followed as it traveled in a steady NE direction at speeds approaching 8 knots. Station A in the Oblique Assessment form was conducted in the presence of this whale, and supports our belief of non-feeding behavior with densities no higher than other areas, (and not near the threshold density shown to release feeding behavior) and with no higher percentage of *Calanus finmarchicus* than at other stations sampled. All measures for the SW quadrant where the right whales have been resident and subsurface feeding show a great decline in the available resource and therefore it is likely this aggregation of whales has already or will shortly disperse.

Surface Layer Assessment:

SW333 brought great change to the surface sample collections in the form of extreme decreases of values of all measures. Total zooplankton densities dropped to less than 100 organisms/m^3 at most stations, the stellar exception being station LP (near Provincetown Harbor). The surface layer of the entire bay has changed drastically in the last week, coinciding with a rapid increase in surface water temperature (now 7-9 Celsius degrees). Due to a program error with our CTD graphing software, we were not able to graphically depict the temperature and salinity data from the casts, but suspect that there is now a thermocline forming in the water column. Surface samples consistently showed higher densities of the euryhaline *Acartia* spp., (found more commonly in brackish waters), than in the oblique tows. Also, the unusual strong late-season occurrence of *Pseudocalanus* spp. appears to finally be diminishing. The results of our surface tows suggest that right whales will not engage in skim feeding behavior in any area of the bay, except perhaps near Provincetown Harbor, if that dense zooplankton patch persists.

Midwater Resource Assessment:

The data from midwater/oblique nets collected at all stations also show a steady decline in all measures throughout CCB. Although densities were 20-30x higher than those from surface tows, the average bay-wide density dropped nearly 7,000 organisms/m^3 from the previous cruise on 4/23/03; settled volume, caloric, and dry weight densities also dropped substantially. The data suggest that the incredibly dense resource of *Pseudocalanus* spp., presumably responsible for anchoring the subsurface feeding right whales in the area, is no longer present. The good news is that the overall species composition is following the normal seasonal trend and is increasingly dominated by the calorically-rich *Calanus finmarchicus* (76%-85% at most stations). Although organism and caloric densities no

longer are exceeding the proposed benchmarks, they are hovering near to them in the eastern and southwestern regions of CCB. This leaves open the possibility, but not necessarily the strong likelihood, of whale aggregation and feeding in these areas.

General:

The total organism, settled volume, caloric, and dry weight density measures all decreased on SW333, more so at the surface than in the midwater column. Data no longer show an incredibly rich, dense biomass of zooplankton in the bay. However, *Calanus finmarchicus* is increasing, and there is still enough zooplankton in the midwater region, especially in the eastern bay, to potentially support right whale presence. Yet, with these current measures, we do not expect very large aggregations or extended residency periods with bouts of surface skim feeding in the near future.

Interpreted likelihood (1-10) of
Aggregation: medium (5)
Residency: medium (5)
Near-Surface feeding: very low (2)
Feeding in the water column: medium (5)
Trend in above: declining
Quadrant Quality/Attractiveness: NE medium-high (6), NW low (3), SE medium-high (6), SW medium (5)

Interpretation of Zooplankton: SW334
Cruise Date: 5/4/03
J.D.: 124

In spite of traveling to every quadrant of CCB, SW334 was the first habitat cruise in nearly a month with no sightings of right whales. Fortunately, dolphins, porpoises, and fin whales kept us happy. Our seven surface and seven oblique tows, and 2 vertical pump stations, continued to show low values for all zooplankton measures of our analysis. Due to these low measures, the lateness of the season, and probable competition from other habitats, we feel there is an extremely small chance of right whale aggregation or residency. We are seeing the considerable patchiness in zooplankton densities normally expected at this time of year, and this could result in occasional visitation and brief feeding by single or small groups of right whales, but again, right whales most likely will no longer inhabit CCB in 2003.

Surface Layer Assessment:

The surface layer has strengthened slightly at all stations, yet densities remain well below feeding threshold. Patches of *Acartia* spp. seen at the surface on SW333 were only observed on SW334 at station 6S, and were not large enough to contribute to a high total zooplankton density at that station. The collection near Provincetown Harbor, at station LP, showed the dense patch in that area had also broken up since our last cruise 4 days prior. Finally, densities of *Pseudocalanus* spp. are a still relatively small part of total zooplankton at most stations, but in some areas, such as LP and 7SX, accounted for 40%-50% of all copepods. All stations continue to be dominated by increasingly late-stage *Calanus finmarchicus*, especially in the NW quadrant and resulting in higher caloric availability there (see attached Surface Assessment Form: Caloric Density Geographic Quadrant graph: NW quadrant symbol). These results, like those from SW333, lead us to NOT expect right whales to skim or shallow sub-surface feed anywhere in the bay.

Oblique (surface - 19m) Assessment:

The data from midwater/oblique nets collected at all stations show a slight average increase over SW333 in all measures throughout CCB, yet also remain well below the calculated feeding threshold density of 3,750 organisms/m^3. As with surface tows, densities displayed less inter-station variation, with all quadrants of CCB appearing more uniform in the total zooplankton available to right whales. Copepod species percent composition shows the highest % of *Calanus finmarchicus* in the NW and SW quadrants, the areas where right whales were present at the last sighting, 4/30/03.

Vertical Pump Profile:

We conducted 5m - increment vertical pump stations in the NW and SW quadrants (depths were 45m and 21m, respectively), to assess the likelihood of deep subsurface feeding behavior by right whales. The general trend in these verticals was a gradual increase in overall density from surface to bottom, with most depth densities ranging

from 1000-2000 organisms/m^3, not supportive of right whale feeding. Our other measures: caloric, settled volume, and dry weight densities, cannot currently be applied to vertical pump samples. An exciting surprise find was a dense layer (total density: 11,249 organisms/m^3) of CV *Calanus finmarchicus* at 40m in the northwestern quadrant.

General:

Combined results from surface and oblique tows and vertical pump samples emphasize the rapidly changing nature of zooplankton densities and species composition that is normal for early May. This patchiness and layering may result in random visits by individual right whales in selected areas, but all available measures, combined with likely competition from other habitats, suggest an extremely low chance it will support periods of residency or aggregations of whales.

Interpreted likelihood (1-10) of
Aggregation: very low (2)
Residency: very low (2)
Near-Surface feeding: very low (2)
Feeding in the water column: low (4), possible only in dense patches
Trend in above: steady or declining
Quadrant Quality/Attractiveness: NE fair (5), NW very low (2), SE low (3), SW fair (5)

Interpretation of Zooplankton: SW336
Cruise Date: 5/10/03
J.D.: 130

Once again, there were no right whales sighted on our most recent habitat cruise, SW336. We sampled in all quadrants of the bay, but the only marine mammals seen were whitesided dolphins, observed feeding on baitfish with plunge-diving northern gannets. With all zooplankton measures below threshold benchmarks on this cruise and SW334, we were not surprised to see that the right whales have apparently abandoned CCB. The results of our zooplankton sampling show us that densities are steady or in slight decline, and that the patchiness of species composition and density among different areas remains. There will be one more habitat cruise of 2003, on 5/14, and shortly after that cruise we hope to send out an assessment that encompasses the entire season and shows trends in our various zooplankton measures. We are also looking at the CCS aerial survey sighting data from 2003, and plan on including these data in our end-of-season interpretation.

Surface Layer Assessment:

Surface densities at all stations have declined considerably in the 6 days since our last cruise. In fact, we are seeing the lowest densities since March 17th, (SW320), and during SW336 recorded a record low of the season at station 5S (SE quadrant), of 4.84 organisms/m^3. This station was very interesting, as it contained few copepods. The only calanoid copepod species represented were very small numbers of *Pseudocalanus* spp., *Acartia* spp., and *Temora longicornis*. The majority of our net tow sample consisted of extraordinary amounts of very small jellyfish. Also, we did collect 4 parasitic copepods of the Order Siphonostomatoida, a first for us in CCB. Other stations, especially those in the middle of the bay, contained a more attractive species composition to right whales (a higher percentage of late-stage *Calanus finmarchicus*), but total organism and caloric densities are extremely low and will not support feeding.

Oblique (surface - 19m) Assessment:

Our last three cruises have all resulted in average densities from the midwater/oblique tows hovering between 1800 and 2000 organisms/m^3. On SW336, the far eastern side of the bay contained the lowest mid-water densities, and the central and southwestern areas were highest. Yet at no station did densities climb over 3,000 organisms/m^3, and we did not find any isolated, dense patches that would lead us to suggest potential right whale aggregation or feeding. Due to the transition to later stage *Calanus finmarchicus*, total caloric density has increased in the central and southwestern bay, but still is likely too low to support right whales.

General:

Combined results from surface and oblique tows continue to emphasize the rapidly changing nature of zooplankton densities and species composition as we proceed through this month. Now that right whales have not been seen in 2 weeks, we will have one more

cruise to measure densities and finalize our vision of "post-departure" Cape Cod Bay. Then, we can finally combine all our data from the season, and using settled volume, dry weight, calorie and total organism measures along with right whale sighting information, provide an interpretation of how and why right whales utilized this habitat from January-April.

Interpreted likelihood (1-10) of
Aggregation: extremely low (1)
Residency: extremely low (1)
Near-Surface feeding: extremely low (1)
Feeding in the water column: very low (2)
Trend in above: steady or declining
Quadrant Quality/Attractiveness: NE very low (2), NW low (3),
SE extremely low (1), SW low (3)

Interpretation of Zooplankton: SW338
Cruise Date: 5/14/03
J.D.: 134

SW338, on 5/14, was our final right whale habitat cruise of 2003 and was a 4-hour, half-day cruise. We used our limited time to target the western reaches of CCB, because [1)] that was the region with the highest densities on SW336, and [2)] a skim feeding right whale was reported off Manomet the previous day, 5/13. This sighting occurred approximately 6 nm west of our westernmost trackline (track 8). Surface densities from track 8 on our last cruise were extremely low, in the range of 60- 100 organisms/m^3, but given the rapidly changing array of zooplankton patch formation throughout CCB observed on recent cruises, we were eager to learn about the resource this whale was feeding on. We directed our cruise to the coordinates of the right whale sighting, but did not re-locate the animal. We conducted sampling stations (surface and oblique tows, vertical pumps) approximately 8 nm NE (station 8N) and 7 nm SE (station 8S) of this site, and found significant increases in overall densities, and in the % of *Calanus finmarchicus,* at both stations. It is unlikely that these measured densities could support large aggregations or periods of residency of right whales, but it does appear that more zooplankton is moving into the bay, and it is possible this resource could potentially grow to trigger feeding and periods of residency in single or small groups of whales. With no more planned habitat cruises in 2003, we will not be able to report on this process as it unfolds.

Surface Layer Assessment:

Perhaps most exciting in the results of our surface tows was the great increase in the % of *Calanus finmarchicus* at both stations on SW338. In fact, we had our first station all year that contained 100% *Calanus finmarchicus*. This present species composition is undoubtedly more attractive to feeding right whales, and it was not surprising to find it so near, both temporally and spatially, to a sighting of a skim-feeding whale. Total organism densities in this region have increased 10-20x over SW336, yet still were not above the established threshold to trigger feeding behavior. But again, with the rapid formation and movement of zooplankton patches, this is to be expected.

Oblique (surface - 19m) Assessment:

Our two oblique tows also showed an increase in total organism and caloric densities in western CCB during the past 4 days. The resource is denser throughout the water column than it is at the surface, but it contains a greater proportion of other copepod species, such as *Pseudocalanus* spp., *Acartia* spp., and *Temora longicornis*, which results in equal or lesser caloric densities compared to the surface layer and it's strong concentration of *Calanus finmarchicus.*

Vertical Pump Profile:

Analysis of samples collected at 7-10m increments throughout the water column at both stations (30m and 50m depths) has not been fully completed, but these samples did not produce any layers of especially dense zooplankton patches. Densities appear relatively constant at all depths.

General:

As mentioned earlier, SW338 was the last habitat cruise of 2003, and was limited in coverage to the western side of CCB. All zooplankton measures showed increases since the previous cruise 4 days ago, and obviously were high enough to support at least one right whale's skim feeding behavior of unknown duration in the general proximity the previous day. We have no more planned cruises to continue to monitor the rapid and exciting changes in the system over the next few weeks/months, but it is clear that zooplankton moving into the bay ***could*** condense into layers and patches and potentially support feeding for right whales in any area of CCB when/where this occurs.

Interpreted likelihood (1-10) of
Aggregation: low (3)
Residency: low (3)
Near-Surface feeding: fair (5)
Feeding in the water column: fair (5)
Trend in above: increasing
Quadrant Quality/Attractiveness: NE no data, NW fair (6),
SE no data, SW fair (5)

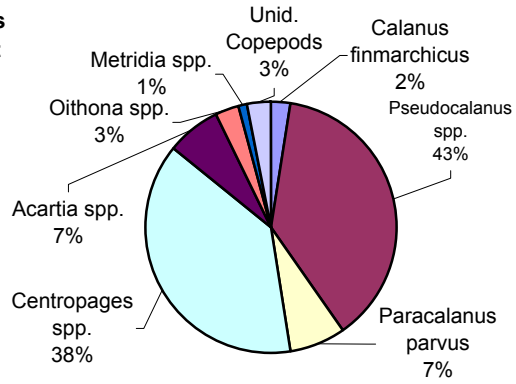
*****NOTE: These predictions only refer to the western side of CCB (sampled on SW338).**

Zooplankton Assessment: SW316 (2/27/2003) Julian Day 58

MEASURES

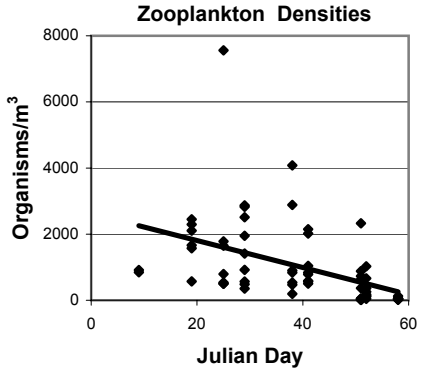
Technique	Station	Total Zpl/m3	Settled Vol/m3	Total Calories/m3	Total Dry Wt./m3
surface tow	6N	53.49	0.04	4.72	7.91E-04
surface tow	6M	26.91	0.05	1.68	3.45E-04
surface tow	7N	55.52	0.10	5.34	9.96E-04
surface tow	5S	23.14	0.02	1.79	3.53E-04
surface tow	6S	12.88	0.02	0.64	1.29E-04
surface tow	7S	48.13	0.04	3.61	7.03E-04
surface tow	8M	42.73	0.09	4.28	7.99E-04
surface tow	LP	127.74	0.11	11.36	2.18E-03
Cruise Average:		**48.82**	**0.06**	**4.18**	**7.9E-04**

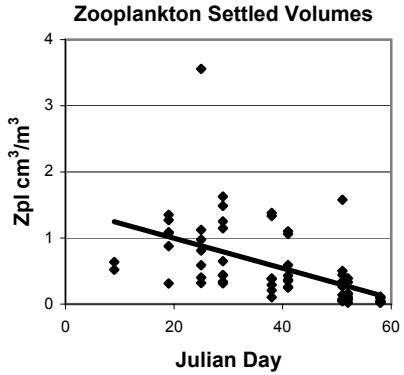
Copepod Species Average Percent Composition: SW316

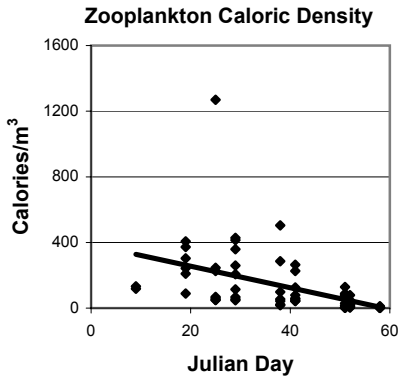


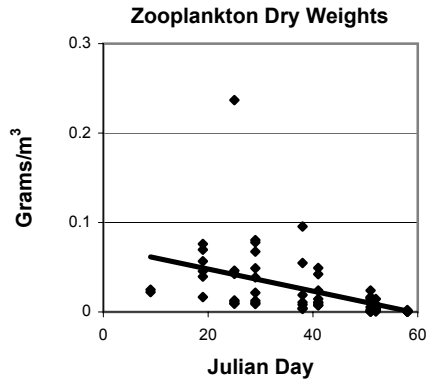
2003 SEASONAL TRENDS

Entire Cape Cod Bay:

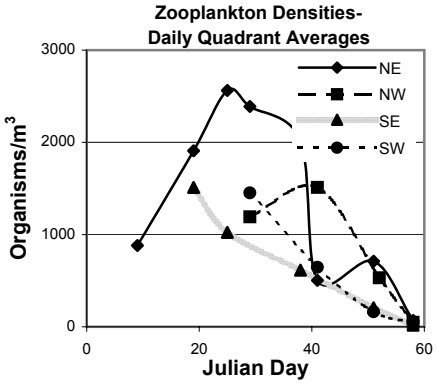


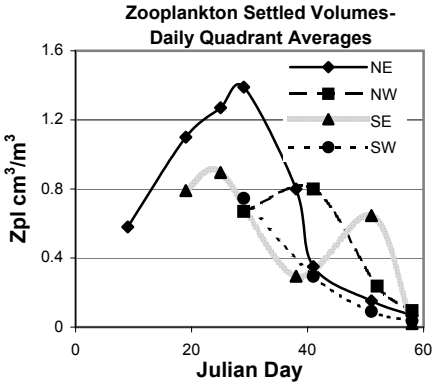


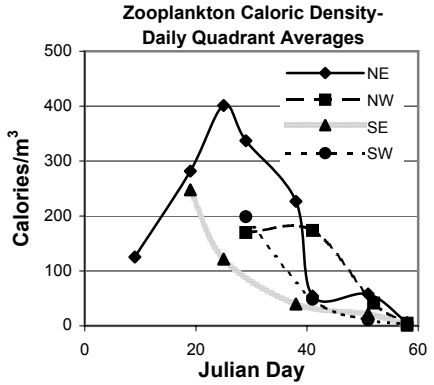


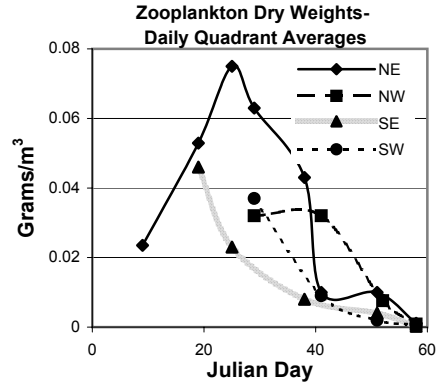


Geographic Quadrants:







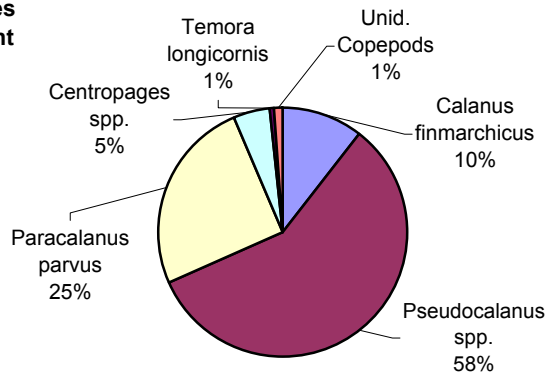


Zooplankton Assessment: SW318 (3/7/2003) Julian Day 66

MEASURES:

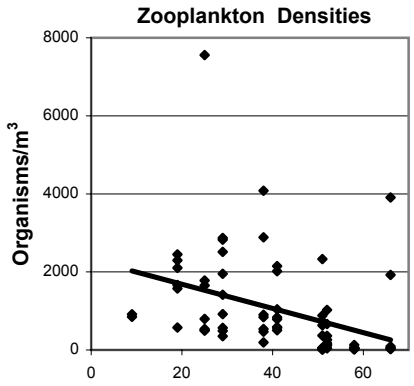
Technique	Station	Total Zpl/m3	Settled Vol/m3	Total Calories/m3	Total Dry Wt./m3
Surface Tow	6M	1923.93	0.89	234.28	4.27E-02
Surface Tow	7N	3909.30	1.45	310.41	5.69E-02
Surface Tow	8M	91.52	0.09	16.89	3.80E-03
Surface Tow	6S	42.80	0.06	2.23	4.68E-04
Surface Tow	5S	19.22	0.03	0.79	1.68E-04
Surface Tow	LP	43.39	0.06	3.07	6.26E-04
Cruise Average:		**1005.03**	**0.43**	**94.61**	**1.74E-02**

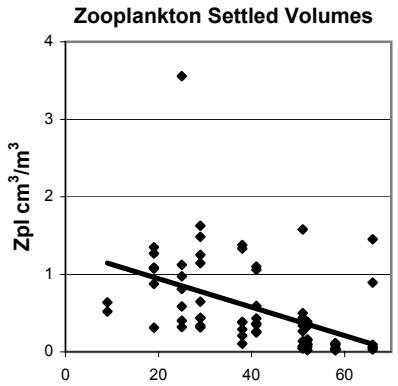
Copepod Species Average Percent Composition: SW318

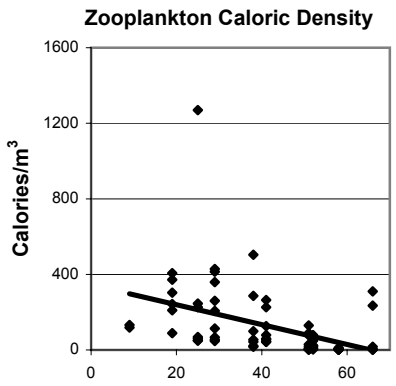


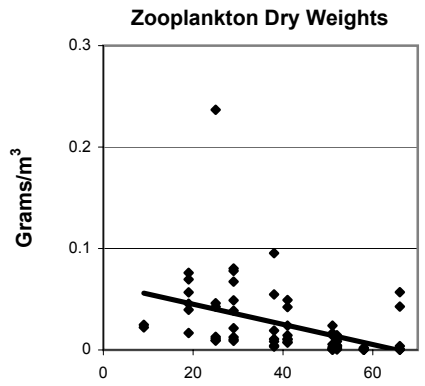
2003 SEASONAL TRENDS: x-axis values are expressed as Julian days in all graphs

Entire Cape Cod Bay:

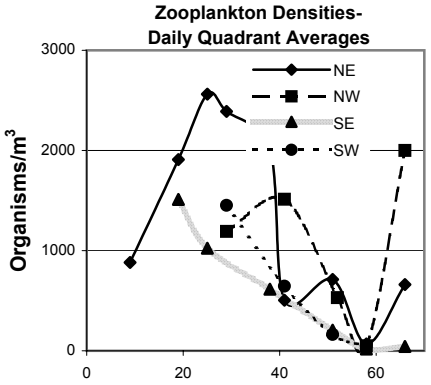


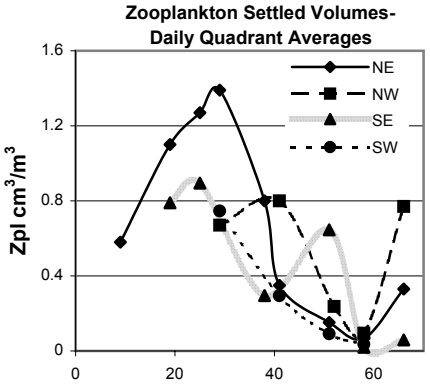


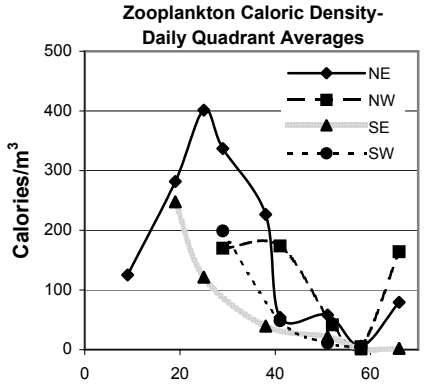


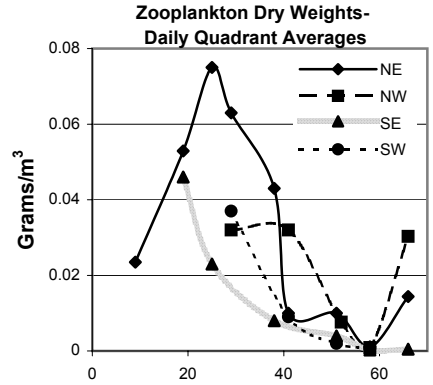


Geographic Quadrants:







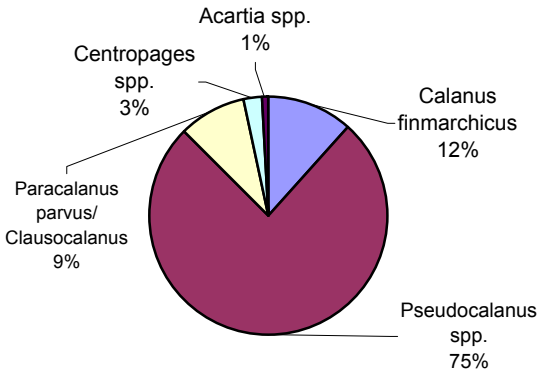


Zooplankton Assessment: SW319 (3/13/2003) Julian Day 72

MEASURES:

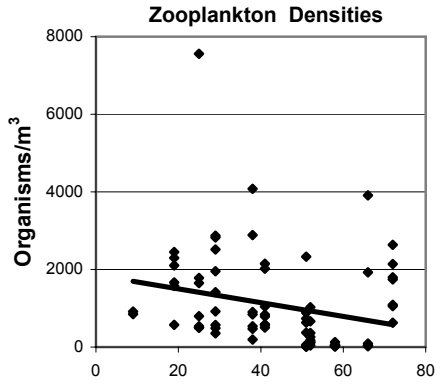
Technique	Station	Total Zpl/m3	Settled Vol/m3	Total Calories/m3	Total Dry Wt./m3
Surface Tow	6N	2635.50	1.22	161.48	2.59E-02
Surface Tow	7N	1745.07	0.70	305.39	5.73E-02
Surface Tow	6M	2140.42	0.91	189.94	3.09E-02
Surface Tow	7S	1054.22	0.48	117.66	2.41E-02
Surface Tow	6S	1799.16	0.71	195.33	3.63E-02
Surface Tow	5S	626.41	0.24	37.26	6.59E-03
Surface Tow	LP	1089.79	0.42	60.56	1.01E-02
Cruise Average:		**1584.37**	**0.67**	**152.52**	**2.73E-02**

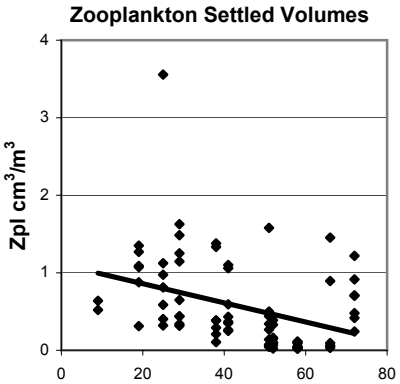
Copepod Species Average Percent Composition: SW319

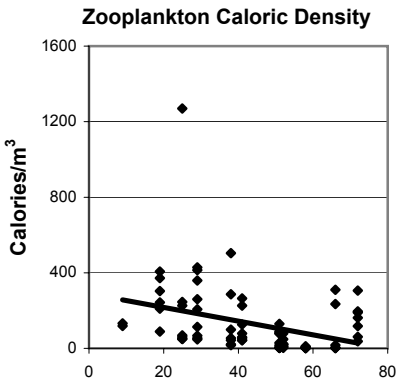


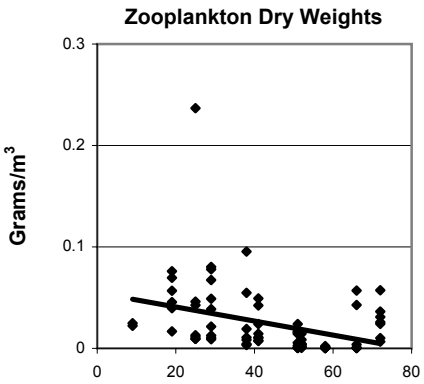
2003 SEASONAL TRENDS: x-axis values are expressed as Julian days in all graphs

Entire Cape Cod Bay:

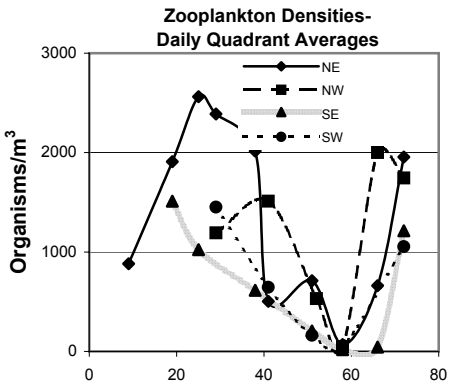


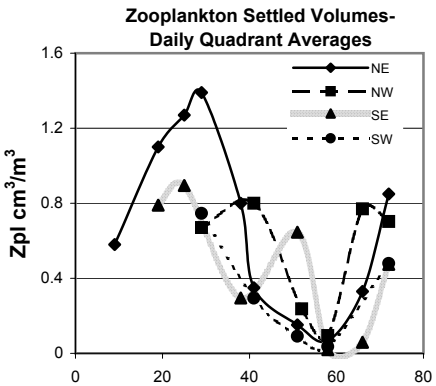


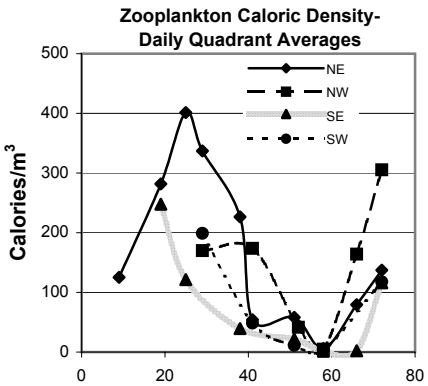


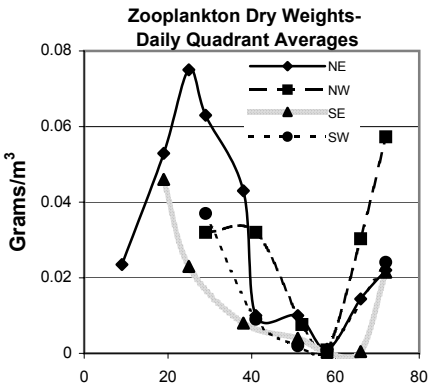


Geographic Quadrants:







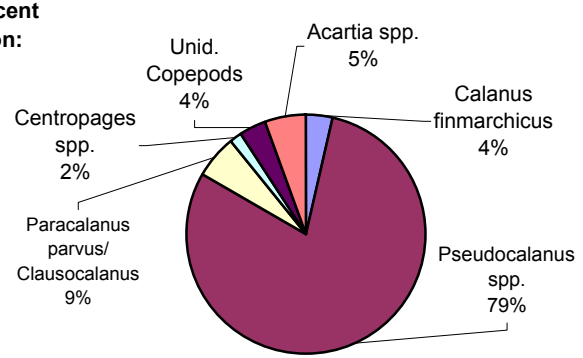


Zooplankton Assessment: SW320 (3/17/2003) Julian Day 76

MEASURES:

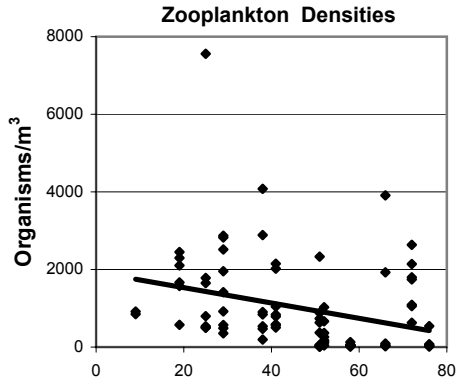
Technique	Station	Total Zpl/m3	Settled Vol/m3	Total Calories/m3	Total Dry Wt./m3
Surface Tow	6S	12.95	0.01	0.93	2.33E-04
Surface Tow	8N	43.70	0.03	2.17	4.12E-04
Surface Tow	5N	32.18	0.02	0.98	2.04E-04
Surface Tow	5S	538.71	0.26	27.88	4.58E-03
Surface Tow	7S	73.72	0.09	5.86	9.90E-04
Cruise Average:		**140.25**	**0.08**	**7.56**	**1.28E-03**
Previous Cruise Avg:		**1584.37**	**0.67**	**152.52**	**2.73E-02**

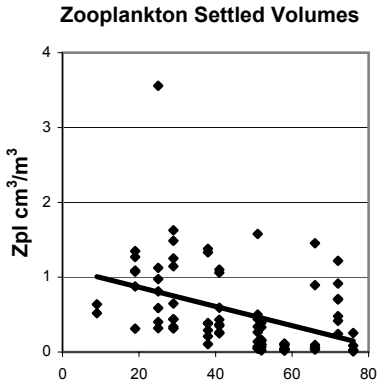
Copepod Species Average Percent Composition: SW320

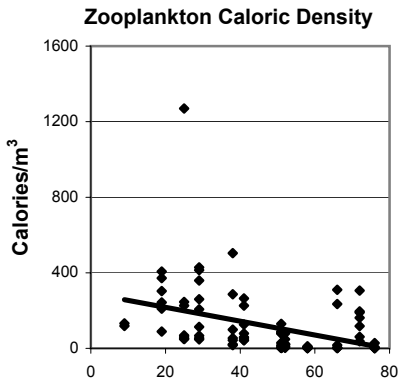


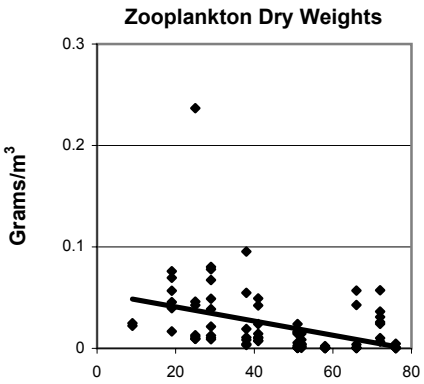
2003 SEASONAL TRENDS: x-axis values are expressed as Julian days in all graphs

Entire Cape Cod Bay:

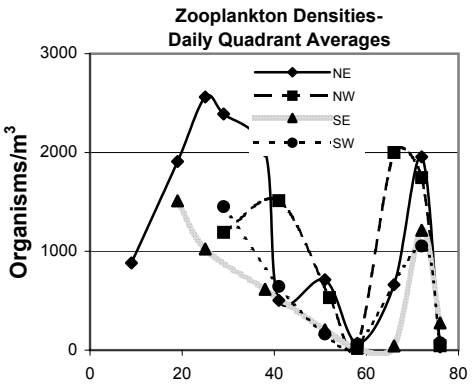


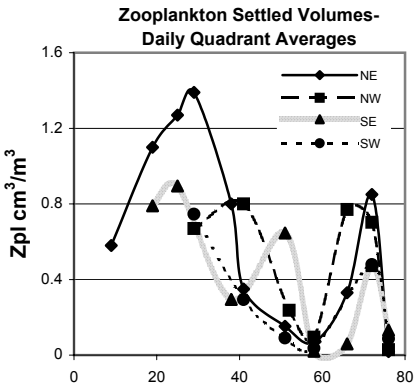


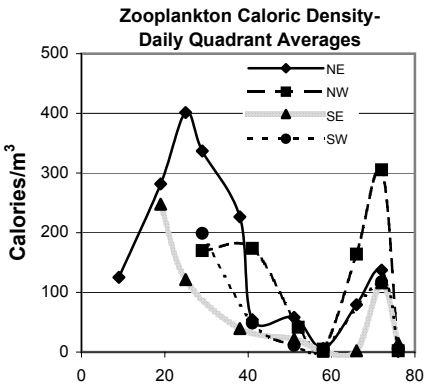


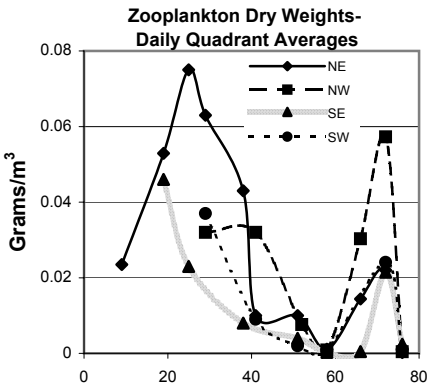


Geographic Quadrants:







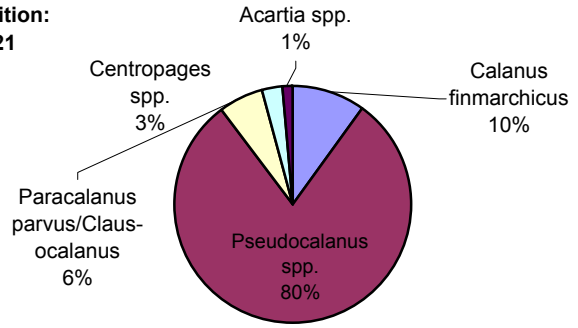


Surface Zooplankton Assessment: SW321 (3/23/2003) Julian Day 82

MEASURES:

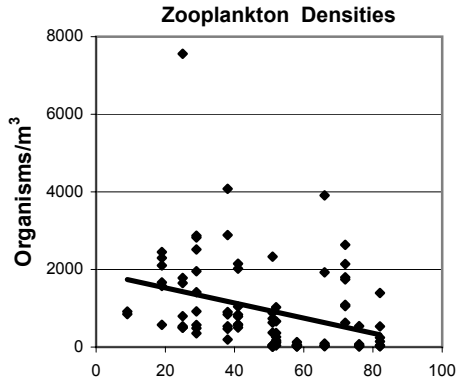
Technique	Station	Total Zpl/m3	Settled Vol/m3	Total Calories/m3	Total Dry Wt./m3
Surface Tow	6N	45.55	0.07	6.46	1.64E-03
Surface Tow	8N	244.36	0.19	50.62	1.16E-02
Surface Tow	9S	144.50	0.06	8.98	2.12E-03
Surface Tow	7S	21.75	0.04	0.95	1.91E-04
Surface Tow	6SX	23.43	0.03	0.85	1.65E-04
Surface Tow	5S	532.41	0.26	30.14	4.98E-03
Surface Tow	LP	1393.54	0.69	75.80	1.22E-02
Cruise Average:		**343.65**	**0.19**	**24.83**	**4.70E-03**
Previous Cruise Avg:		**140.25**	**0.08**	**7.56**	**1.28E-03**

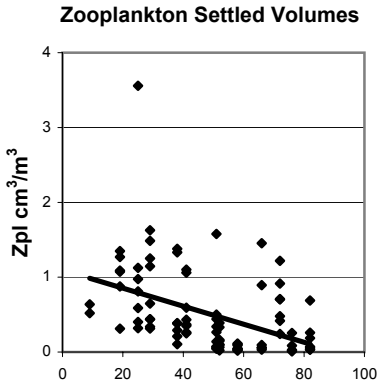
Copepod Species Average Percent Composition: SW321

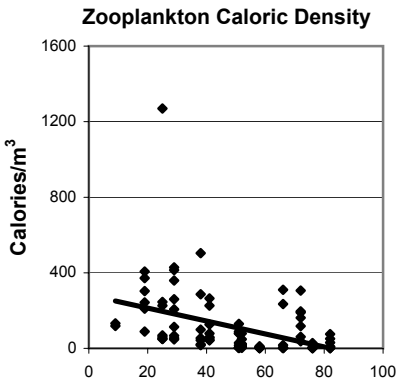


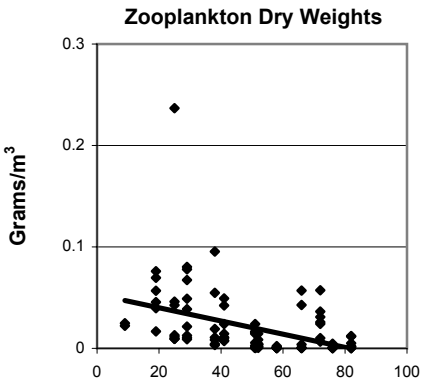
2003 SEASONAL TRENDS: x-axis values are expressed as Julian days in all graphs

Entire Cape Cod Bay:

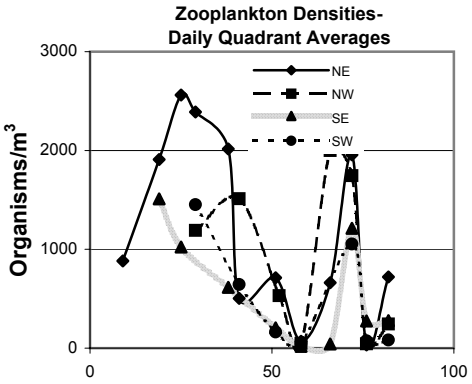


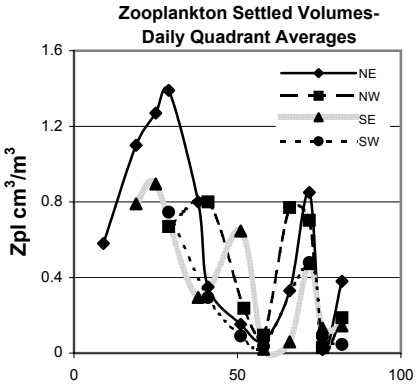


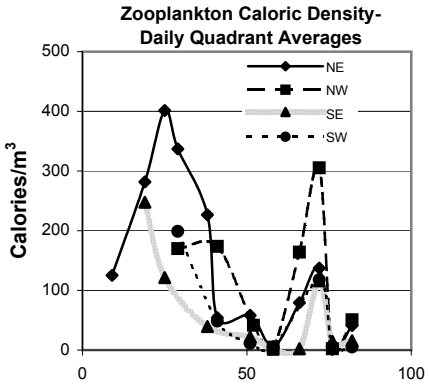


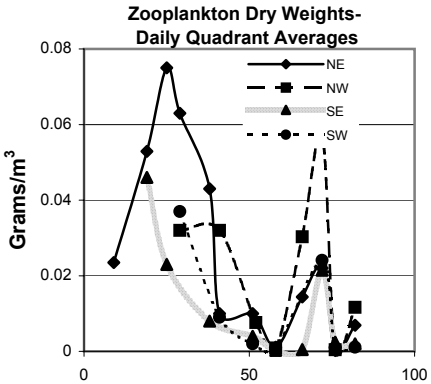


Geographic Quadrants:







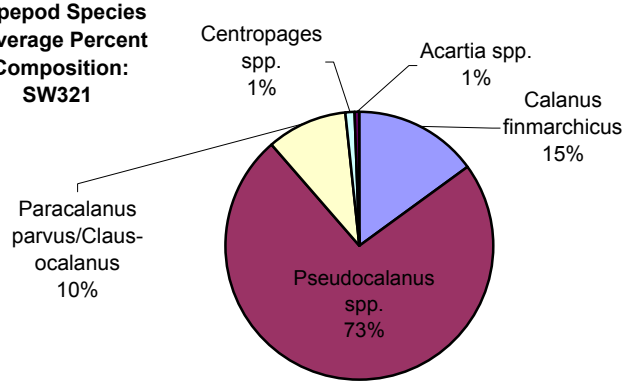


Oblique Zooplankton Assessment: SW321 (3/23/2003) Julian Day 82

MEASURES:

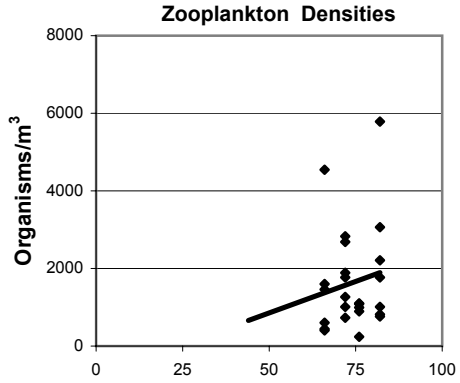
Technique	Station	Total Zpl/m3	Settled Vol/m3	Total Calories/m3	Total Dry Wt./m3
Oblique Tow	6N	3064.02	1.78	14.52	2.71E-03
Oblique Tow	8N	1768.55	1.02	120.30	2.53E-02
Oblique Tow	9S	5783.81	1.71	0.32	7.28E-05
Oblique Tow	7S	814.87	0.38	2.93	5.37E-04
Oblique Tow	6SX	1009.58	0.40	3.27	6.17E-04
Oblique Tow	5S	760.97	0.45	28.32	5.45E-03
Oblique Tow	LP	2211.17	0.95	72.44	1.22E-02
Cruise Average:		**2201.85**	**0.95**	**34.58**	**6.70E-03**
Previous Cruise Avg:		**2116.08**	**0.78**	**21.46**	**3.77E-03**

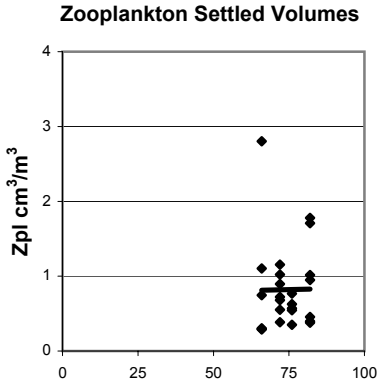
Copepod Species Average Percent Composition: SW321

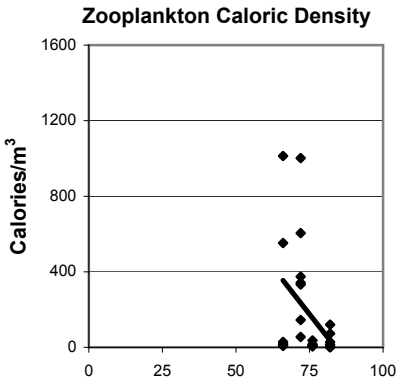


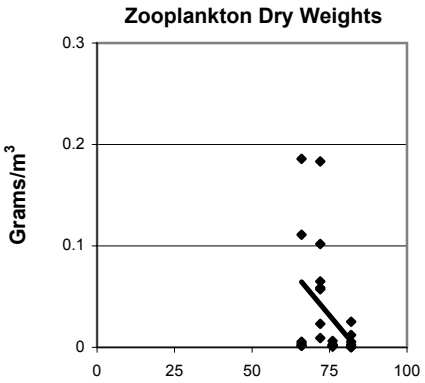
2003 SEASONAL TRENDS: x-axis values are expressed as Julian days in all graphs

Entire Cape Cod Bay:

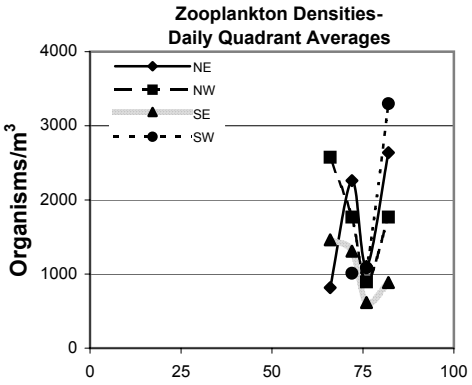


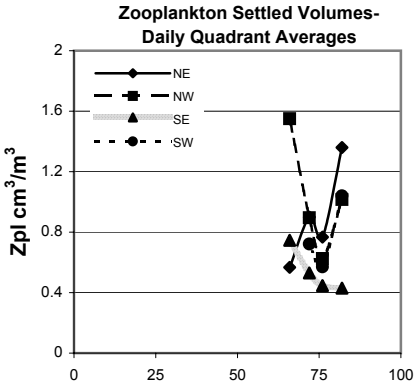


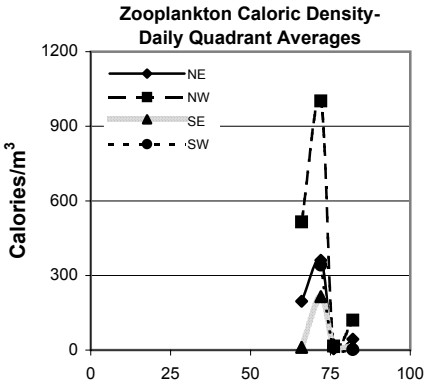


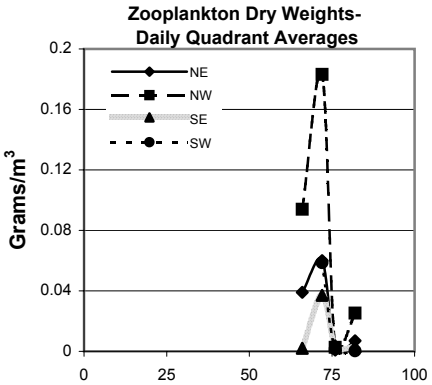


Geographic Quadrants:









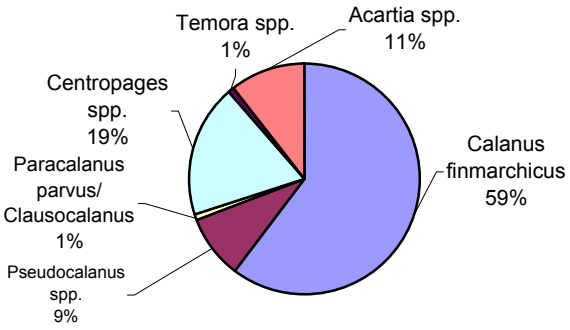
Zooplankton Assessment: SW322 (3/24/2003) Julian Day 83

MEASURES:

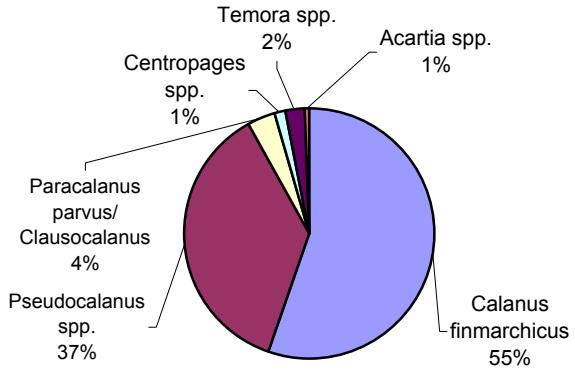
Technique	Station	Total Zpl/m3	Settled Vol/m3	Total Calories/m3	Total Dry Wt./m3
Surface Tow	NI	74.88	0.11	17.69	4.07E-03
Surface Tow	HL	1629.14	2.20	543.54	1.01E-01
Oblique Tow	A	1230.17	n/a	n/a	n/a
Oblique Tow	NI	441.65	n/a	n/a	n/a
Oblique Tow	HL	2141.25	n/a	n/a	n/a

Surface Tow Species Composition:

Station NI

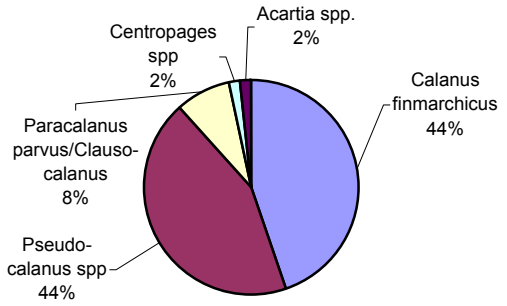


Station HL

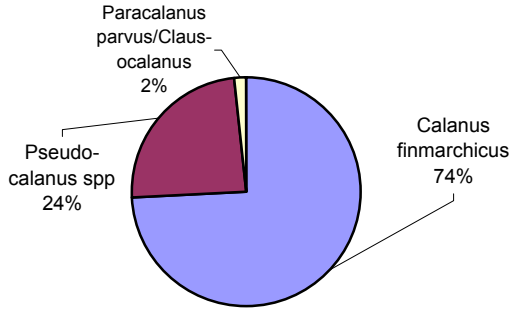


Oblique Tow Species Composition:

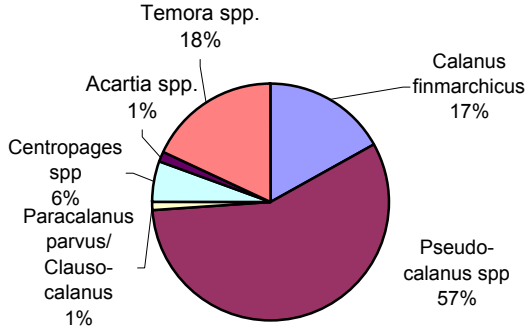
Station A



Station NI



Station HL

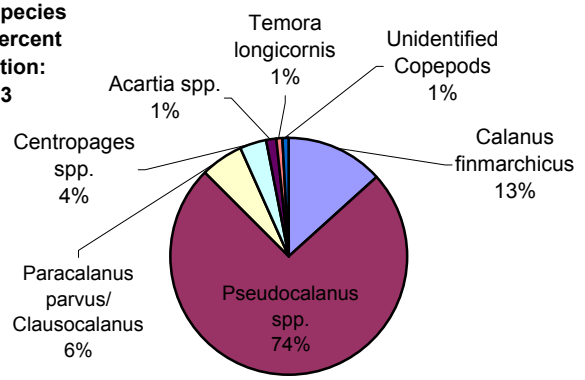


Surface Zooplankton Assessment: SW323 (4/2/2003) Julian Day 92

MEASURES:

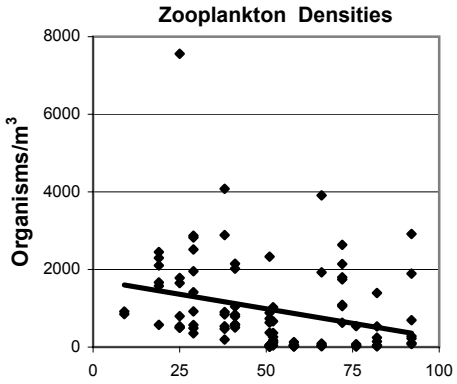
Technique	Station	Total Zpl/m^3	Settled Vol/m^3	Total Calories/m^3	Total Dry Wt./m^3
Surface Tow	6N	104.62	0.09	8.12	1.62E-03
Surface Tow	8N	77.02	0.09	7.52	1.65E-03
Surface Tow	8M	224.40	0.17	44.60	1.06E-02
Surface Tow	7S	694.57	0.44	130.88	2.75E-02
Surface Tow	6M	279.59	0.24	63.21	1.18E-02
Surface Tow	5S	2914.74	0.97	191.69	3.12E-02
Surface Tow	LP	1893.79	0.91	185.91	3.13E-02
Cruise Average:		**884.11**	**0.41**	**90.28**	**1.65E-02**
Previous Cruise Avg:		**343.65**	**0.19**	**24.83**	**4.70E-03**

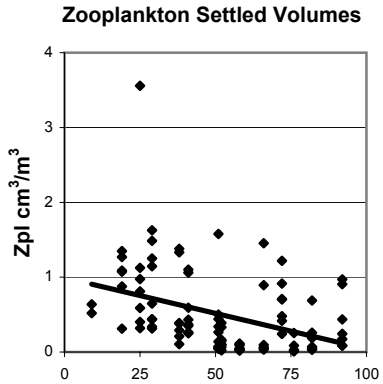
Copepod Species Average Percent Composition: SW323

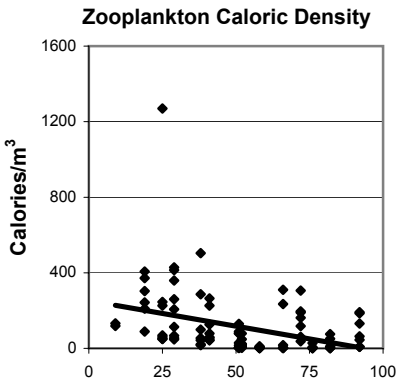


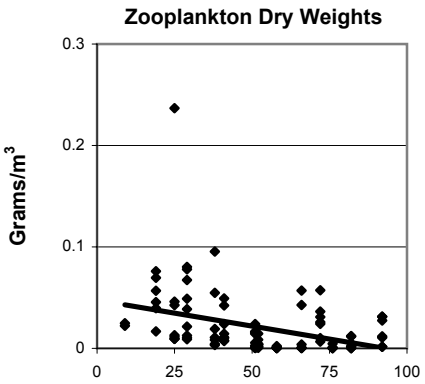
2003 SEASONAL TRENDS: x-axis values are expressed as Julian days in all graphs

Entire Cape Cod Bay:

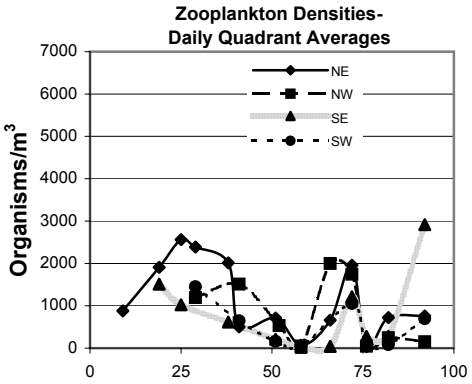


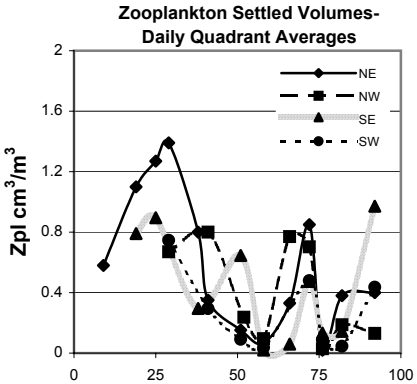


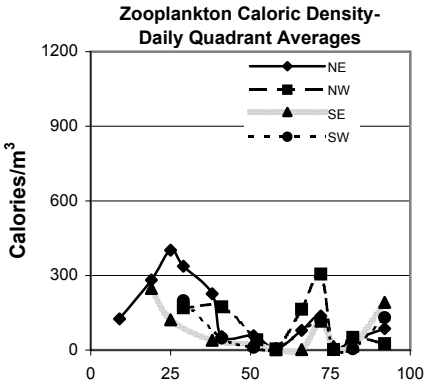


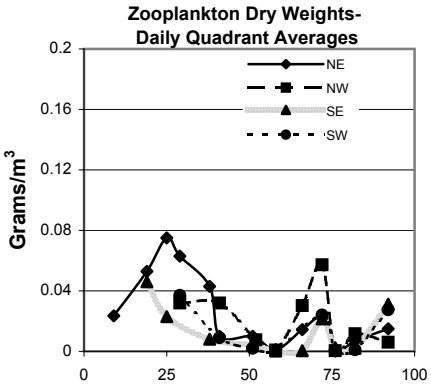


Geographic Quadrants:







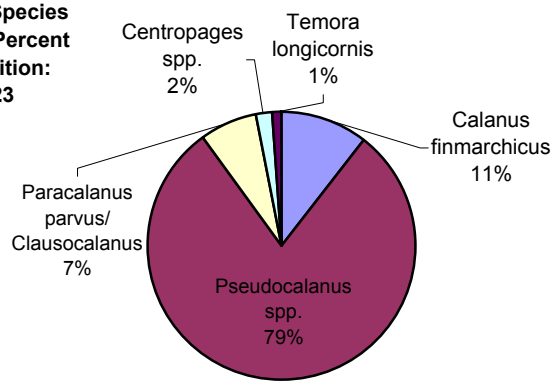


Oblique Zooplankton Assessment: SW323 (4/2/2003) Julian Day 92

MEASURES:

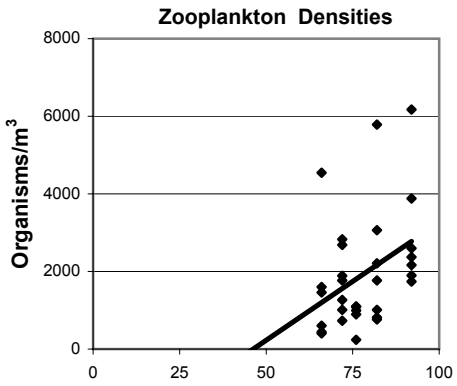
Technique	Station	Total Zpl/m^3	Settled Vol/m^3	Total Calories/m^3	Total Dry Wt./m^3
Oblique Tow	6M	3880.98	2.12	44.32	7.17E-03
Oblique Tow	7S	2165.35	1.63	87.98	1.71E-02
Oblique Tow	8M	1898.88	1.45	43.06	9.34E-03
Oblique Tow	8N	2369.28	1.58	26.92	6.07E-03
Oblique Tow	6N	1741.55	1.08	20.53	4.29E-03
Oblique Tow	LP	2598.67	1.02	169.17	3.13E-02
Oblique Tow	5S	6172.01	1.32	147.42	2.38E-02
Cruise Average:		**2975.25**	**1.46**	**77.06**	**1.41E-02**
Previous Cruise Avg:		**2201.85**	**0.95**	**34.58**	**6.70E-03**

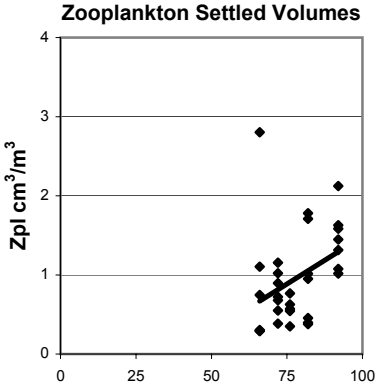
Copepod Species Average Percent Composition: SW323

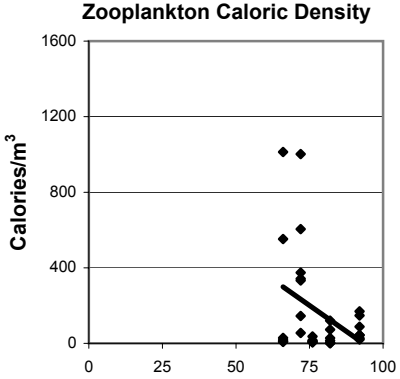


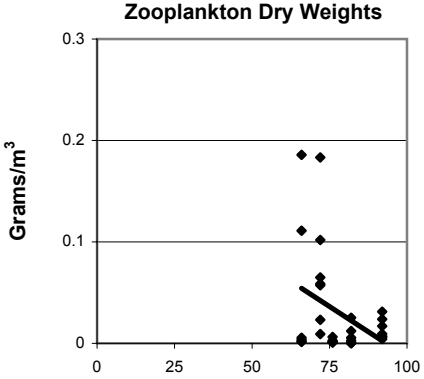
2003 SEASONAL TRENDS: x-axis values are expressed as Julian days in all graphs

Entire Cape Cod Bay:

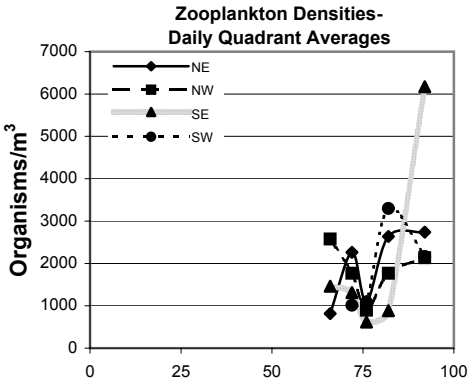


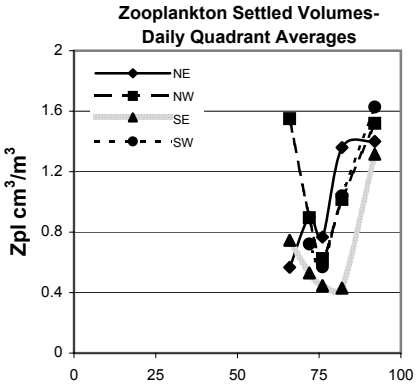


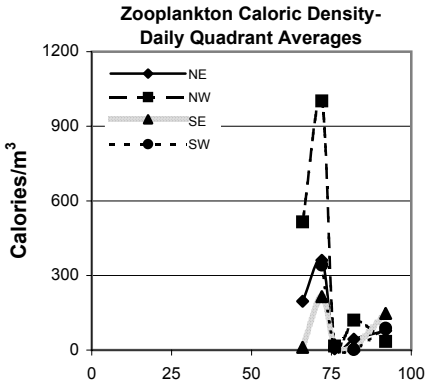


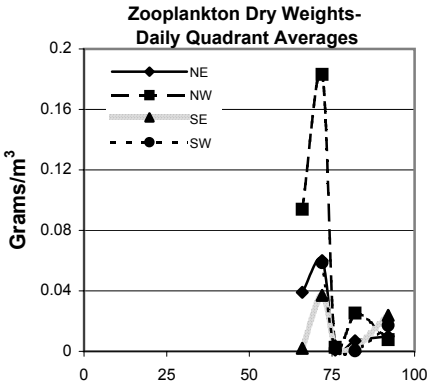


Geographic Quadrants:







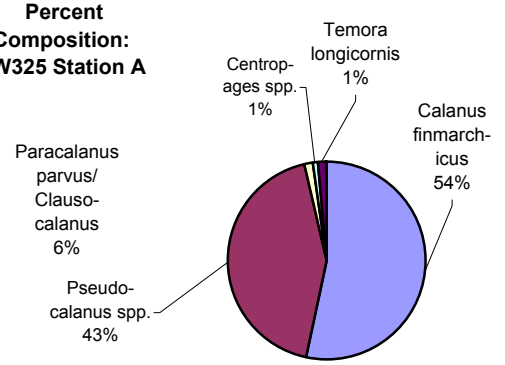


Surface Zooplankton Assessment: SW325 (4/9/2003) Julian Day 99

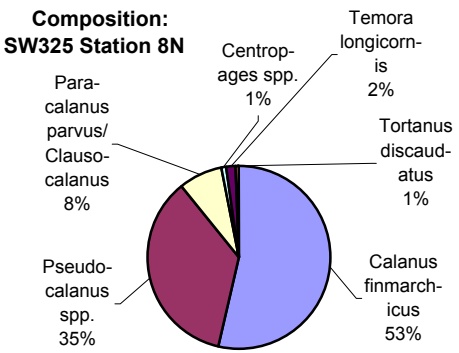
MEASURES:

Technique	Station	Total Zpl/m^3	Settled Vol/m^3	Total Calories/	Total Dry Wt./m^3
Surface Tow	8N	4883.89	4.30	1249.67	2.55E-01
Surface Tow	A	2048.44	1.97	481.78	9.79E-02
Cruise Average:		**3466.17**	**3.14**	**865.72**	**1.76E-01**
Previous Cruise Avg:		**884.11**	**0.41**	**90.28**	**1.65E-02**

Copepod Species Percent Composition: SW325 Station A

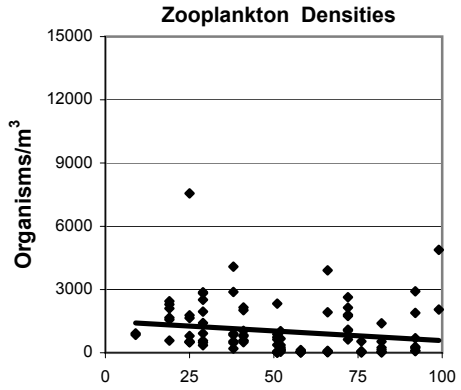


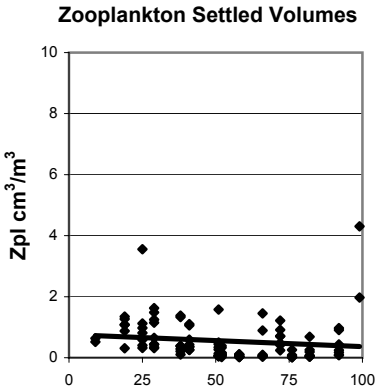
Copepod Species Percent Composition: SW325 Station 8N

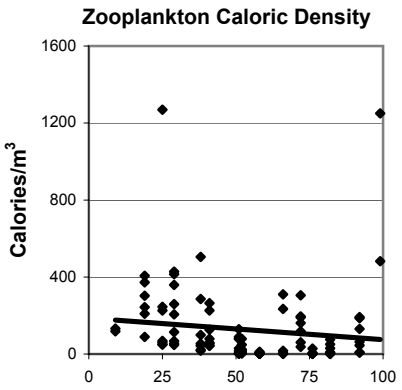


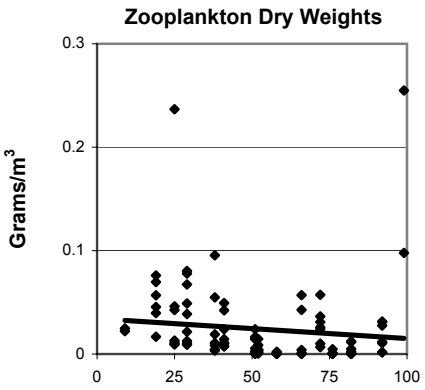
2003 SEASONAL TRENDS: x-axis values are expressed as Julian days in all graphs

Entire Cape Cod Bay:

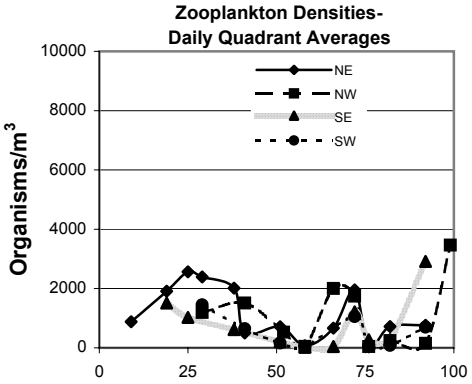


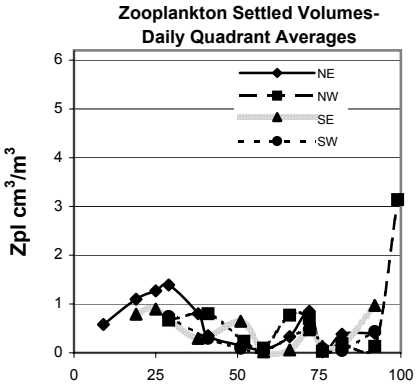


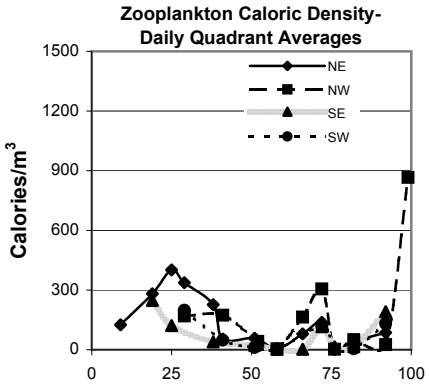


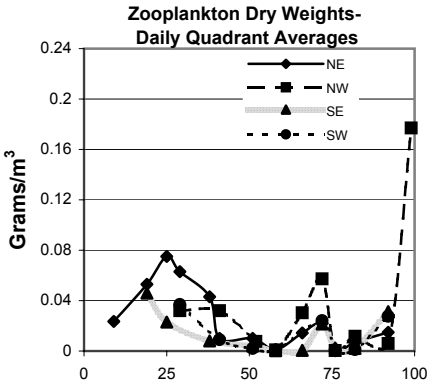


Geographic Quadrants:







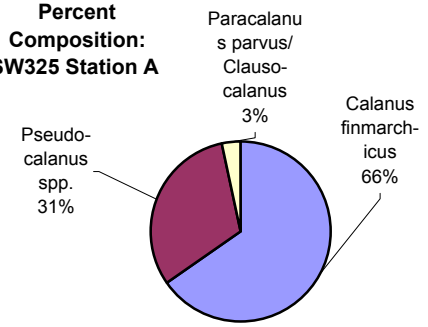


Oblique Zooplankton Assessment: SW325 (4/9/2003) Julian Day 99

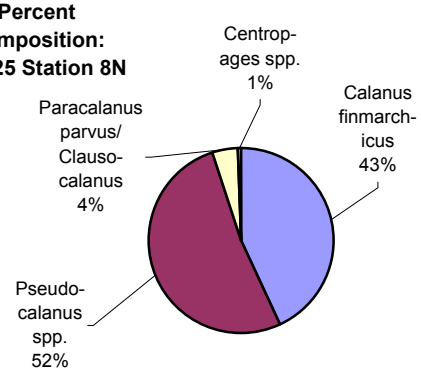
MEASURES:

Technique	Station	Total Zpl/m^3	Settled Vol/m^3	Total Calories/	Total Dry Wt./m^3
Oblique Tow	8N	13169.65	8.43	1346.70	2.51E-01
Oblique Tow	A	4981.97	3.79	982.31	1.91E-01
Cruise Average:		**4981.97**	**3.79**	**982.31**	**0.19**
Previous Cruise Avg:		**2975.25**	**1.46**	**77.06**	**1.41E-02**

Copepod Species Percent Composition: SW325 Station A

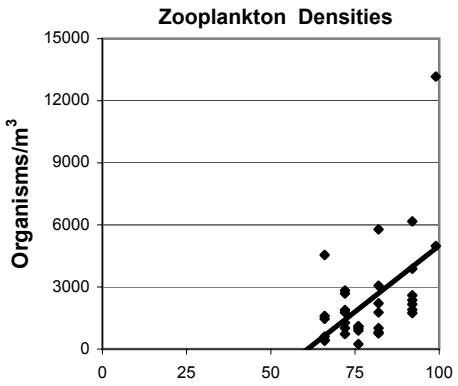


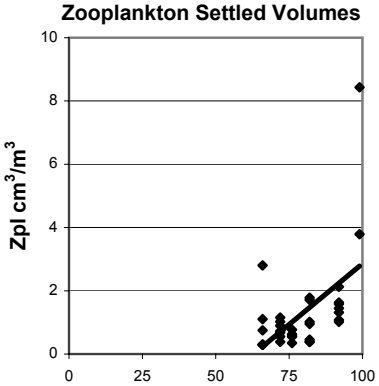
Copepod Species Percent Composition: SW325 Station 8N

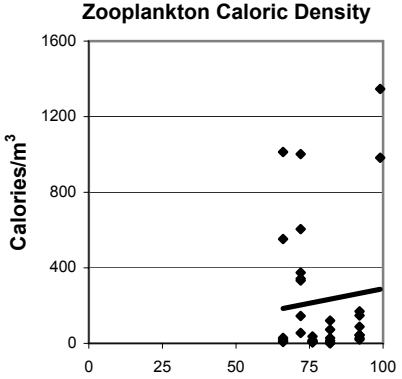


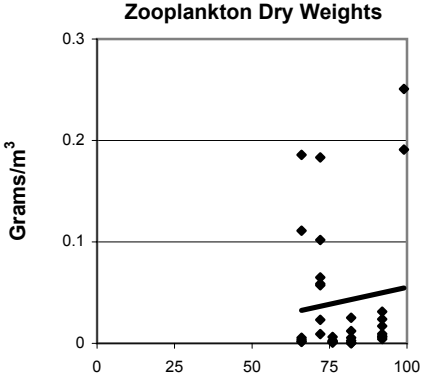
2003 SEASONAL TRENDS: x-axis values are expressed as Julian days in all graphs

Entire Cape Cod Bay:

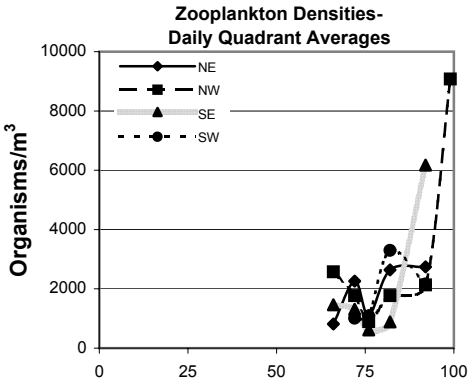


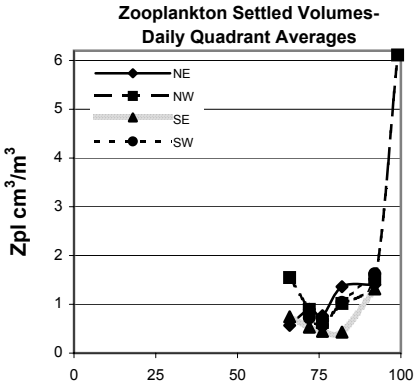


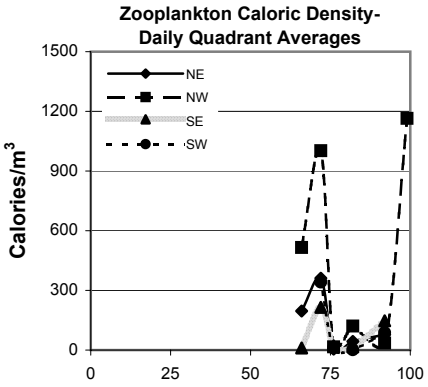


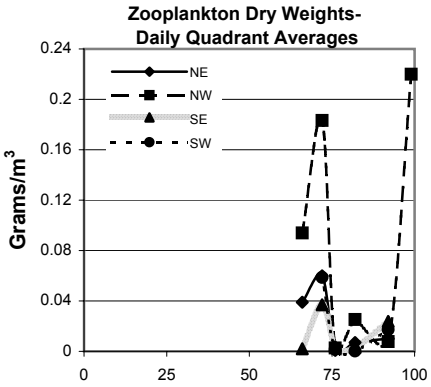


Geographic Quadrants:





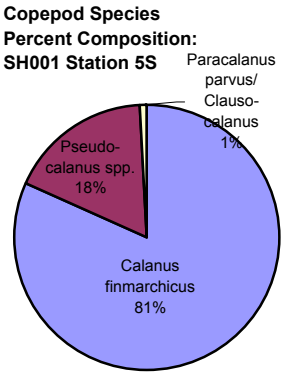


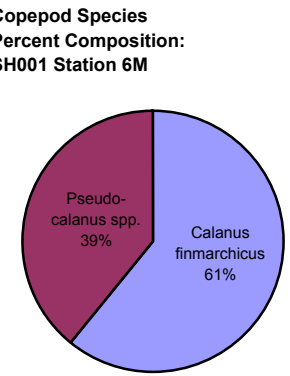


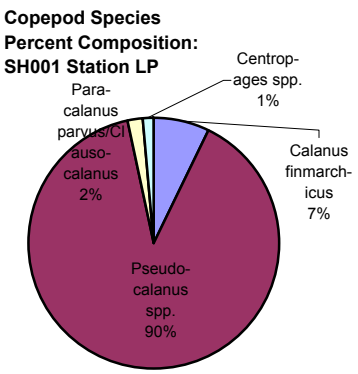
Oblique Zooplankton Assessment: SH001 (4/15/2003) Julian Day105

MEASURES:

Technique	Station	Total Zpl/m^3	Settled Vol/m^3	Total Calories/	Total Dry Wt./m^3
Oblique Tow	5S	15899.13	13.88	4829.21	1.09E+00
Oblique Tow	6M	10704.26	13.97	2399.05	5.60E-01
Oblique Tow	LP	7131.25	3.47	499.77	1.00E-01
Cruise Average:		**11244.88**	**10.44**	**2576.01**	**5.84E-01**
Previous Cruise Avg:		**4981.97**	**3.79**	**982.31**	**1.90E-01**

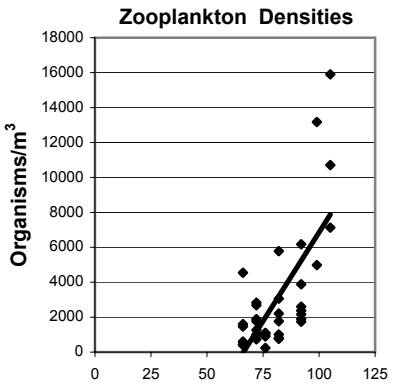


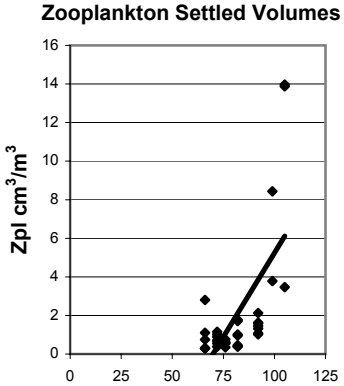


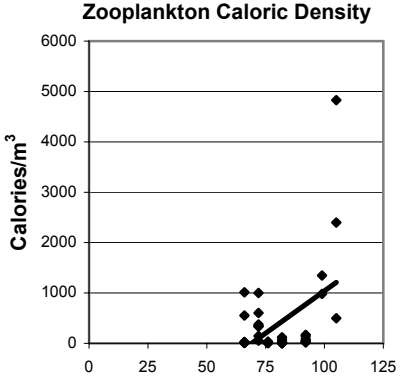


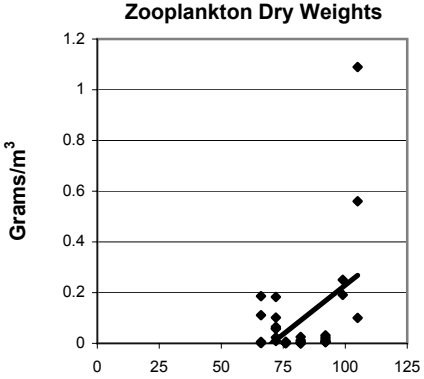
2003 SEASONAL TRENDS: x-axis values are expressed as Julian days in all graphs

Entire Cape Cod Bay:

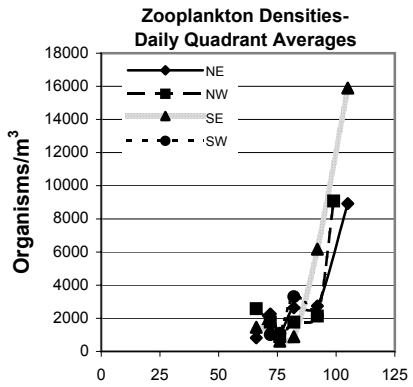


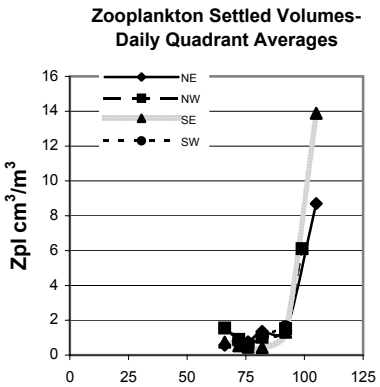


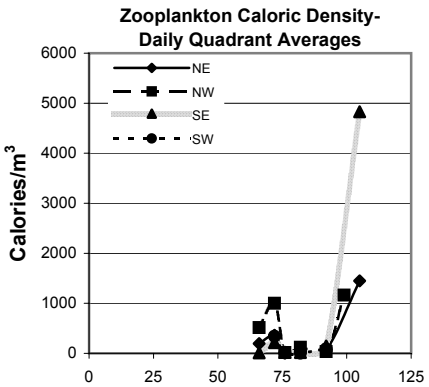


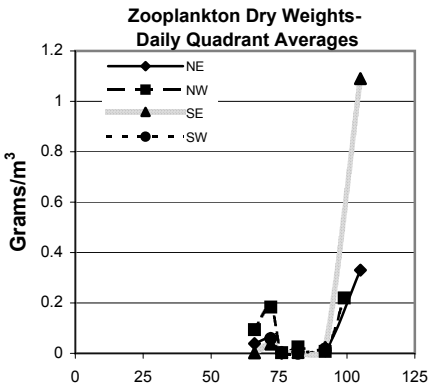


Geographic Quadrants:







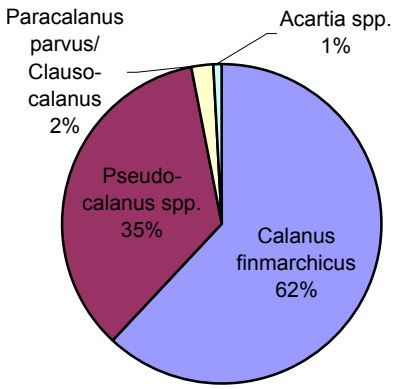


Surface Zooplankton Assessment: SW328 (4/19/2003) Julian Day 109

MEASURES:

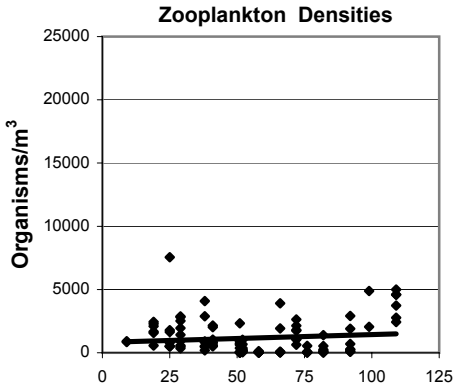
Technique	Station	Total Zpl/m^3	Settled Vol/m^3	Total Calories/	Total Dry Wt./m^3
Surface Tow	LP	2435.20	2.14	546.07	1.26E-01
Surface Tow	5S	3729.55	2.06	396.89	8.76E-02
Surface Tow	6M	2769.28	2.49	874.61	1.92E-01
Surface Tow	6S	4592.08	2.95	962.46	2.16E-01
Surface Tow	7S	4594.22	3.45	910.39	2.26E-01
Surface Tow	7N	4995.97	8.12	1658.01	3.81E-01
Cruise Average:		**3852.72**	**3.54**	**891.41**	**2.05E-01**
Previous Cruise Avg:		**3466.17**	**3.14**	**865.72**	**1.76E-01**

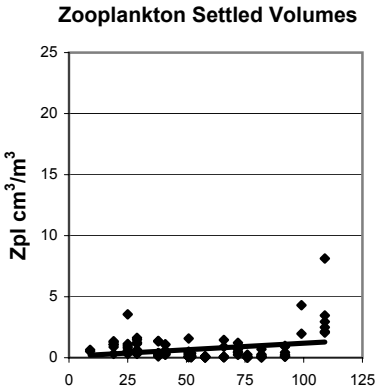
Copepod Species Average Percent Composition: SW328

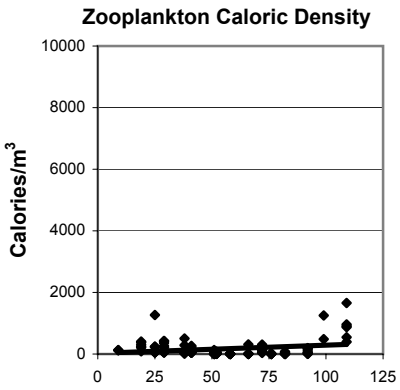


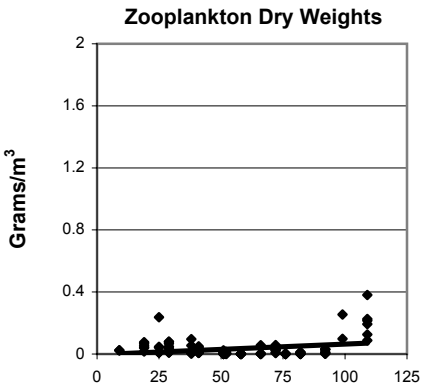
2003 SEASONAL TRENDS: x-axis values are expressed as Julian days in all graphs

Entire Cape Cod Bay:

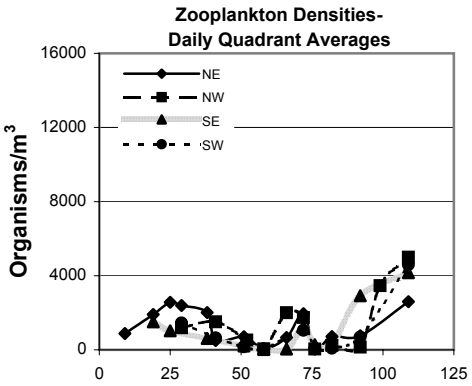


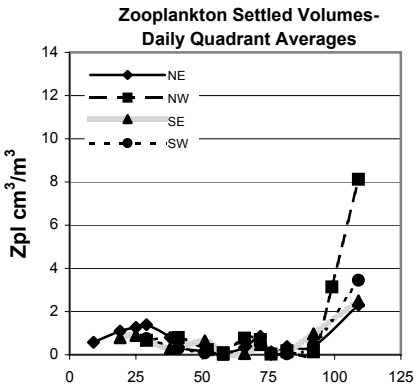


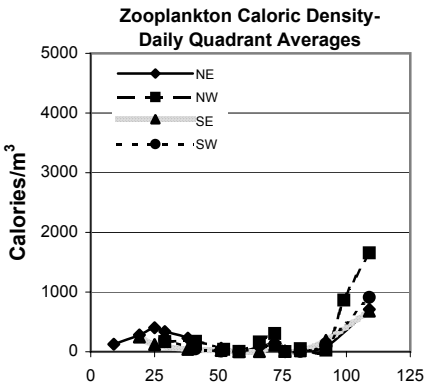


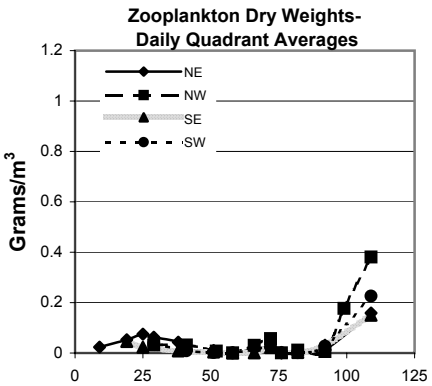


Geographic Quadrants:









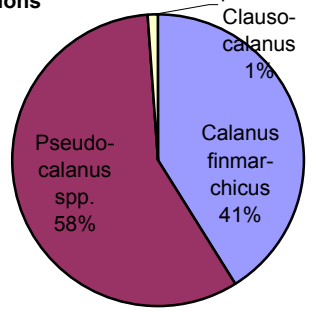
Oblique Zooplankton Assessment: SW328 (4/19/2003) Julian Day109

MEASURES:

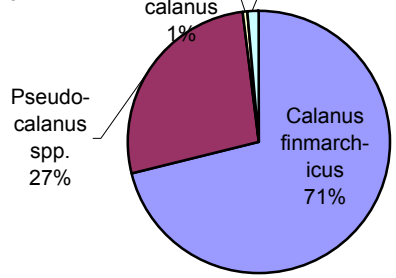
Technique	Station	Total Zpl/m^3	Settled Vol/m^3	Total Calories/	Total Dry Wt./m^3
Oblique Tow	7N	4579.29	11.66	974.14	2.32E-01
Oblique Tow	7S	8950.96	5.62	1652.25	4.37E-01
Oblique Tow	6S	4630.24	3.14	733.41	1.59E-01
Oblique Tow	6M	5891.56	4.19	1442.52	3.03E-01
Oblique Tow	5S	9348.54	3.86	522.59	8.83E-02
Oblique Tow	LP	6456.06	4.02	1228.92	2.62E-01
Oblique Tow	A	24297.28	23.97	9428.01	1.81E+00
Cruise Average:		**6642.78**	**5.42**	**1092.30**	**2.47E-01**
Previous Cruise Avg:		**11244.88**	**10.44**	**2576.01**	**5.84E-01**

*Note: Values from Station A were not included in the cruise averages

Copepod Species Average Percent Composition: SW328 Regular Stations

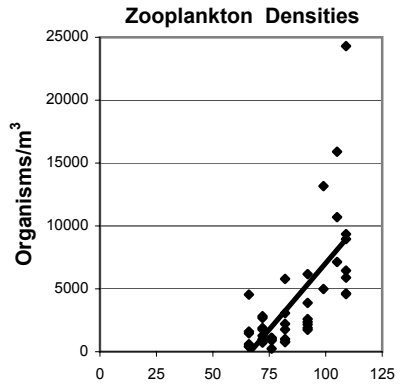


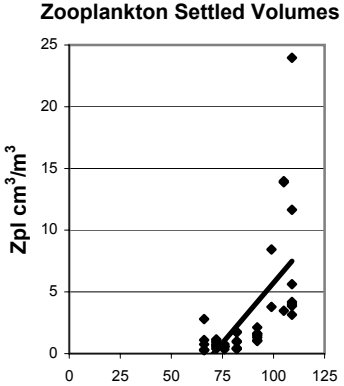
Copepod Species Percent Composition: SW328 Station A

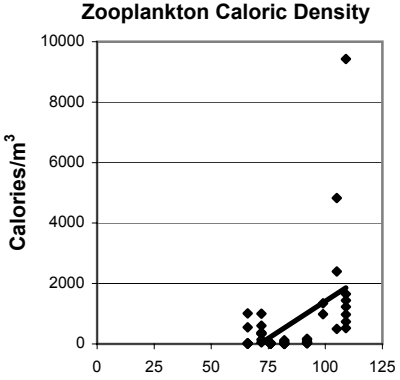


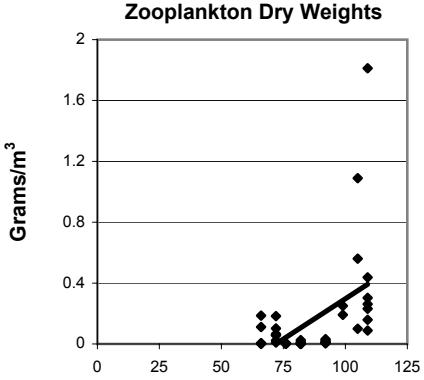
2003 SEASONAL TRENDS: x-axis values are expressed as Julian days in all graphs

Entire Cape Cod Bay:

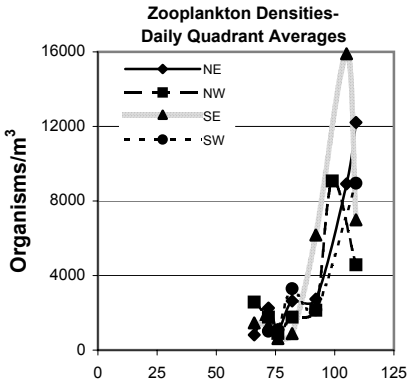


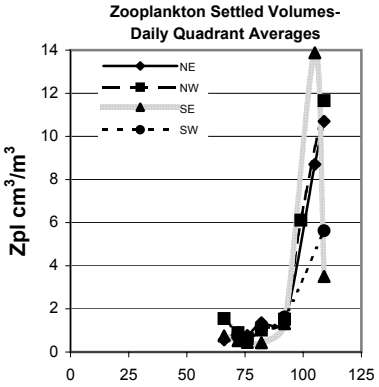


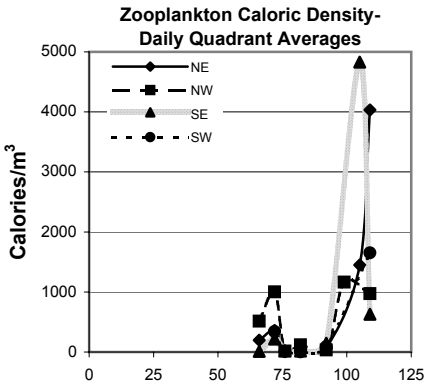


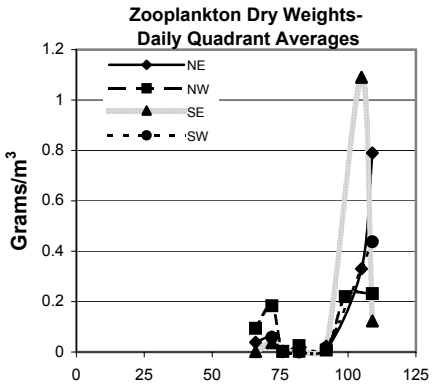


Geographic Quadrants:







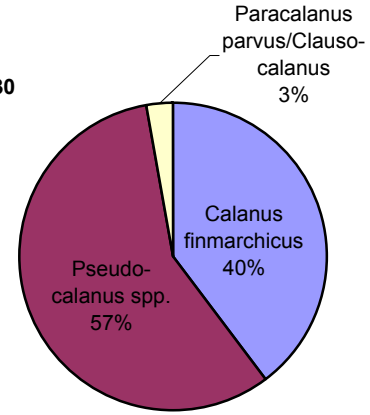


Surface Zooplankton Assessment: SW330 (4/23/2003) Julian Day 113

MEASURES:

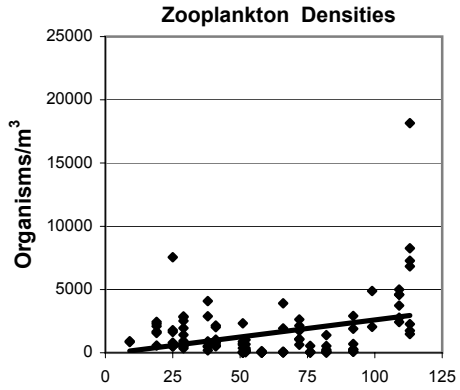
Technique	Station	Total Zpl/m^3	Settled Vol/m^3	Total Calories/	Total Dry Wt./m^3
Surface Tow	LP	8256.05	5.33	746.48	0.17
Surface Tow	7M	2260.51	2.53	958.46	0.20
Surface Tow	8S	1748.57	1.77	540.07	0.12
Surface Tow	7SX	1486.33	1.06	294.99	0.07
Surface Tow	6S	18160.77	10.22	2894.37	0.57
Surface Tow	5SX	7271.01	3.54	660.13	0.11
Surface Tow	5S	6831.06	4.82	1869.03	0.47
Cruise Average:		**6573.47**	**4.18**	**1137.65**	**0.24**
Previous Cruise Avg:		**3852.72**	**3.54**	**891.41**	**0.21**

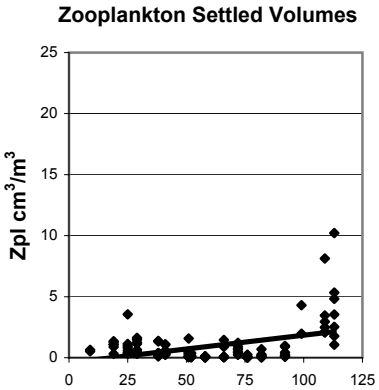
Copepod Species Average Percent Composition: SW330

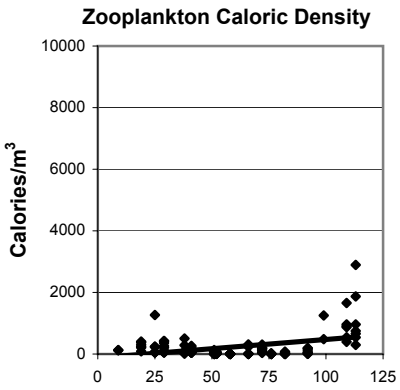


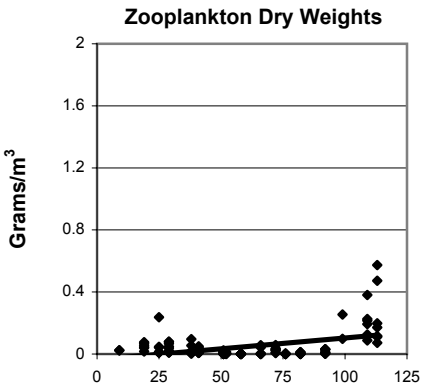
2003 SEASONAL TRENDS: x-axis values are expressed as Julian days in all graphs

Entire Cape Cod Bay:

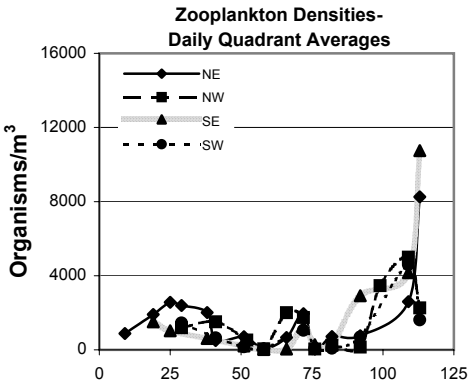


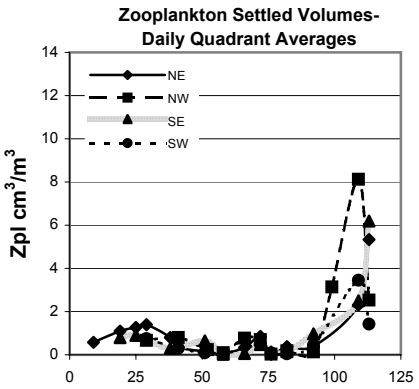


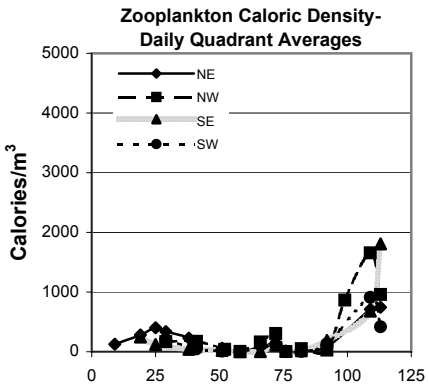


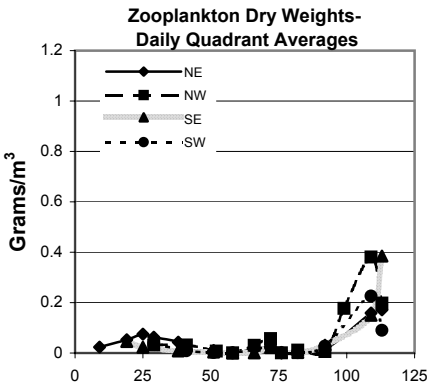


Geographic Quadrants:







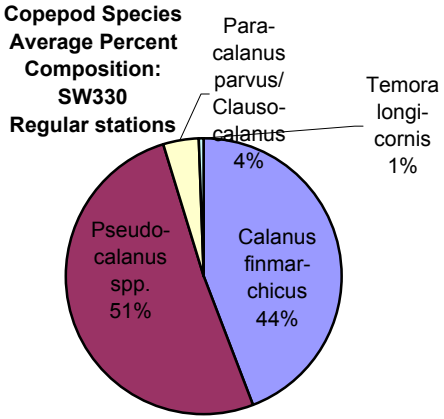


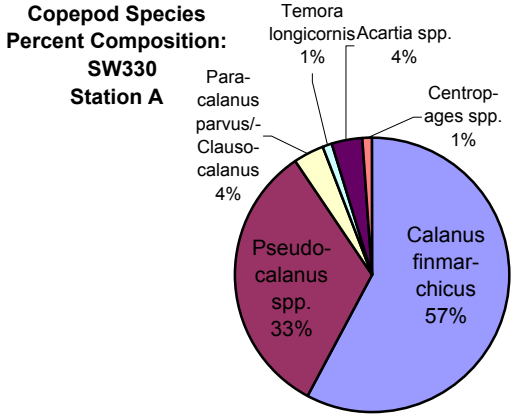
Oblique Zooplankton Assessment: SW330 (4/23/2003) Julian Day113

MEASURES:

Technique	Station	Total Zpl/m^3	Settled Vol/m^3	Total Calories/	Total Dry Wt./m^3
Oblique Tow	LP	13814.50	8.34	1188.05	0.24
Oblique Tow	7M	3028.50	2.89	835.32	0.20
Oblique Tow	5S	8671.98	5.66	2063.64	0.50
Oblique Tow	7SX	9333.91	5.66	1629.68	0.39
Oblique Tow	6S	11960.27	7.46	1729.71	0.39
Oblique Tow	8S	3191.12	2.65	957.10	0.21
Oblique Tow	A	4790.27	3.64	1055.98	0.23
Cruise Average:		**8333.38**	**5.44**	**1400.58**	**0.32**
Previous Cruise Avg:		**6642.78**	**5.42**	**1092.30**	**0.25**

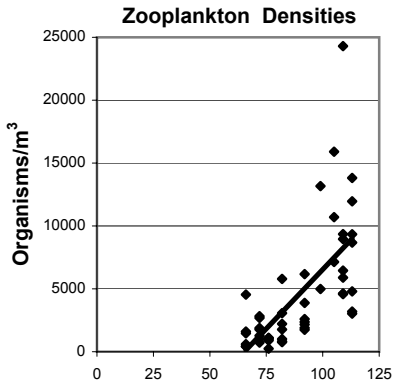
*Note: Values from Station A were not included in the cruise averages

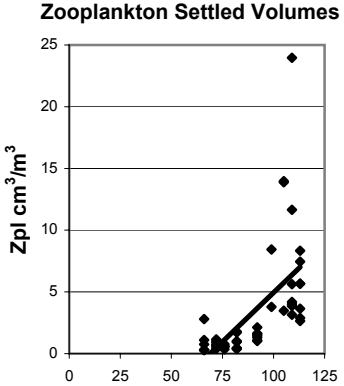


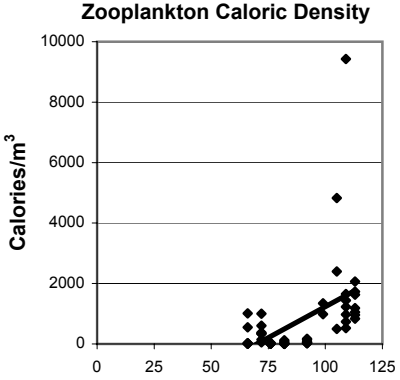


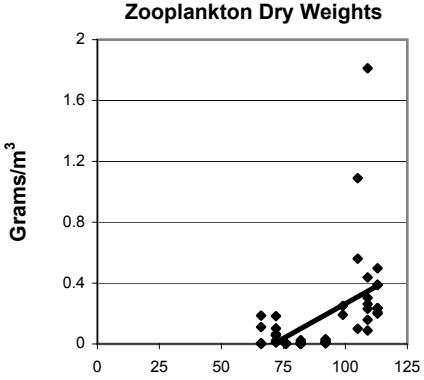
2003 SEASONAL TRENDS: x-axis values are expressed as Julian days in all graphs

Entire Cape Cod Bay:

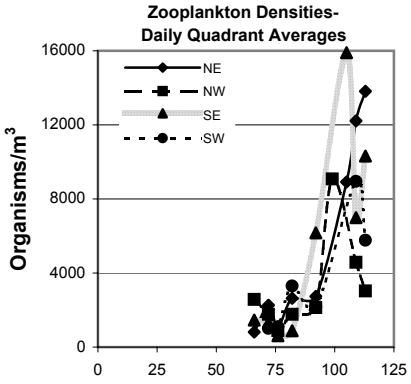


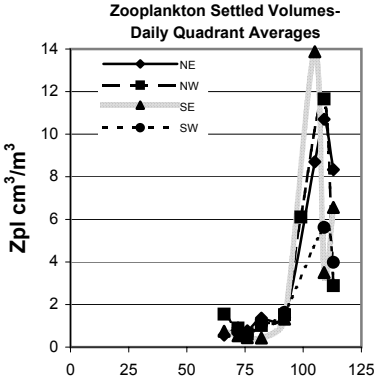


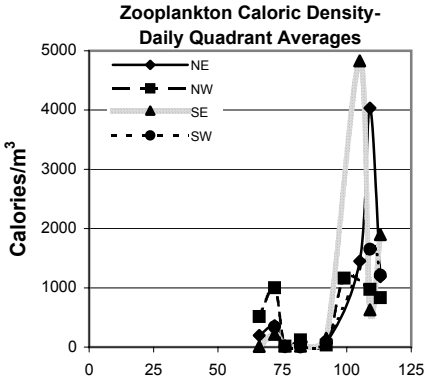


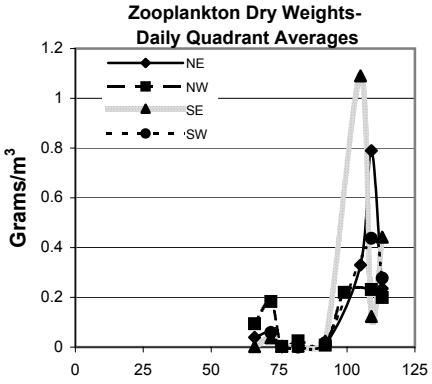


Geographic Quadrants:







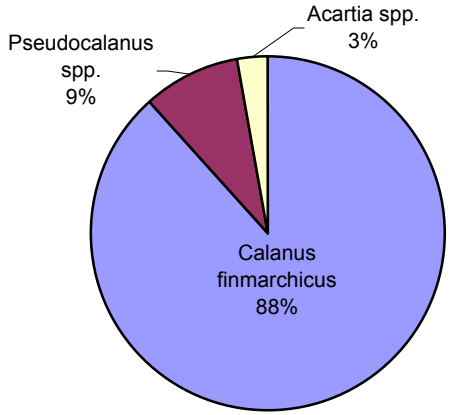


Surface Zooplankton Assessment: SW333 (4/30/2003) Julian Day 120

MEASURES:

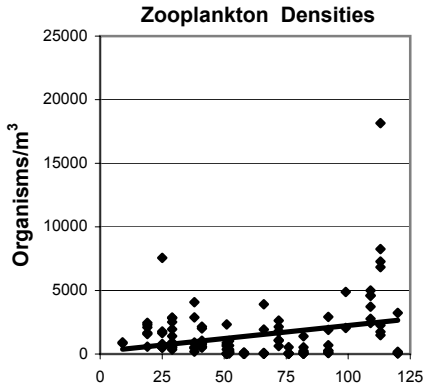
Technique	Station	Total Zpl/m^3	Settled Vol/m^3	Total Calories/m^3	Total Dry Wt./m^3
Surface Tow	8M	80.84	0.29	15.31	2.98E-03
Surface Tow	7N	52.47	0.18	15.48	2.72E-03
Surface Tow	6M	68.58	0.12	8.42	1.96E-03
Surface Tow	5S	174.88	0.28	51.65	9.61E-03
Surface Tow	LP	3233.75	6.06	1614.24	3.06E-01
Cruise Average:		**722.10**	**1.39**	**341.02**	**6.46E-02**
Previous Cruise Avg:		**6573.47**	**4.18**	**1137.65**	**2.45E-01**

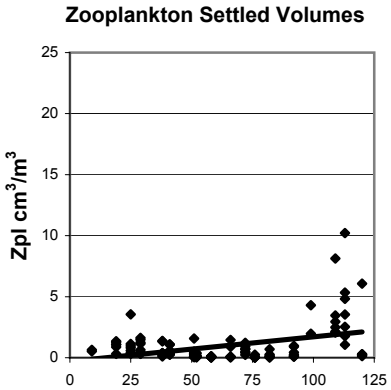
Copepod Species Average Percent Composition: SW333

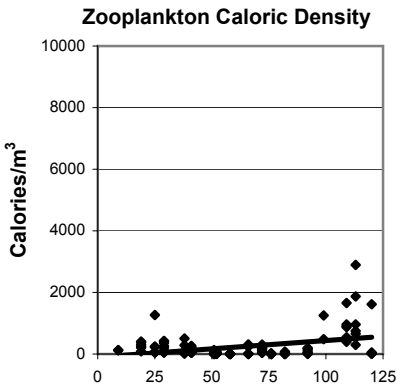


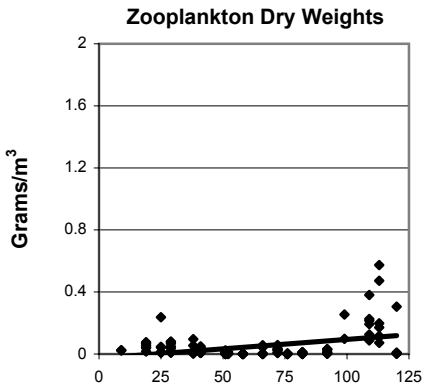
2003 SEASONAL TRENDS: x-axis values are expressed as Julian days in all graphs

Entire Cape Cod Bay:

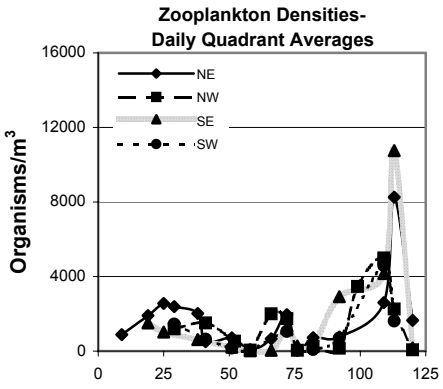


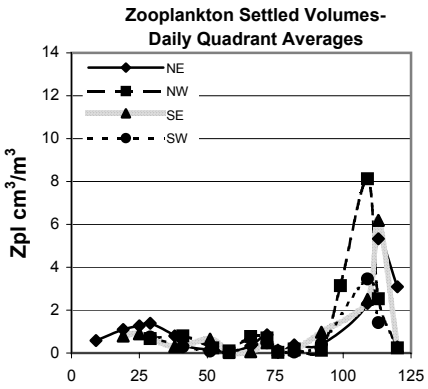


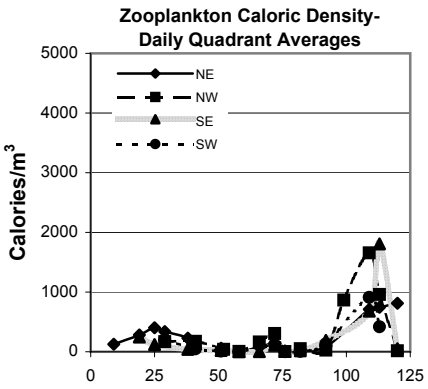


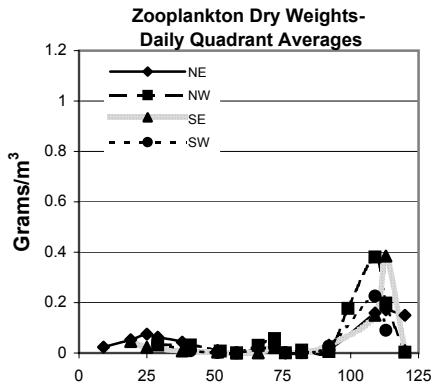


Geographic Quadrants:







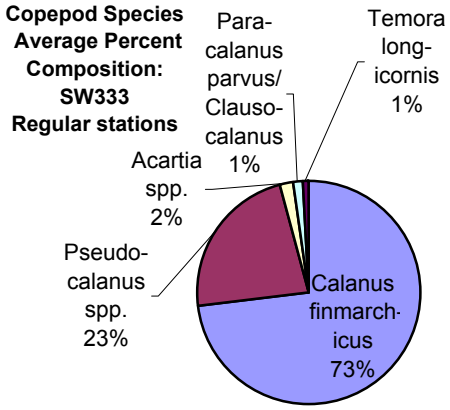


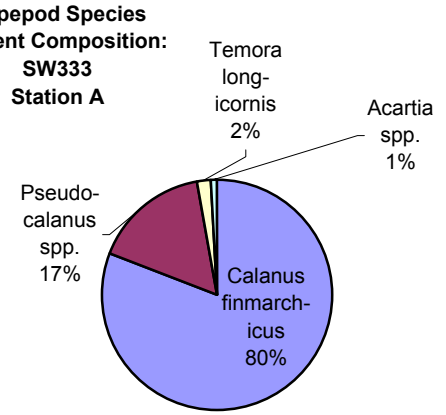
Oblique Zooplankton Assessment: SW333 (4/30/2003) Julian Day120

MEASURES:

Technique	Station	Total Zpl/m^3	Settled Vol/m^3	Total Calories/m^3	Total Dry Wt./m^3
Oblique Tow	LP	1592.02	2.80	709.72	0.14
Oblique Tow	5S	3295.99	2.61	639.66	0.14
Oblique Tow	6M	2557.85	2.65	712.94	0.17
Oblique Tow	7N	862.39	1.29	317.79	0.07
Oblique Tow	8M	690.97	2.35	272.66	0.05
Oblique Tow	A	2043.57	2.86	594.09	0.14
Cruise Average:		**1799.85**	**2.34**	**530.55**	**0.11**
Previous Cruise Avg:		**8333.38**	**5.44**	**1400.58**	**0.32**

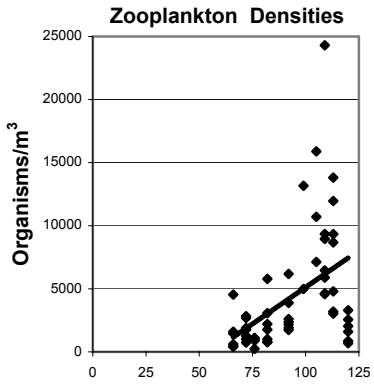
*Note: Values from Station A were not included in the cruise averages

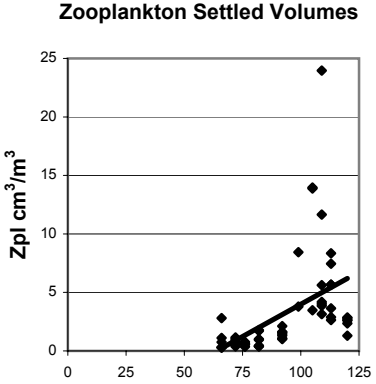


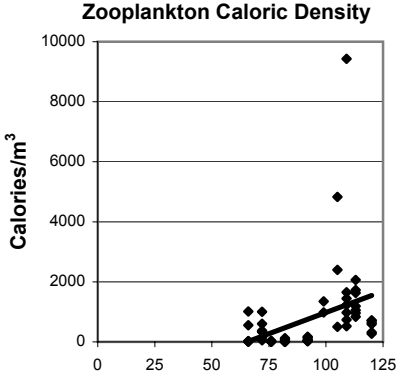


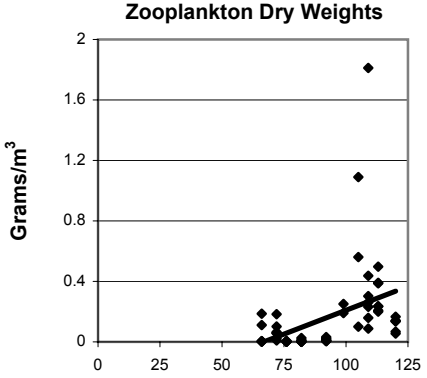
2003 SEASONAL TRENDS: x-axis values are expressed as Julian days in all graphs

Entire Cape Cod Bay:

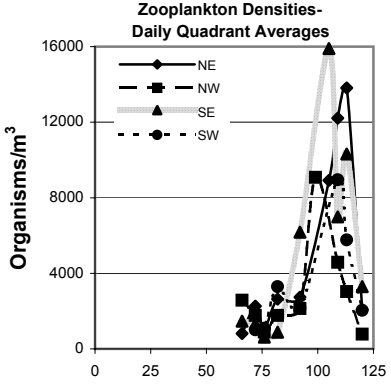


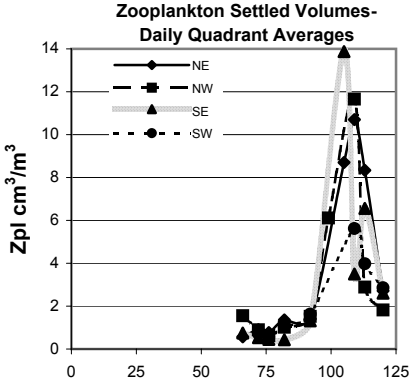


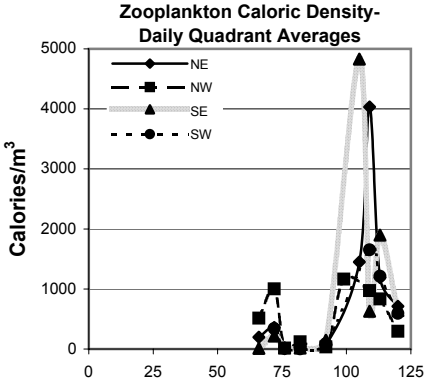


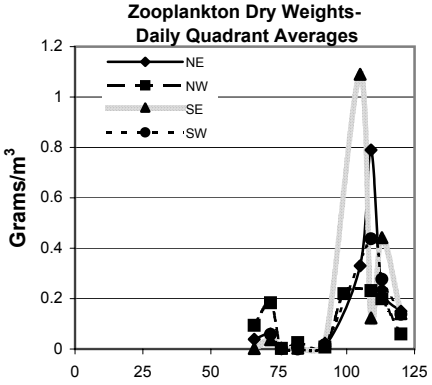


Geographic Quadrants:







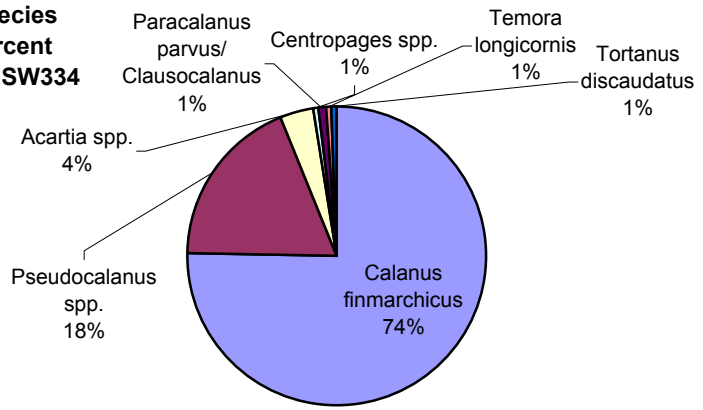


Surface Zooplankton Assessment: SW334 (5/4/2003) Julian Day 124

MEASURES:

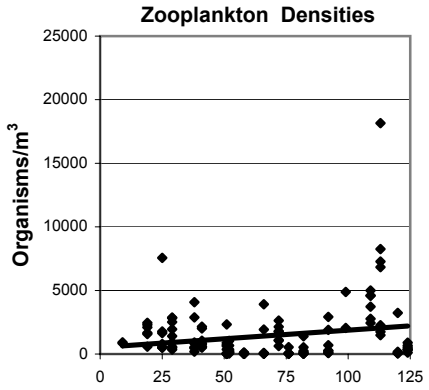
Technique	Station	Total Zpl/m^3	Settled Vol/m^3	Total Calories/m^3	Total Dry Wt./m^3
Surface Tow	LP	667.54	0.80	171.93	3.35E-02
Surface Tow	8M	527.04	0.87	246.71	4.72E-02
Surface Tow	7N	315.23	0.70	194.50	3.34E-02
Surface Tow	5S	393.54	0.78	178.54	3.30E-02
Surface Tow	6S	109.83	0.13	24.68	4.16E-03
Surface Tow	7SX	352.38	0.48	136.32	2.35E-02
Surface Tow	9S	889.93	0.94	265.07	5.68E-02
Cruise Average:		**465.07**	**0.67**	**173.96**	**3.31E-02**
Previous Cruise Avg:		**722.10**	**1.39**	**341.02**	**6.46E-02**

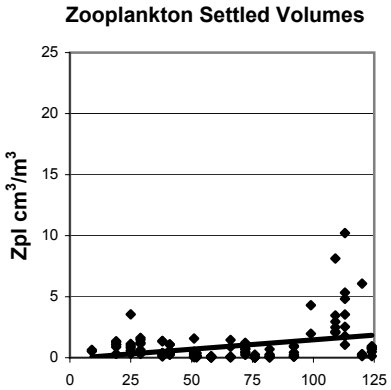
Copepod Species Average Percent Composition: SW334

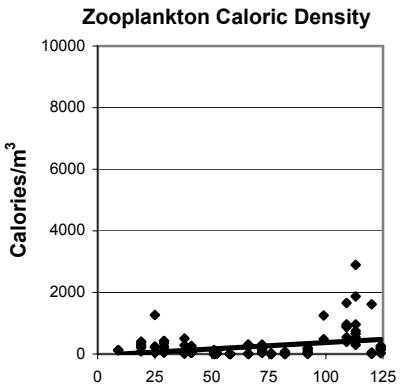


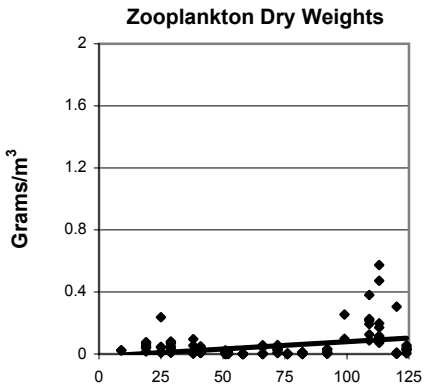
2003 SEASONAL TRENDS: x-axis values are expressed as Julian days in all graphs

Entire Cape Cod Bay:

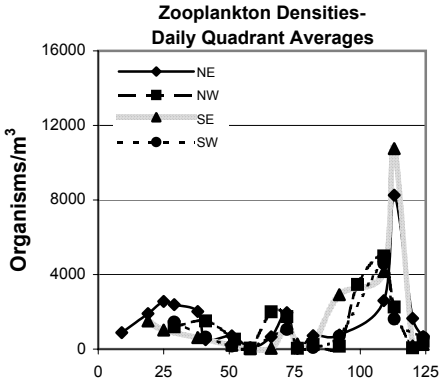


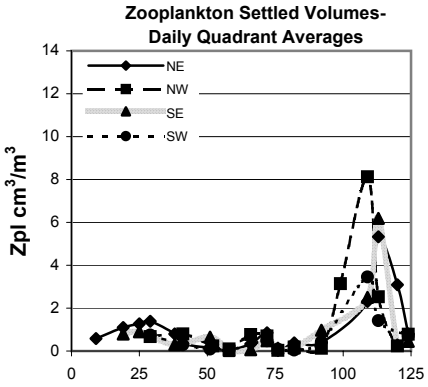


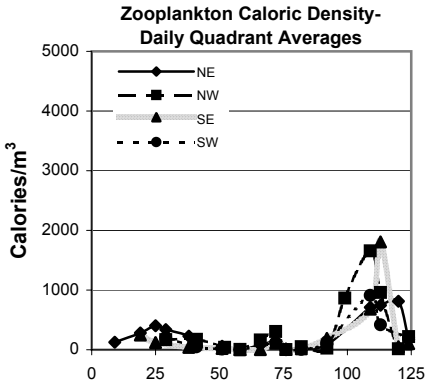


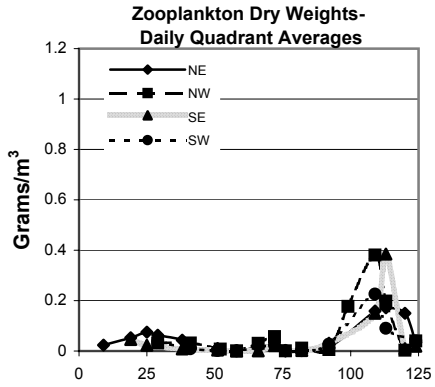


Geographic Quadrants:







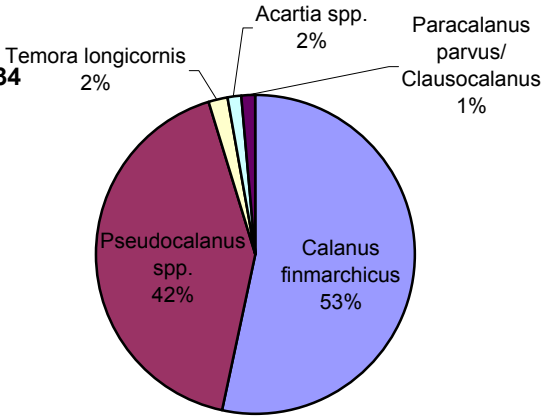


Oblique Zooplankton Assessment: SW334 (5/4/2003) Julian Day124

MEASURES:

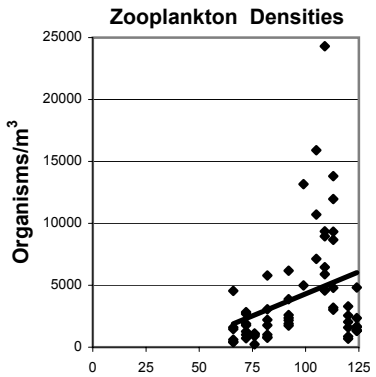
Technique	Station	Total Zpl/m^3	Settled Vol/m^3	Total Calories/m^3	Total Dry Wt./m^3
Oblique Tow	LP	4825.24	3.92	772.04	1.47E-01
Oblique Tow	8M	1346.72	2.31	469.73	1.01E-01
Oblique Tow	7N	1617.56	1.66	659.30	1.31E-01
Oblique Tow	5S	1680.35	1.57	326.18	6.57E-02
Oblique Tow	6S	1311.57	0.86	207.44	3.99E-02
Oblique Tow	9S	2351.72	2.55	802.53	1.70E-01
Oblique Tow	7SX	1358.18	1.13	280.64	5.67E-02
Cruise Average:		**2070.19**	**2.00**	**502.55**	**0.10**
Previous Cruise Avg:		**1799.85**	**2.34**	**530.55**	**1.13E-01**

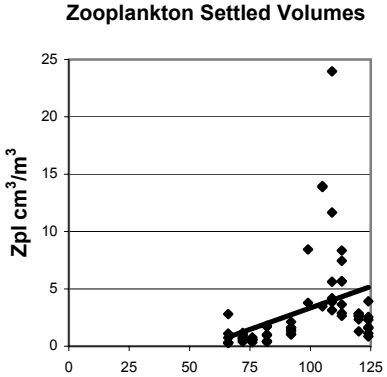
Copepod Species Average Percent Composition: SW334

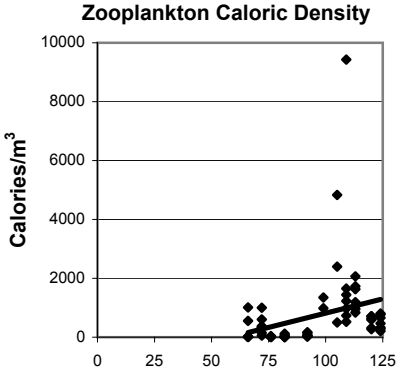


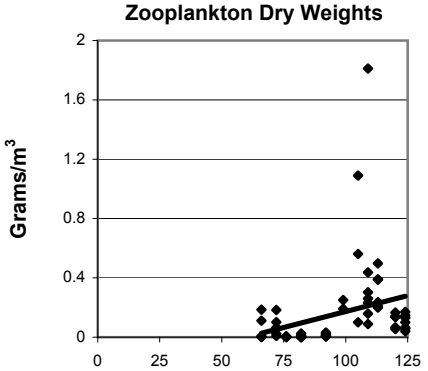
2003 SEASONAL TRENDS: x-axis values are expressed as Julian days in all graphs

Entire Cape Cod Bay:

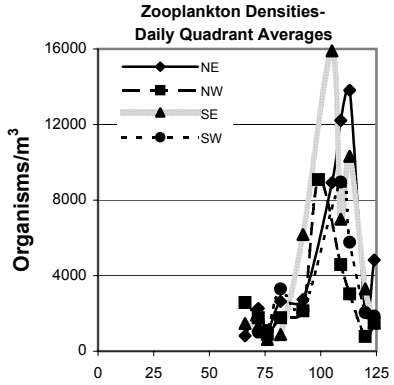


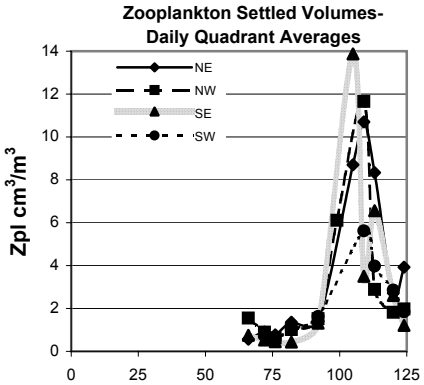


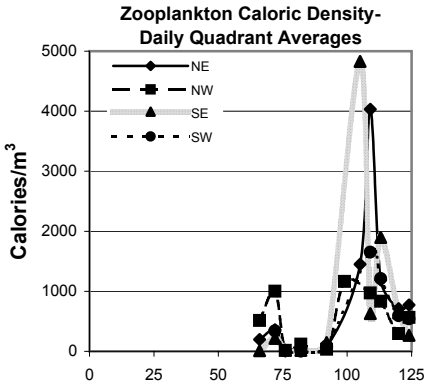


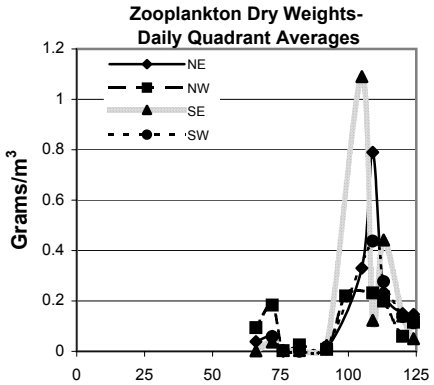


Geographic Quadrants:







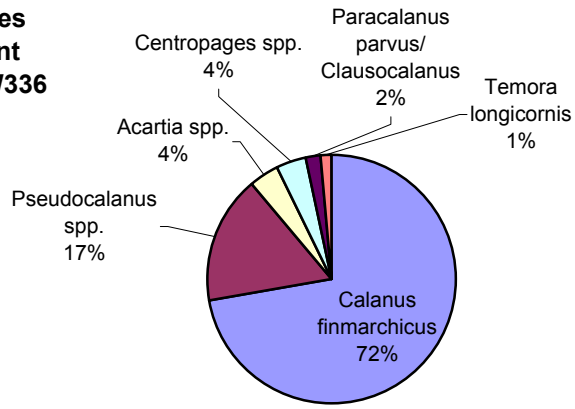


Surface Zooplankton Assessment: SW336 (5/10/2003) Julian Day130

MEASURES:

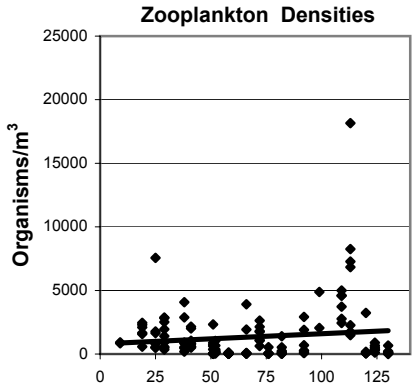
Technique	Station	Total Zpl/m^3	Settled Vol/m^3	Total Calories/m^3	Total Dry Wt./m^3
Surface Tow	LP	666.40	0.59	191.05	3.83E-02
Surface Tow	6M	211.53	0.32	94.62	1.85E-02
Surface Tow	8M	92.27	0.17	12.11	2.27E-03
Surface Tow	7N	71.83	0.30	24.58	4.40E-03
Surface Tow	5S	4.84	0.04	0.06	1.17E-05
Surface Tow	7S	142.73	0.25	69.15	1.26E-02
Surface Tow	8SX	62.11	0.10	28.05	4.90E-03
Cruise Average:		**178.82**	**0.25**	**59.94**	**1.16E-02**
Previous Cruise Avg:		**465.07**	**0.67**	**173.96**	**3.31E-02**

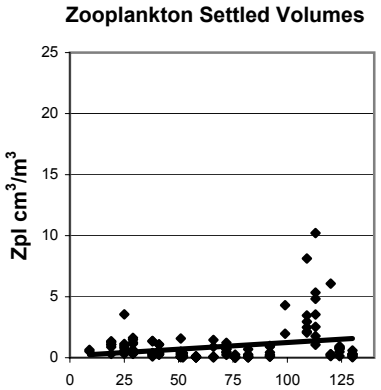
Copepod Species Average Percent Composition: SW336

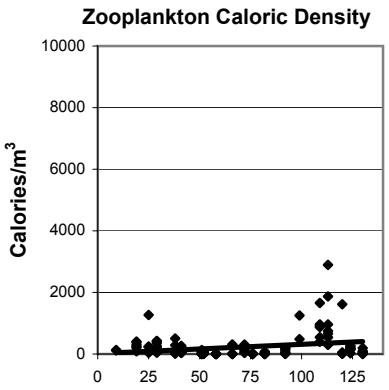


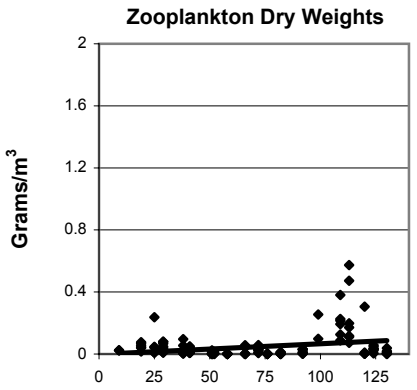
2003 SEASONAL TRENDS: x-axis values are expressed as Julian days in all graphs

Entire Cape Cod Bay:

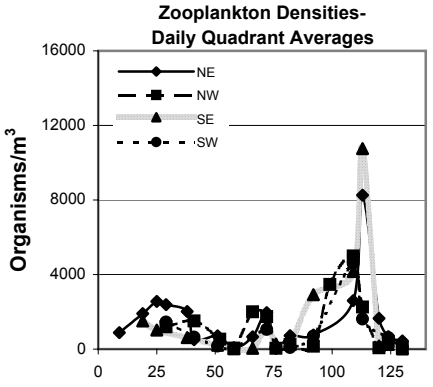


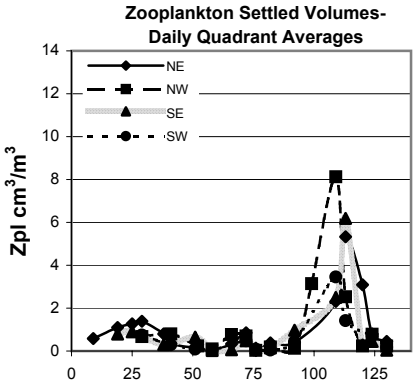


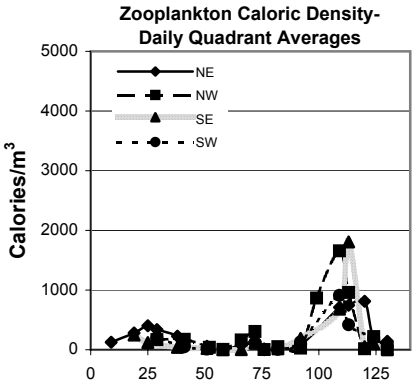


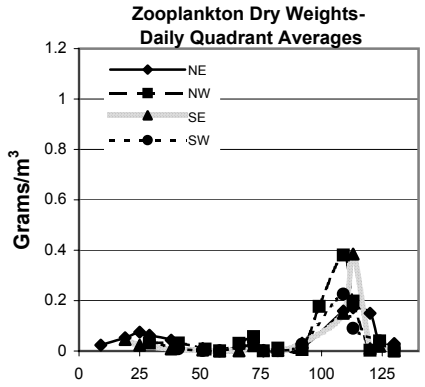


Geographic Quadrants:







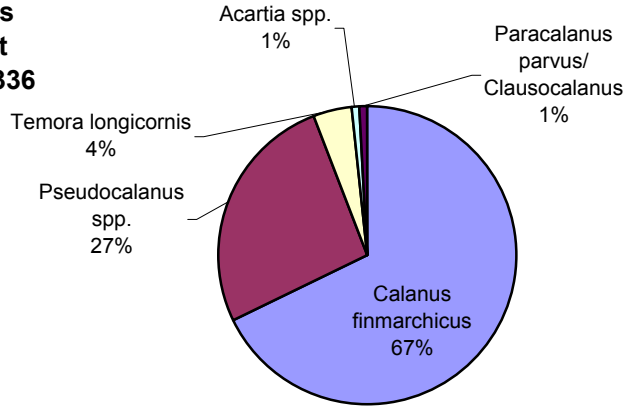


Oblique Zooplankton Assessment: SW336 (5/10/2003) Julian Day130

MEASURES:

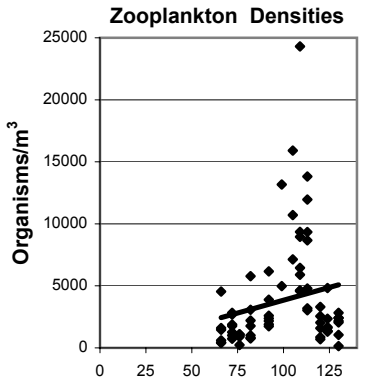
Technique	Station	Total Zpl/m^3	Settled Vol/m^3	Total Calories/m^3	Total Dry Wt./m^3
Oblique Tow	LP	1045.14	0.71	257.66	5.09E-02
Oblique Tow	6M	2413.81	1.82	802.77	1.69E-01
Oblique Tow	8M	2819.69	3.27	1245.19	2.41E-01
Oblique Tow	7N	2168.09	1.84	673.26	1.46E-01
Oblique Tow	5S	136.29	0.16	2.40	6.03E-04
Oblique Tow	7S	2049.86	1.49	622.69	1.27E-01
Oblique Tow	8SX	2410.65	1.29	451.84	8.66E-02
Cruise Average:		**1863.36**	**1.51**	**579.40**	**1.17E-01**
Previous Cruise Avg:		**2070.19**	**2.00**	**502.55**	**1.02E-01**

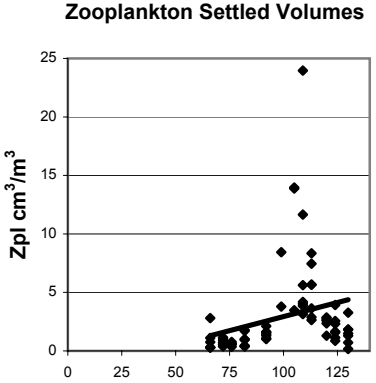
Copepod Species Average Percent Composition: SW336

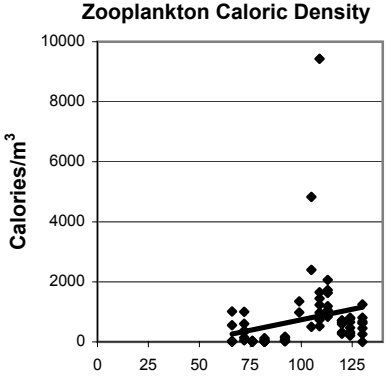


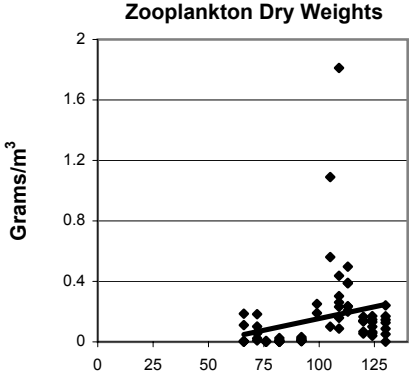
2003 SEASONAL TRENDS: x-axis values are expressed as Julian days in all graphs

Entire Cape Cod Bay:

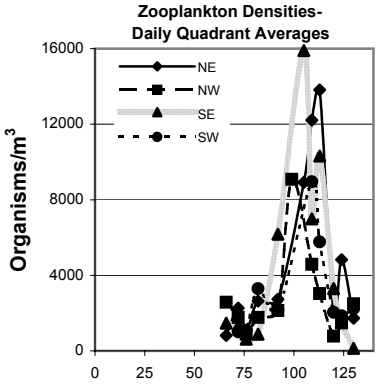


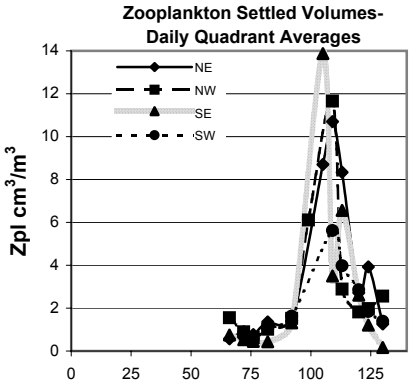


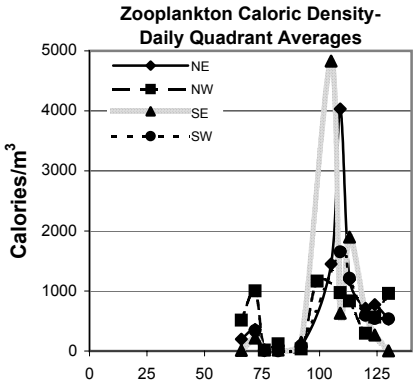


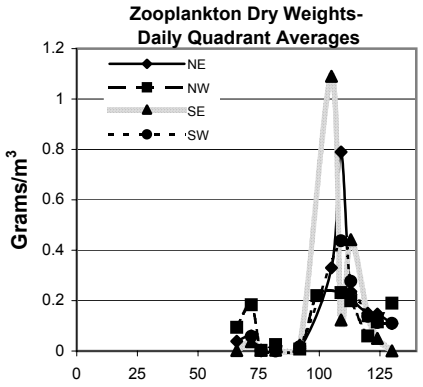


Geographic Quadrants:







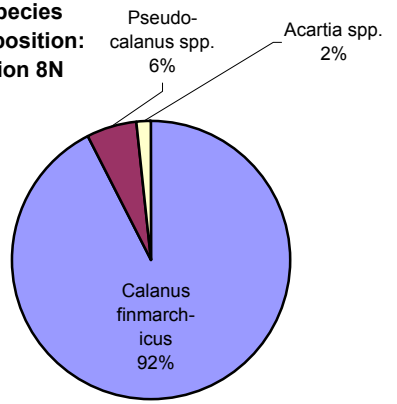


Surface Zooplankton Assessment: SW338 (5/14/2003) Julian Day 134

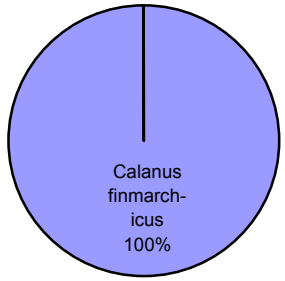
MEASURES:

Technique	Station	Total Zpl/m^3	Settled Vol/m^3	Total Calories/m^3	Total Dry Wt./m^3
Surface Tow	8N	1404.44	1.66	747.75	1.39E-01
Surface Tow	8S	1935.70	2.26	1047.34	1.99E-01
Cruise Average:		**1670.07**	**1.96**	**897.54**	**1.69E-01**
Previous Cruise Avg:		**178.82**	**0.25**	**59.94**	**1.16E-02**

Copepod Species Percent Composition: SW338 Station 8N

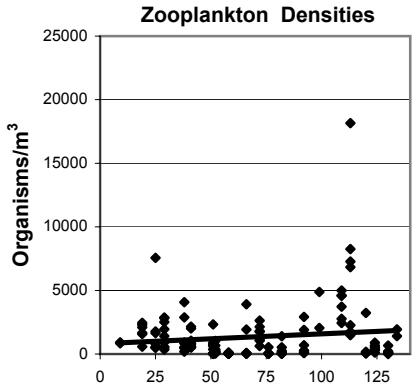


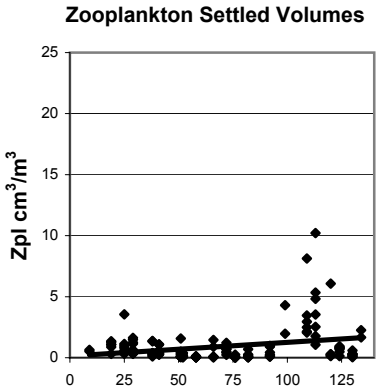
Copepod Species Percent Composition: SW338 Station 8S

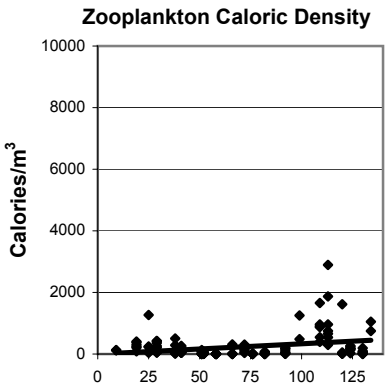


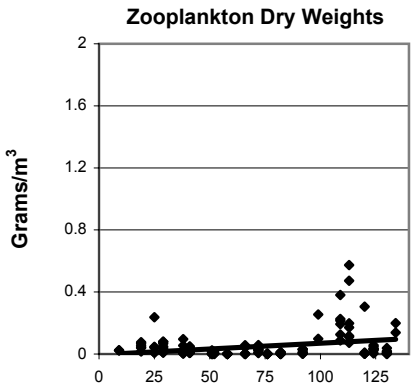
2003 SEASONAL TRENDS: x-axis values are expressed as Julian days in all graphs

Entire Cape Cod Bay:

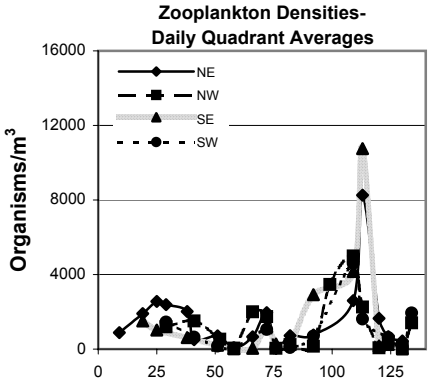


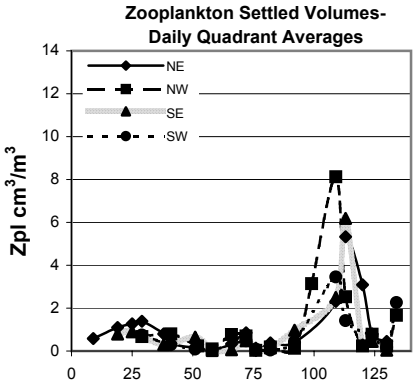


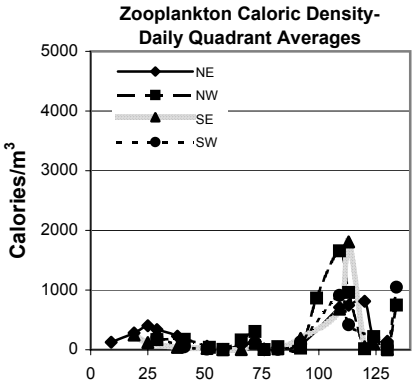


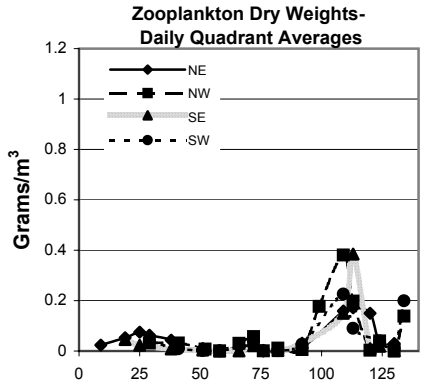


Geographic Quadrants:





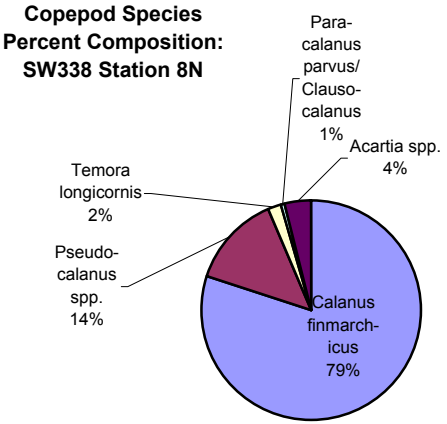


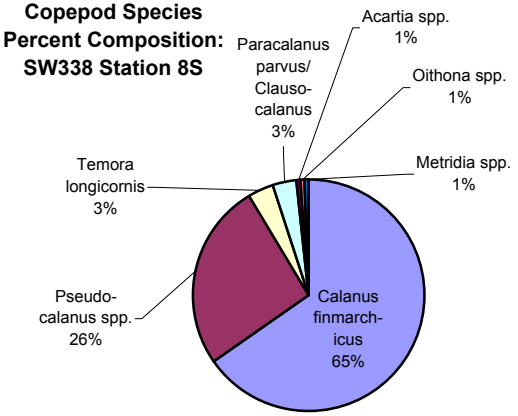


Oblique Zooplankton Assessment: SW338 (5/14/2003) Julian Day134

MEASURES:

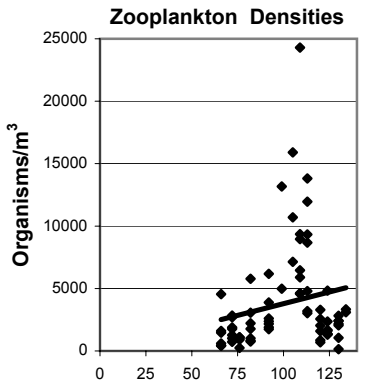
Technique	Station	Total Zpl/m^3	Settled Vol/m^3	Total Calories/m^3	Total Dry Wt./m^3
Oblique Tow	8N	3097.60	2.64	1019.13	2.15E-01
Oblique Tow	8S	3336.87	2.98	1000.03	2.00E-01
Cruise Average:		**3217.24**	**2.81**	**1009.58**	**2.08E-01**
Previous Cruise Avg:		**1863.36**	**1.51**	**579.40**	**1.17E-01**

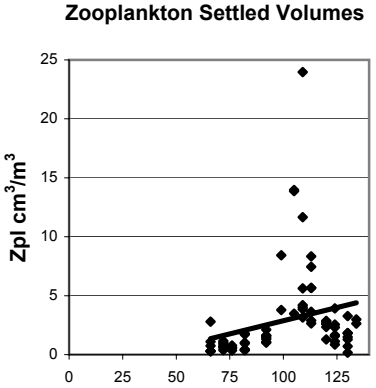


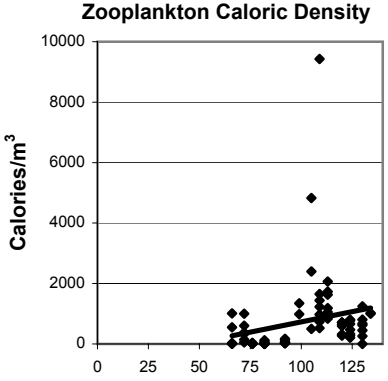


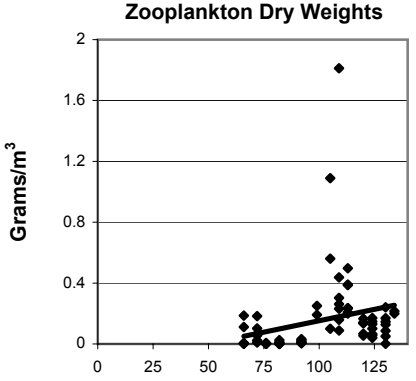
2003 SEASONAL TRENDS: x-axis values are expressed as Julian days in all graphs

Entire Cape Cod Bay:

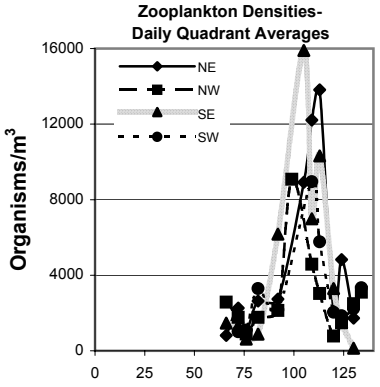


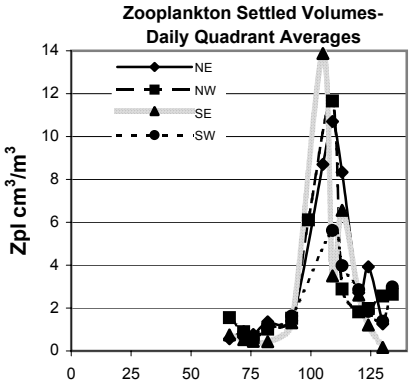


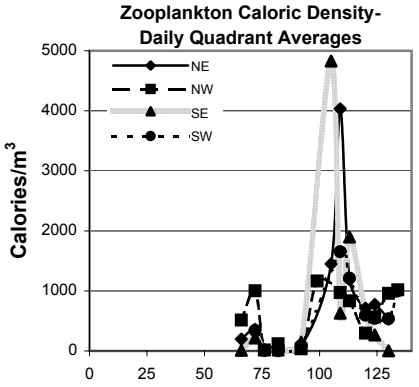


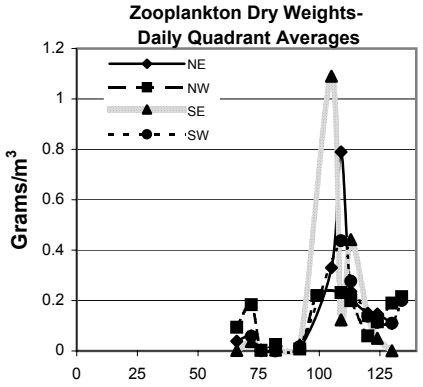


Geographic Quadrants:



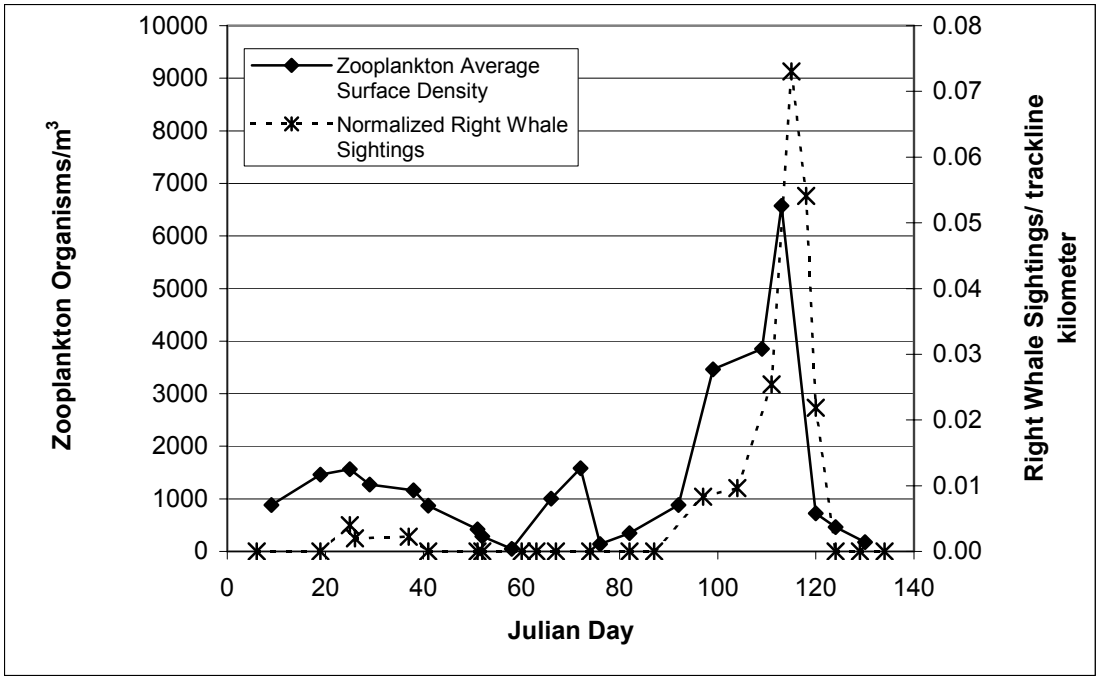




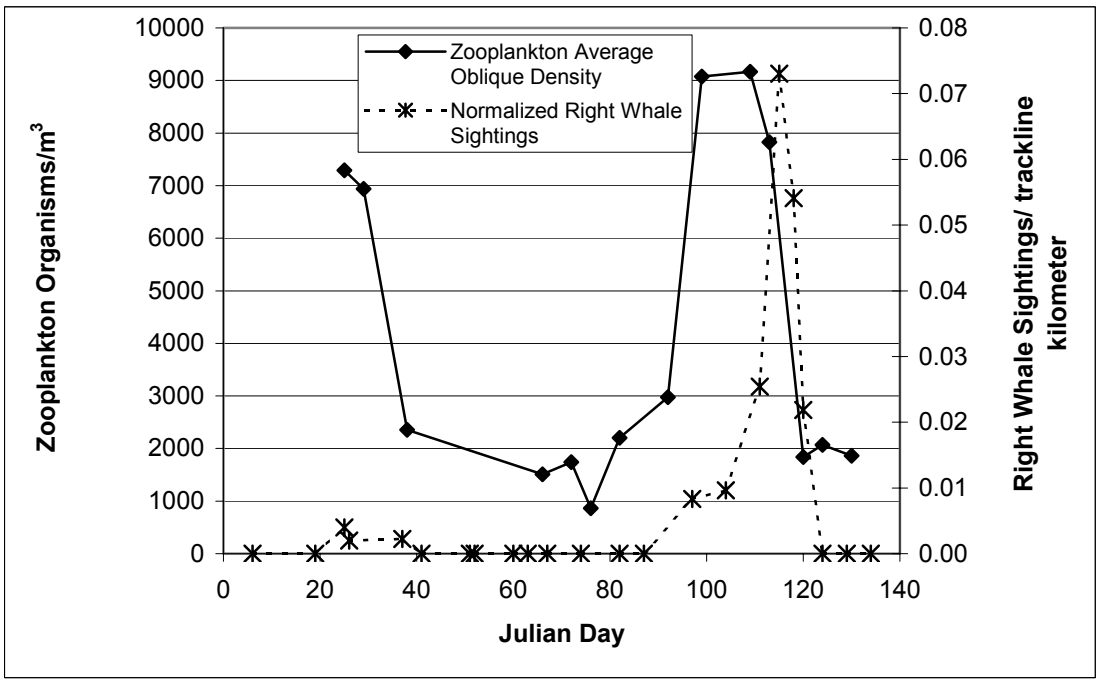


Center for Coastal Studies
End-of-Season Zooplankton Assessment
including data from 20 CCB Habitat Cruises (January 9-May 10) and 23 CCB Aerial Surveys (January 6- May 14)

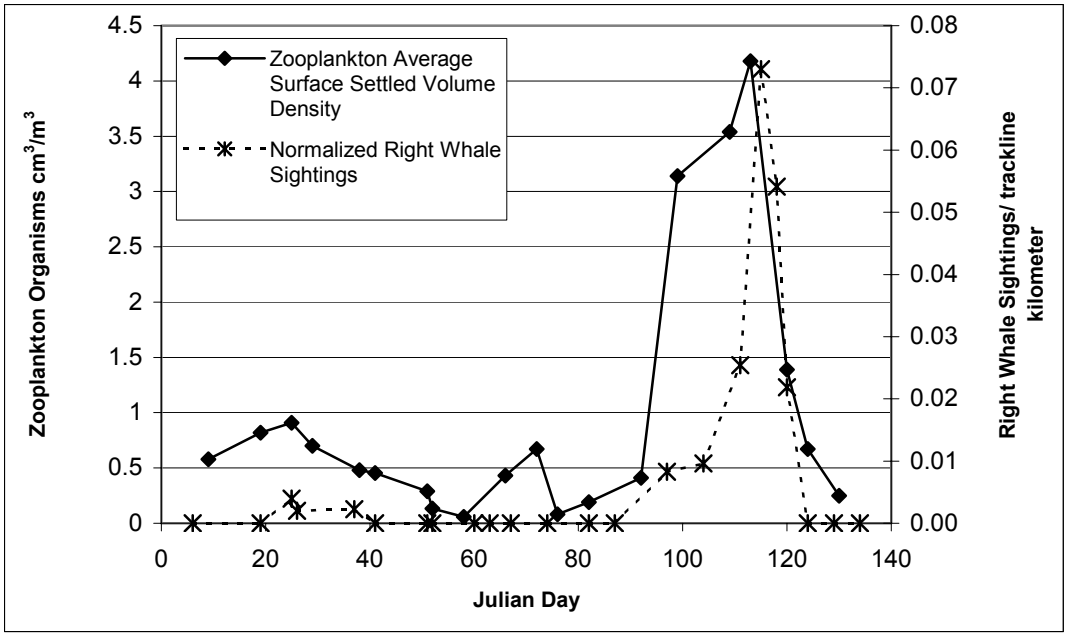
The four graphs that follow represent a compendium of the three main zooplankton density measures (total organism, caloric, settled volume) we have monitored during the 2003 season. The graphs pair zooplankton trends with the 2003 CCB right whale sighting data, generously supplied to us by the CCS aerial survey team, under the direction of Dr. Moira Brown. The Division of Marine Fisheries, Commonwealth of Massachusetts, has provided ongoing funding for both the aerial surveys and the zooplankton sampling.



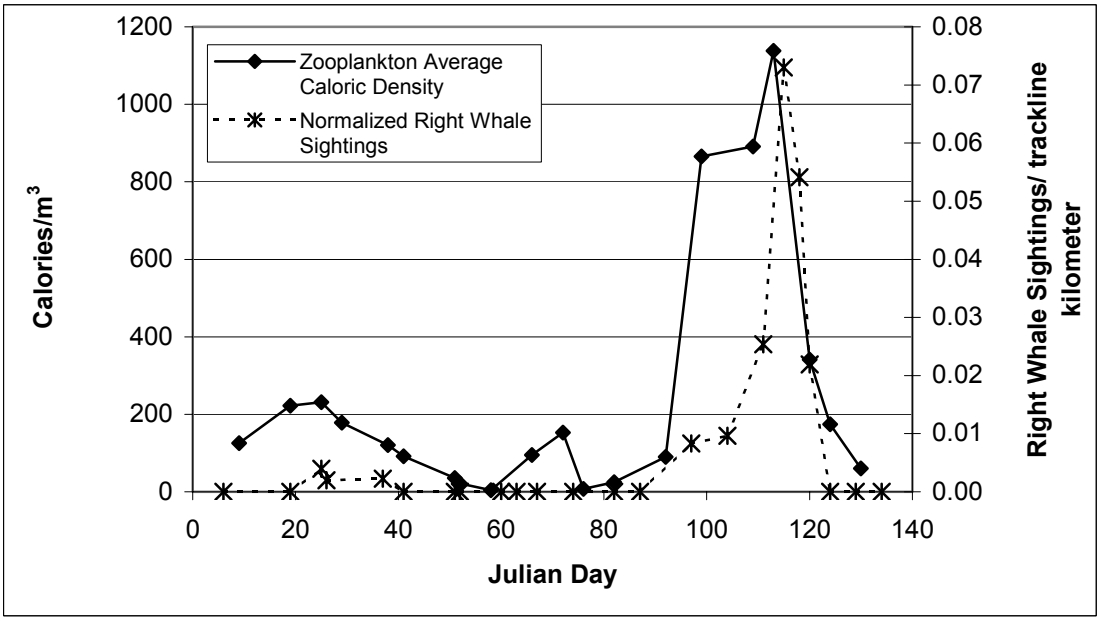
A comparison of mean zooplankton density estimated from samples collected at the surface in Cape Cod Bay as compared to right whale density calculated from aircraft surveys in the winter and spring of 2003.



A comparison of mean zooplankton density estimated from samples collected from oblique net tows (0-19m) in Cape Cod Bay as compared to right whale density calculated from aircraft surveys in the winter and spring of 2003.



A comparison of mean zooplankton settled volume density estimated from samples collected at the surface in Cape Cod Bay as compared to right whale density calculated from aircraft surveys in the winter and spring of 2003.



A comparison of mean zooplankton caloric density estimated from samples collected at the surface in Cape Cod Bay as compared to right whale density calculated from aircraft surveys in the winter and spring of 2003.