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MARINE MAMMALS, SEABIRDS AND MARINE TURTLES IN THE GULF OF MAINE AND MASSACHUSETTS BAY WITH SPECIAL EMPHASIS ON THE LOCATIONS OF THE FOUL-AREA DISPOSAL SITE AND THE CAPE ARUNDEL DISPOSAL SITE

by

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INTRODUCTION

The Marine Protection, Research and Sanctuaries Act (MPRSA) of 1972 (Public Law 92-532, called the Ocean Dumping Act) was passed in recognition that the disposal of wastes into ocean waters could result in adverse environmental impacts. Under Title I of the MPRSA, the Environmental Protection Agency (EPA) and the U.S. Army Corps of Engineers (COE) cooperatively share the basic responsibility for designating and managing the waste disposal sites and for developing technical guidance and regulatory programs to ensure that ocean disposal will not adversely affect the marine environment or ecological systems.

An EPA/COE Working Group consisting of eight individuals from each agency (see COE 1984, Table 1, p. 2) developed a workbook to provide the technical guidance for site designation. The workbook "Technical Guidance for the Designation of Ocean Dredged Material Disposal Sites" was submitted and has been used in case studies since November 1983. The guide serves as a general framework and is presently followed to the maximum practical extent in site-designation efforts.

The COE administers and enforces the overall regulatory program for ocean dredged material disposal. The EPA (under section 103 [A-H] of the MPRSA), in consultation with the COE, has primary responsibility for site designation and is required to establish criteria that are to be addressed before an ocean dredged material disposal permit can be granted. The EPA specific factors and general criteria for selection of ocean sites for dredged material disposal are provided in Table 1 (from COE 1984, Table 2, p. 5).

The EPA initially designates a site by establishing the broadest economically and operationally feasible radius from the point of dredging. This is called the Zone of Siting Feasibility (ZSF). An heirarchical-stepwise evaluation is then conducted to eliminate unsuitable subareas (based on factors and criteria identified in Table 1) within the ZSF.

The EPA's ocean dumping criteria require that site designation be based on environmental studies of each site, regions adjacent to the site, and on historical knowledge of the physical, chemical and biological impact of dredged material disposal on areas similar to such sites. The environmental factors which must be considered in criteria development (under Section 103A, MPRSA), as well as in final-site designation, are specifically oriented toward the protection of sensitive marine resources and marine resources of limited distribution. The overriding consideration in locating an acceptable ocean disposal site should be to prevent or minimize adverse impacts to sensitive biological resources. Critical habitats of threatened and endangered species must be depicted within the ZSF and the delineation of finalized disposal sites should not include critical habitats of threatened or endangered species.

Table 1. EPA Specific Factors and General Criteria for Selection of Ocean Sites for Dredged Material Disposal

Specific Factors

Geographical position, depth of water, bottom topography, and distance from coast.

Location in relation to breeding, spawning, nursery, feeding, or passage areas of living resources in adult or juvenile phases.

Location in relation to beaches or other amenity areas.

Types and quantities of wastes proposed to be disposed of and proposed methods of release, including methods of packaging the waste, if any.

Feasibility of surveillance and monitoring.

Dispersal, horizontal transport, and vertical mixing characteristics of the area, including prevailing current velocity, if any.

Existence and effects of present or previous discharges and dumping in the area (including cumulative effects).

Interference with shipping, fishing, recreation, mineral extraction, desalination, fish and shellfish culture, areas of specific scientific importance, and other legitimate uses of the ocean.

Existing water quality and ecology of the site as determined by available data or by trend assessment or baseline surveys.

Potential for the development or recruitment of nuisance species within the disposal site.

Existence at or in close proximity to the site of any significant natural or cultural features of historical importance.

General Criteria

The dumping of materials into the ocean will be permitted only at sites or in areas selected to minimize the interference of disposal activities with other activities in the marine environment, particularly avoiding areas of existing fisheries or shellfisheries, and regions of heavy commercial or recreational navigation.

Location and boundaries of disposal sites will be chosen so that temporary perturbations in water quality or other environmental conditions during initial mixing caused by disposal operations anywhere within the site can be expected to be reduced to normal ambient seawater levels or to undetectable contaminant concentrations or effects before reaching any beach, shoreline, marine sanctuary, or known geographically limited fishery or shellfishery.

If at anytime during or after disposal site evaluation studies, it is determined that existing disposal sites presently approved on an interim basis for ocean dumping do not meet the criteria for site selection set forth in Section 228.5-228.6, the use of such sites will be terminated as soon as suitable alternative disposal sites can be designated.

The sizes of ocean disposal sites will be limited in order to localize for identification and control any immediate adverse impacts and to permit the implementation of effective monitoring and surveillance programs to prevent adverse long-range impacts. The size, configuration, and location of any disposal site will be determined as a part of the disposal site evaluation or designation study.

EPA will, wherever feasible, designate ocean dumping sites beyond the edge of the continental shelf and other such sites that have been historically used.

-START-
reference to FCSS- here

This study examines the occurrence of marine mammals, turtles and seabirds in the waters included within, and adjacent to, two Gulf of Maine disposal sites for dredged materials: the Cape Arundel Disposal site (CADS) and the Foul-Area Disposal site (FADS). The Cape Arundel Disposal site is located in nearshore Maine waters (43°17'45"N, 70°27'12"W). The Foul-Area Disposal site is located in Massachusetts Bay (42°25'42"N, 70°35'W), approximately mid-way between the coastline and Stellwagen Bank. The Gulf of Maine, including Massachusetts Bay, is within the seasonal range of five species of endangered cetaceans and three species of endangered or threatened sea turtles. In addition, approximately 30 species of marine mammals, four species of marine turtles (Tables 2-5) and 40 species of seabirds occur within the boundaries of the Gulf of Maine. This study characterizes the Gulf of Maine, including Georges Bank (Gulf of Maine south to 40°00'N latitude), Massachusetts Bay and Cape Cod Bay, in terms of whale, turtle and seabird distributions, abundance and behaviors. The study focuses on the endangered or threatened species which might be impacted by dumping activities in waters including, and adjacent to, the FADS and CADS dredged material dumpsites. An outline of the objectives is as follows:

1. To provide a description of populations (with current population estimates) and seasonal migration patterns of Endangered and Threatened Species, including turtles, from a north Atlantic Ocean perspective and a Gulf of Maine regional perspective, including Massachusetts Bay and Cape Cod Bay.

2. To provide an intensive discussion of whale use of the Massachusetts Bay study area (FADS). This discussion will address:

   a. Areal and seasonal distributions and densities in Massachusetts Bay.

   b. Habitat use comparison with other areas including Gulf of Maine, Cape Cod Bay and the other New England Shelf areas.

   c. Review of observed and potential behaviors displayed in the study area.

   d. The seasonal distribution of whale sightings in the three 10' quadrats of latitude in the FADS study area. Data will be incorporated from available sources including:

      1) Standardized surveys

      2) Opportunistic sightings from whale watching vessels, and the Gulf of Maine Cetacean Sighting Network, College of the Atlantic, Bar Harbor, Maine.

      3) Sightings from aerial surveys of this contract.

3. To review Endangered and Threatened Species found in the Cape Arundel Study Area (population estimates, seasonal distributions and movements, behavior, etc.).

4. To provide a review of non-endangered mammals and seabirds in the Gulf of Maine including Massachusetts Bay and Cape Cod Bay with emphasis on the waters surrounding FADS and CADS.

Table 2. List of whales, dolphins and porpoises (order Cetacea) which commonly occur in the waters of the Gulf of Maine, including Georges Bank.

Suborder Mysticeti (Baleen Whales)		
Family Balaenopteridae		
Finback Whale	(*Balaenoptera physalus*)	**Endangered**
Minke Whale	(*B. acutorostrata*	
Sei Whale	(*B. borealis*	**Endangered**
Humpback Whale	(*Megaptera novaeangliae*)	**Endangered**
Family Balaenidae		
Northern Right Whale	(*Eubalaena glacialis*)	**Endangered**
Suborder Odontoceti (Toothed Whales)		
Family Phocoenidae		
Harbor Porpoise	(*Phocoena phocoena*)	
Family Delphinidae		
Bottlenosed Dolphin	(*Tursipos truncatus*)	
Spotted Dolphin	(*Stenella plagiodon/attenuata*)	
Striped Dolphin	(*S. coerueoalba*)	
Common Dolphin	(*Delphinus delphis*)	
White-sided Dolphin	(*Lagenorhynchus acutus*)	
White-beaked Dolphin	(*L. albirostris*)	
Grampus (Risso's Dolphin)	(*Grampus griseus*)	
Long-finned Pilot Whale	(*Globicephala melaena*)	
Killer Whale	(*Orcinus orca*)	
Family Physeteridae		
Sperm Whale	(*Physeter macrocephalus*)	**Endangered**

Source: Hain *et al*. 1981; CETAP 1982; Katona *et al*. 1983; Payne *et al*. 1984.

Table 3. List of whales, dolphins and porpoises (Order Cetacea) which occur uncommonly (from sight records or strandings) in waters of the Gulf of Maine, including Georges Bank.

Suborder Mysticeti (Baleen Whales)		
Family Balaenopteridae		
Blue Whale	(*Balaenoptera musculus*)	**Endangered**
Suborder Odontoceti (Toothed Whales)		
Family Delphinidae		
Family Monodontidae		
Beluga	(*Delphinapterus leucas*)	
Family Physeteridae		
Pygmy Sperm Whale	(*Kogia breviceps*)	
Family Ziphiidae		
Northern Bottlenosed Whale	(*Hyperoodon ampullatus*)	
Dense-beaked Whale	(*Mesoplodon densirostris*)	
True's Beaked Whale	(*M. mirus*)	
North Sea Beaked Whale	(*M. bidens*)	

Source: Katona et al. 1983

Table 4. List of rare (r) and commonly (c) occurring marine turtles (Order Testudines) in the waters of the Gulf of Maine, including Georges Bank.

Family Cheloniidae			
Loggerhead Turtle	(*Caretta caretta*)	**Threatened**	(c)
Green Turtle	(*Chelonia mydas*)	**Endangered**	(r)
Kemp's Ridley Turtle	(*Lepidochelys kempi*)	**Endangered**	(r)
Hawksbill Turtle	(*Eretmochelys imbricata*)	**Endangered**	(r)
Family Dermochelydae			
Leatherback Turtle	(*Dermochelys coriacea*)	**Endangered**	(c)

Source: French (1986)

Table 5. List of rare (r) and commonly (c) occurring pinnipeds in coastal waters of the Gulf of Maine.

Family Phocidae (True or Hair Seals)		
Harbor Seal	(*Phoca vitulina concolor*)	(c)
Ringed Seal	(*P. hispida*)	(r)
Gray Seal	(*Halichoerus grypus*)	(c)
Harp Seal	(*Pagophilus groenlandicus*)	(r)
Hooded Seal	(*Cystophora cristata*)	(r)
Family Odobenidae		
Atlantic Walrus	(*Odobenus rosmarus rosmarus*)	fossil records

Source: Katona *et al*. 1983

STUDY AREA

Physical Characteristics of the Gulf of Maine, including Massachusetts and Cape Cod Bays

The shelf waters of the northeastern United States can be separated into three major oceanographic regimes -- the Gulf of Maine, Georges Bank and the mid-Atlantic Bight (Fig. 1) -- which differ from one another in terms of bottom topography, sea water temperature and salinity (Bumpus 1976; Edwards 1983).

The Gulf of Maine, with an average depth of approximately 150 m, consists of deep basins interrupted by ridges and swells (Bumpus 1976). Bounded on the west by the New England coastline and to the northeast by the Bay of Fundy and Nova Scotia, the Gulf of Maine has a direct access to the oceanic waters of the Atlantic through the Northeast Channel (230 m) which lies between two large offshore banks, Browns and Georges (Edwards 1983). The relatively shallow (65 m) Great South Channel is the southwestern boundary of the Gulf of Maine basin.

Davis (1984) summarized the hydrography of the Gulf of Maine, including Massachusetts Bay, and Cape Cod Bay. A synthesis of his discussion follows.

The Gulf of Maine displays a counterclockwise flow of surface water which moves southwestward along the coastline into Massachusetts Bay. The flow turns eastward along the northern edge of Cape Cod where it divides. Some of the flow continues in a counterclockwise gyre and passes along the western Scotian Shelf toward the Bay of Fundy, circulating back into the central Gulf of Maine. Some of the flow also passes along the northern edge of Georges Bank and is directed clockwise along the outer edge of the Bank. A portion of the southward flow into Massachusetts Bay also enters Cape Cod Bay. Currents within Cape Cod Bay follow a general counterclockwise pattern (Davis 1984). There are also water mass movements in Cape Cod Bay due to tidal flow. These currents move in and out from the north and east and curve in conformance with the shoreline. As a result, flooding tides tend to add to the counterclockwise circulation, while ebbing tides tend to reduce it (Bumpus 1979).

Average surface temperatures in the Gulf of Maine are colder and less saline than those of adjacent Georges Bank. Average surface temperatures are coldest in spring, ranging from 2.0°C - 6.0°C, and warmest in fall when temperatures throughout the Gulf of Maine basin exceed 8.0°C (Edwards 1983). Surface salinities in the Gulf of Maine are relatively stable throughout the year, ranging from 31.0 - 33.3 ppt (Edwards 1983).

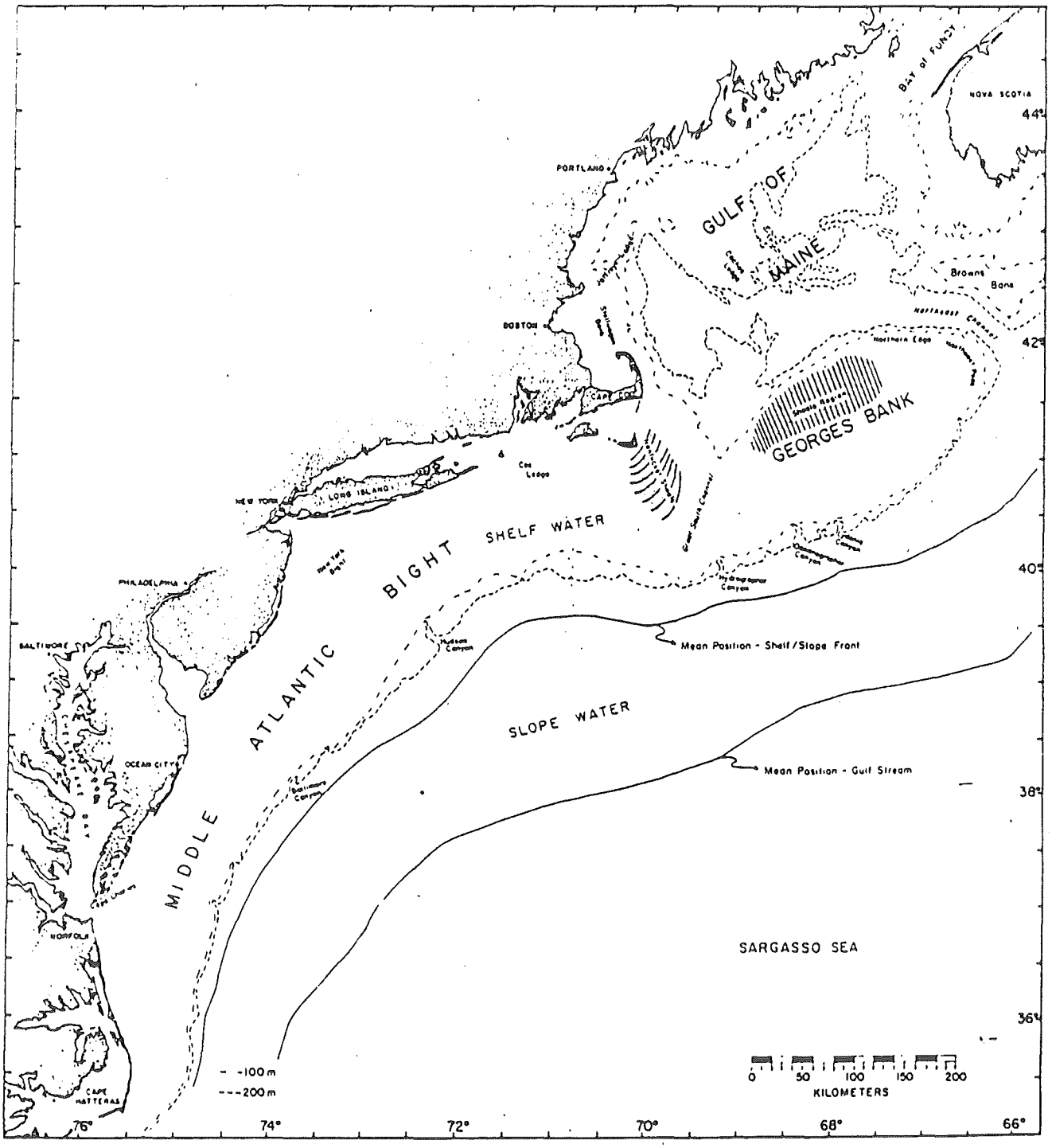


Figure 1. Bathymetry and principal features of the continental shelf and slope off the northeastern United States.

Location of Study Sites

The Foul-Area Disposal Site (FADS) is located in Massachusetts Bay (42°25'42"N, 70°35'W). The three 10-minute quadrats of latitude (the study area surrounding the disposal site) are bounded on the north by 42°30'N, on the west by 70°50'W and on the east by 70°20'W (Fig. 2). The westernmost 10' quadrat extends to the entrance of Boston Harbor. The principal feature of the middle 10' quadrat is Stellwagen Basin which is bounded by the 80 m contour. The designated site-location of the FADS disposal site occurs within this quadrat at the northern end of Stellwagen Basin. Stellwagen Basin extends into the easternmost 10' quadrat to the edge of Stellwagen Bank. Stellwagen Bank is a highly productive area and the principal oceanographic feature of the easternmost 10' quadrat of the study area (see Fig. 2).

The Cape Arundel Disposal Site (CADS) is located at 43°17'45"N, 70°27'12"W in coastal Gulf of Maine waters. The area examined for mammal and bird use around this disposal site is bounded on the north by 43°30'N, on the south by 43°00'N, on the east by 70°10'W and on the west by the coastline of Maine (Fig. 3). The Cape Arundel Disposal Site lies within the 20 m contour just below Kennebunkport, Maine.

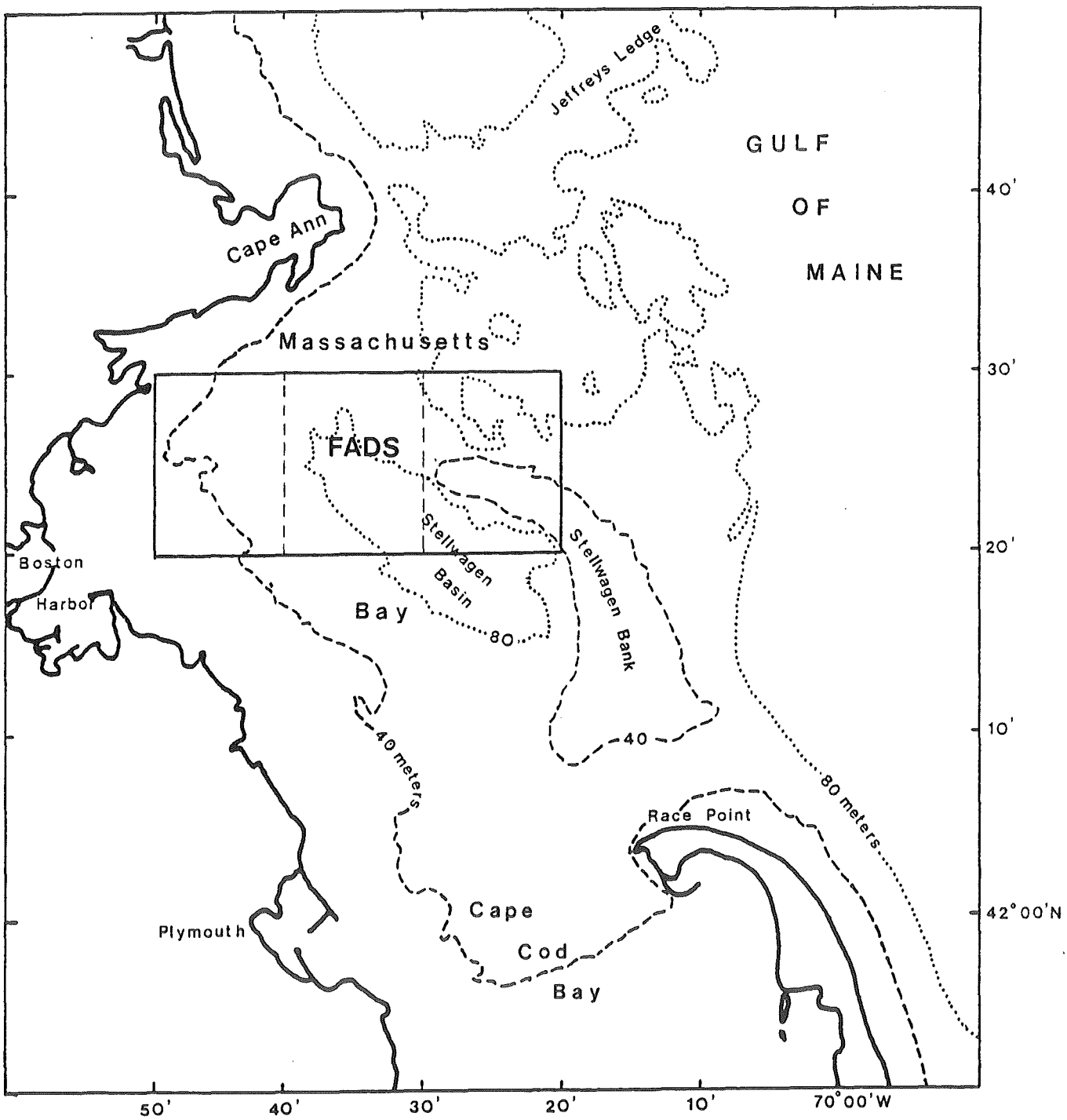


Figure 2. The location of the Foul-Area Disposal Site (FADS) relative to Massachusetts Bay and Cape Cod Bay.

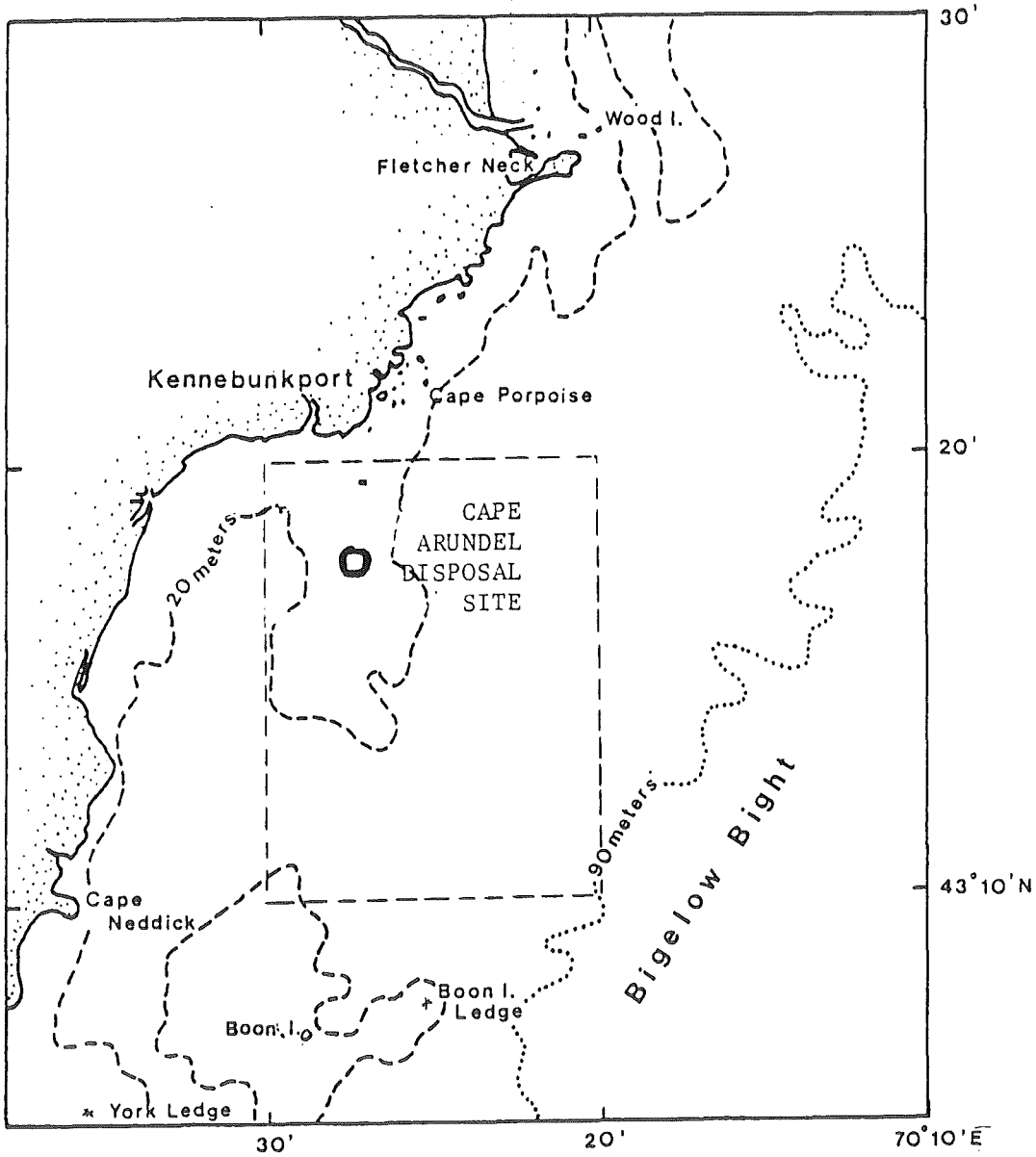


Figure 3. The location of the Cape Arundel Disposal Site (CADS).

METHODS

The contents of this report represent a synthesis of available primary data on the distribution and abundance of cetaceans, marine turtles and seabirds within the Gulf of Maine, including Georges Bank. The available data for cetaceans can be broadly classified into two categories: 1) standardized surveys from which analytical assessments of whale distribution and abundance, both spatial and temporal, can be made; and 2) opportunistic sighting data from which site-specific distribution patterns can be obtained.

The six databases used in this report are: 1) the Bureau of Land Management-sponsored Cetacean and Turtle Assessment Program (CETAP) 1978-1980; 2) the National Marine Fisheries Service, Northeast Fisheries Center-sponsored marine mammal surveys, Manomet Bird Observatory (MBO), Manomet, Massachusetts 1980-1985; 3) the Right Whale Surveys of Cape Cod Bay, Center for Coastal Studies (CCS), Provincetown, Massachusetts 1983-1986; 4) the Cetacean Research Unit (CRU) of the Gloucester Fisherman's Museum, Gloucester, Massachusetts 1980-1985; 5) the Gulf of Maine Cetacean Sighting Network 1975-1981, located at the College of the Atlantic, Bar Harbor, Maine; and 6) data from aerial surveys conducted at the Foul Area Disposal Site, January and June, 1986.

The CETAP surveys (aerial) and MBO surveys (shipboard) provide abundance estimates of all species by season and region, as well as patterns of distribution and abundance that are directly comparable. Data from these two surveys were used in this report as follows:

1. To provide figures for the overview of the relative distributions and abundance by seasons of all cetaceans and marine turtles in the waters of the Gulf of Maine, including Georges Bank.

2. To provide seasonal abundance estimates for all endangered species located within the Gulf of Maine.

3. To provide sighting data for the site-specific evaluations of FADS and CADS.

4. To provide seasonal densities of seabirds for the site-specific evaluations of FADS and CADS relative to the Gulf of Maine (MBO data only).

Data from the standardized Right Whale Surveys of Cape Cod Bay (CCS) were used in the discussion of their abundance, distribution and high-use habitat evaluation.

Data from the aerial surveys were used in the discussion of relative densities and abundance (population) estimates of endangered cetaceans in the waters of the FADS study area, January - June, 1986. Specific methodologies used in the aerial surveys are discussed in a later section.

Opportunistic Sightings

Opportunistic sightings of cetaceans and marine turtles were available for the FADS study area. The most obvious database comes from the whale-watching vessels which make daily trips to Stellwagen Bank. However, sightings from this source are computerized and readily available for analyses at only two

institutions, the Cetacean Research Unit (CRU) of the Gloucester Fisherman's Museum, Gloucester, Massachusetts, and the Center for Coastal Studies (CCS), Provincetown, Massachusetts. The majority of the sightings from CCS did not extend into the three 10' quadrats of the FADS study area; therefore they were of limited use in the analyses of that site.

The data from CRU extended into the northern half of the middle and easternmost 10' quadrat. Although this data is biased in that it does not provide a systematic representation of the entire three 10' quadrats (as in a standardized survey), the amount of effort in the areas covered by the whale-watching vessels from CRU provided the most intensive coverage for the FADS site-specific evaluation. Data from the standardized surveys (MBO, CETAP) and the aerial surveys (this study) also were used in the site-specific evaluations of the FADS and the CADS.

Data from sighting-networks or whale-watching vessels were used in:

1. Site-specific evaluations of the temporal and spatial distribution of cetaceans and marine turtles in the site-specific evaluations of FADS and CADS.

2. A description of high-use areas by cetaceans and observed behaviors of cetaceans at FADS and CADS.

Evaluation of the Cape Arundel Disposal site (CADS) was more difficult in that standardized surveys by CETAP and MBO rarely extended into the location of the FADS site and there are no commercial whale watches in the immediate vicinity of CADS. The single largest source of available data was from the Gulf of Maine Cetacean Sighting Network, Allied Whale, College of the Atlantic (COA), Bar Harbor, Maine. This primary data source represents a collection of sightings from all possible sources (i.e. commercial whale watches, surveys, fishing boats, etc.) that were forwarded to the College of the Atlantic for entry into the sighting network. Between 1975 and 1981, COA acted as the unofficial central repository for whale-sightings throughout Gulf of Maine waters. This endeavor by the COA was aided largely by the effort of all researchers throughout New England to provide photographs of humpback whales to COA for identification of individuals which have been used to determine population estimates, migratory patterns, and geneologies of that species throughout the northwest Atlantic.

Opportunistic sighting data were not used to provide density-estimates, seasonal trends in abundance, or to quantify cetacean high-use or high-density areas throughout the Gulf or Maine, or in waters outside the immediate study-sites of FADS and CADS.

Wherever possible, primary data sources used in the construction of figures, tables or text in this report are cited. Any misrepresentation of these data sources in any manner is the responsibility of the Manomet Bird Observatory.

I. AN OVERVIEW OF HIGH-USE AREAS BY ALL CETACEANS IN THE SHELF WATERS OF THE NORTHEASTERN UNITED STATES BETWEEN CAPE HATTERAS AND NOVA SCOTIA

P. M. Payne

I. An Overview of High-use Areas by all Cetaceans in the Shelf Waters of the Northeastern United States between Cape Hatteras and Nova Scotia.

Observations of cetaceans from ship have been conducted as part of the standardized National Marine Fisheries Service/Northeast Fisheries Center assessment surveys between 1980-1985. Density estimates (animals/km^2) from these surveys provide spatial and temporal accounts of high-use (areas of highest density) areas for marine mammals. The shipboard data is presented by subregions within the shelf waters of the northeastern United States between Cape Hatteras, North Carolina and Nova Scotia (Payne et al. 1984). These subregions were adapted from NMFS/NEFC assessment surveys of groundfish and plankton stocks (Grosslein 1969), based principally on hydrography. The subregions are provided in Figure 4. Aerial surveys conducted by the Cetacean and Turtle Assessment Program (CETAP 1982) also provide densities (animals/km^2) and biomass (kg) per unit effort (Kenney 1985, Kenney et al. 1985) within a spatial and temporal framework. The aerial survey data was examined by 10' blocks of latitude (19 x 14 km) (Kenney 1985), for the same study area. Therefore two independent research efforts can be used to determine high-use areas for cetaceans within the same study area and the approximate temporal framework (1978-1985).

The shipboard data suggest considerable differences in the spatial-temporal distribution of cetaceans by season and region. The data also suggest different patterns of distribution between large whales and dolphins. Gulf of Maine waters were especially important to large whales (Table 6). Baleen whales were recorded throughout the shelf, but greatest concentrations occurred in the southwest Gulf of Maine during spring through fall (Table 6). The southwest Gulf of Maine includes waters from Jeffreys Ledge and Stellwagen Bank south along the 100 m contour outside Cape Cod to the Great South Channel. The central area of the Great South Channel (south-Gulf of Maine) had high densities of whales in spring and summer. An examination of Table 6 suggests that subregions within the Gulf of Maine were the most critical areas used by endangered baleen whales within the entire shelf waters of the eastern United States. The southern New England and mid-Atlantic regions were not recorded in the ten most occupied areas by large whales. This Gulf of Maine-biased distribution is characteristic of finback, minke, humpback and right whales. Dolphins included in this distribution are white-sided, white-beaked, harbor porpoise, killer whale and pilot whale (Hain et al. 1981, Katona et al. 1983). Large whales were most frequently sighted from spring through fall. The importance of the southwest Gulf of Maine to large whales has been well documented (Hain et al. 1981, Kenney et al. 1981, CETAP 1982, Payne et al. 1986). This is the only predictable region where finback and humpback whales overwinter in the Gulf of Maine. The overall trend for large whales to select areas of rapidly changing bathymetry also is evident. The other area of large whale concentrations was principally along the shelf edge of Georges Bank (Table 6).

The greatest concentrations of dolphins occurred from Georges Bank south to the mid-Atlantic regions, principally from mid-shelf seaward to the shelf edge (Table 7), independent of season (Table 7). The species included are common dolphin, striped dolphin, bottlenosed dolphin, grampus, pilot whales (especially mid-winter), and the pygmy sperm whale. These species are common in relatively warm, deeper slope waters along the edge of the continental shelf. The endangered species with this characteristic distribution are sperm whales, and perhaps the sei whale (Katona et al. 1983). The center of abundance for these species is the mid-Atlantic Bight region although it shifts northward and onto the shelf (into the Gulf of Maine) in summer and fall. Only the southwest-Gulf of Maine (spring) and the south-Gulf of Maine (winter)

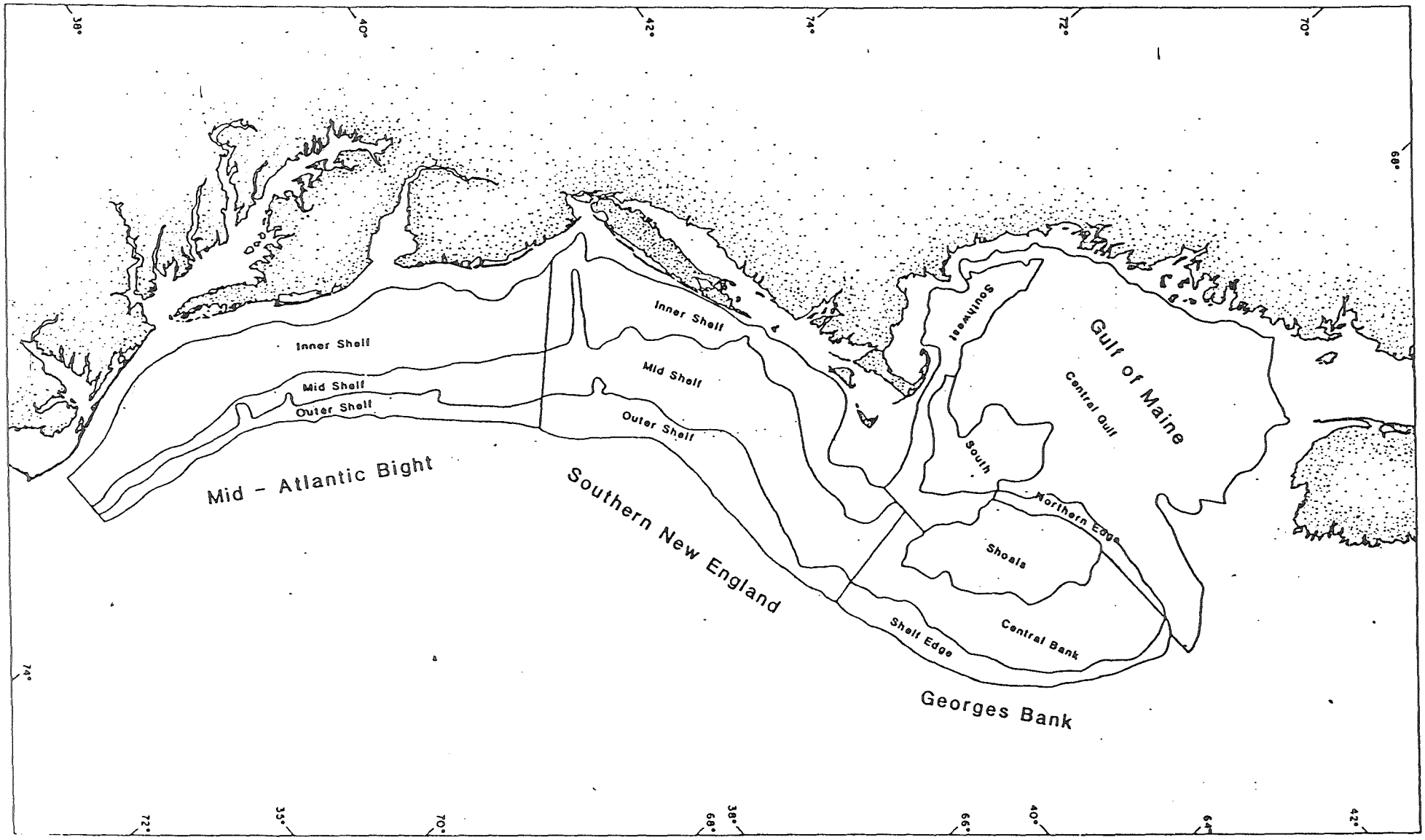


Figure 4. Subregions of the continental shelf of the eastern United States adapted from NMFS/NEFC surveys and mentioned in the text.

were ranked among the ten most important regions for dolphins. The species most often seen in these regions was the white-sided dolphin. Dolphin distribution is most widespread summer through fall, and most restricted in winter.

Kenney (1985) compared the average biomass per unit effort (by 10' blocks of latitude) for the shelf waters between Cape Hatteras, North Carolina and Nova Scotia. The numbers of whales and dolphins in each block was multiplied by the average weight of each species (Kenney et al. 1985) to give the total mammal biomass for the block (Kenney 1985). Kenney then divided this number by the length of the survey tracks within the block to arrive at a single number, the "biomass per unit effort." The average biomass per unit effort for the entire area was 368 kilograms of mammal per kilometer of track; the highest value was nearly 50 times this amount, 15,000 kilo/km or the equivalent of about one large whale every two kilometers (Kenney 1985). Kenney (1985) and Kenney et al. (1985) found the highest habitat use in spring and summer, and the lowest in fall and winter. The blocks with the highest use produced a clear pattern (Fig. 5) and are clustered in the western Gulf of Maine in two areas. The following text is taken directly from Kenney (1985).

"The first high-use habitat is to the east of Cape Cod in the vicinity of the Great South Channel. It is the center of right whale distribution in the spring. Right whales congregate there to feed on dense patches of small crustaceans called copepods. This area also has large numbers of fin and humpback whales and white-sided dolphins during the spring, summer and fall. The second area of high use is north of Cape Cod and nearer to the shore, and it includes two relatively shallow areas called Stellwagen Bank and Jeffreys Ledge. The block with the highest habitat use index in the entire study area is located at the northern end of Stellwagen, just to the east of Gloucester, Massachusetts. These areas also harbor many humpbacks, fin whales, and white-sided dolphins during spring, summer, and fall. Like the Great South Channel, these areas have large populations of a small schooling fish, called sand lance or sand eel, which are the main prey of the marine mammals.

"The second important mammal habitat area off the northeast coast is along the edge of the continental shelf where water depths increase from the shallows of the shelf to the depths of the ocean floor over a relatively short distance -- an area called the shelf break. The primary species found in this area are sperm whales, pilot whales, gray grampus, bottlenosed dolphins, saddleback dolphins, and striped dolphins, but several other species are also sighted there less frequently.

"Many of the marine mammals in the shelf-break area feed exclusively or partly on squid, which are found there in large numbers. Other species feed on a variety of fishes, including flying fish, herring-like fishes, and deep-water species like lanternfishes. The marine mammal community in the shelf-break region is much more diverse than the Gulf of Maine community in terms of both the number of species present and the variety of food species eaten."

The block with the highest habitat use index is the outer 10' block of latitude within the FADS study site.

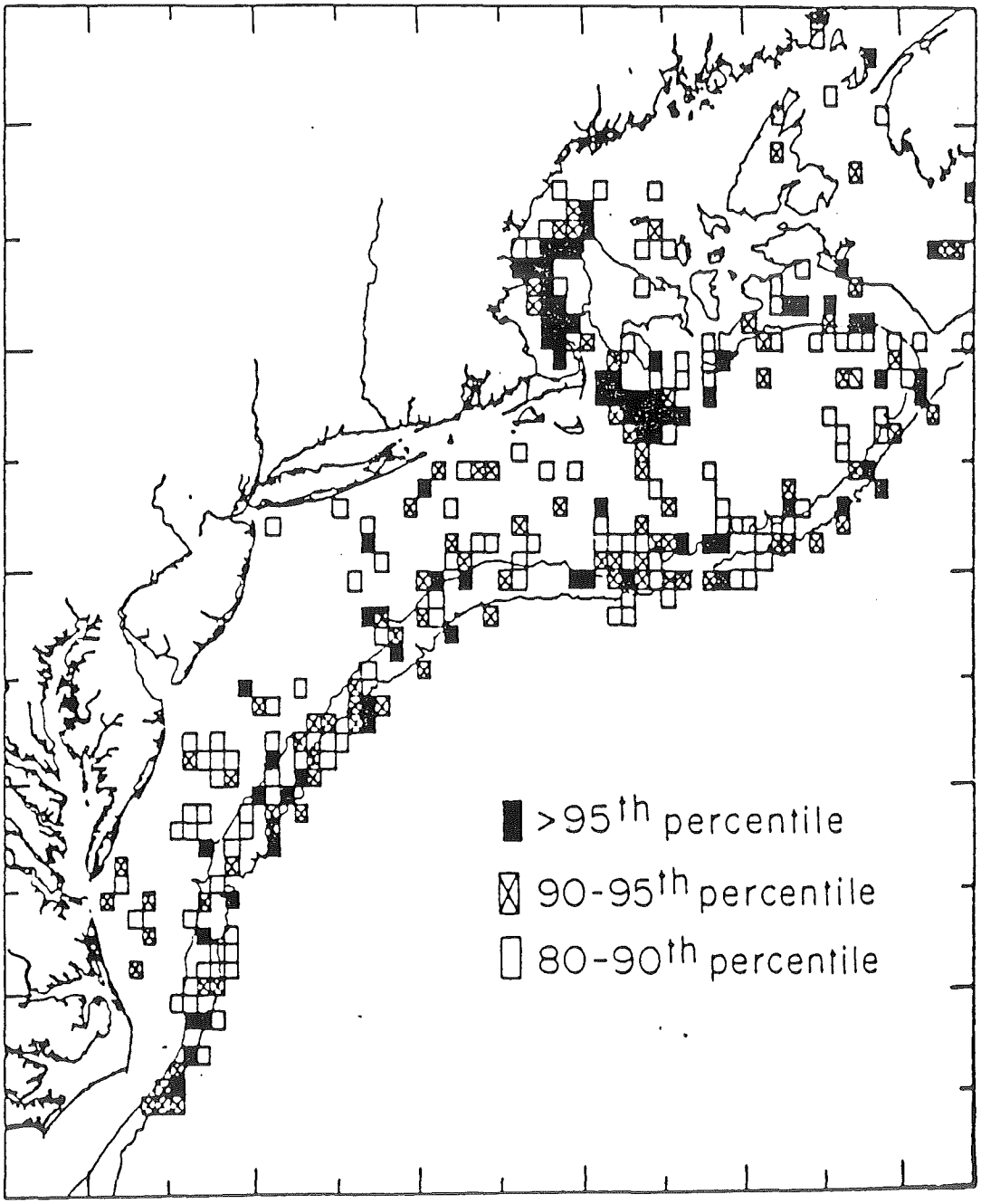


Figure 5. Map of the shelf waters of the eastern United States showing 10' blocks representing areas with a habitat-use index in the top 20% (from Kenney 1985).

·SUMMARY - Cetacean Habitat Use and Characterization

1. The Gulf of Maine waters are high-use habitat for fin, humpback and right whales between spring and fall. Winter concentrations of fin and humpback whales are reduced from the other times of the year. Winter distribution and abundance of right whales in the Gulf of Maine are poorly understood.

2. The southwest-Gulf of Maine (Jeffreys Ledge, Stellwagen Bank south along the 100 m contour outside Cape Cod to the Great South Channel) is the subregion of highest use per unit area (greatest density) by large whales between Cape Hatteras, North Carolina and Nova Scotia. Three species of endangered large whales use this area throughout the year, with densest concentrations occurring spring through fall.

3. The easternmost 10' latitudinal block of the Foul Area Disposal Site (FADS) study area occurs over the northwest corner of Stellwagen Bank, the area Kenney (1985) found to have the highest habitat-use index by cetaceans between Cape Hatteras, North Carolina and Nova Scotia. The middle 10' quadrat also is an area of high cetacean use with a habitat-use index > 90-95th percentile.

II. DISTRIBUTION AND ABUNDANCE OF RARE AND ENDANGERED CETACEANS AND MARINE TURTLES IN THE GULF OF MAINE AND ADJACENT WATERS (NORTH OF 40°00'N LATITUDE) -- AN OVERVIEW

P. M. Payne and L. A. Selzer

CETACEAN SPECIES ACCOUNTS

Fin Whale Balaenoptera physalus
Status: **ENDANGERED**

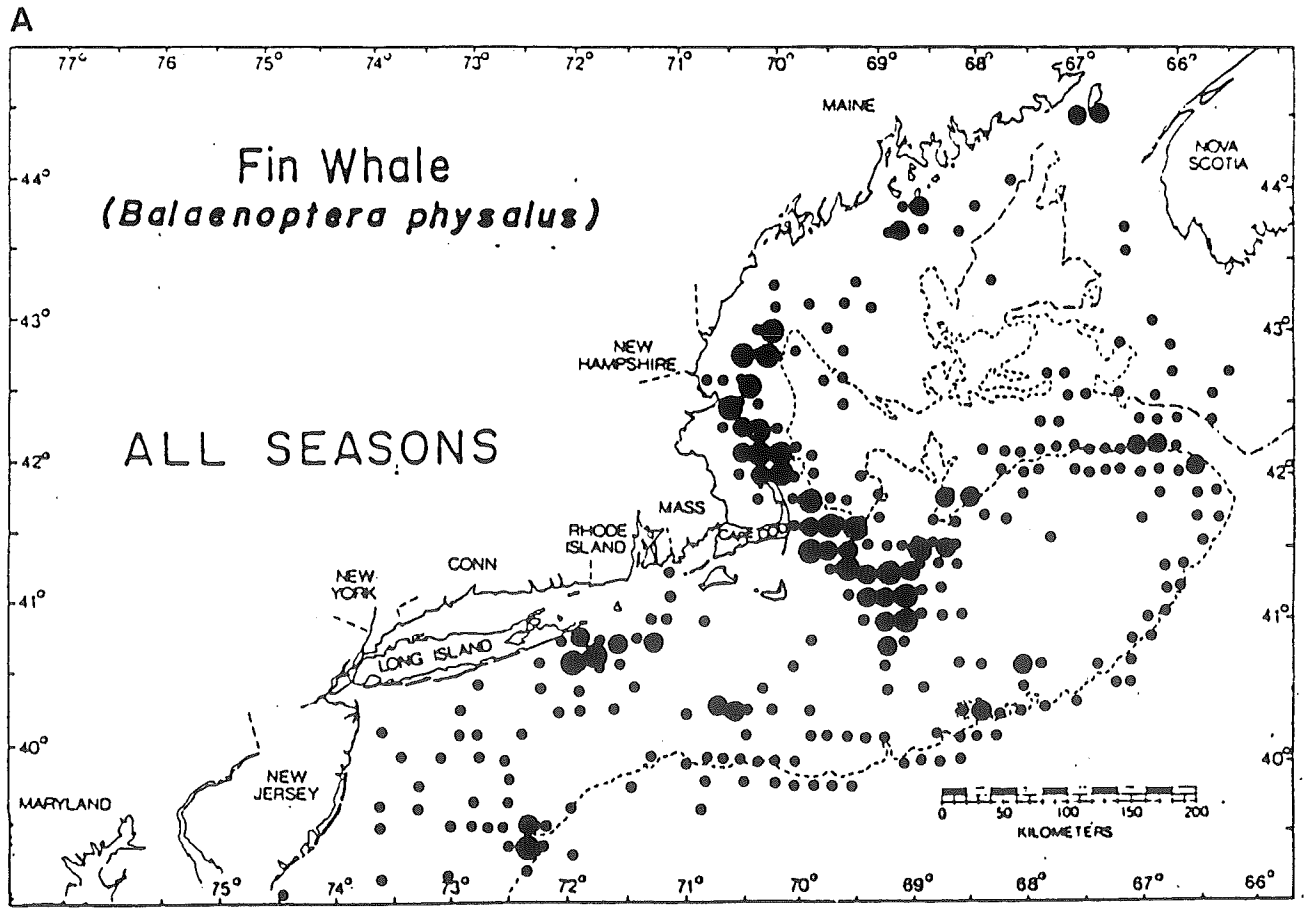
Fin whales are the most cosmopolitan and abundant large baleen whale (Reeves and Brownell 1982). They also are the most widely distributed whale, both spatially and temporally, over the shelf waters of the northwest Atlantic (Leatherwood et al. 1976), occurring as far south as Cape Lookout, North Carolina and penetrating far inside the Gulf of St. Lawrence. Jonsgard (1966), Mitchell (1974a) and Sergeant (1977) conducted extensive studies of fin whales in the North Atlantic. They concluded that a limited migration likely occurs in shelf waters from Cape Cod in June and July north to Labrador. Leatherwood et al. (1976) suggested that most fin whales (in the western North Atlantic) move south and offshore during winter months. Sergeant (1977) suggested that fin whales, existing in discrete stocks within the north Atlantic (although this has recently been challenged), undertake seasonal movements in order to find food.

In the shelf waters of the Gulf of Maine, including Georges Bank, the frequency of fin whale sightings increases from spring through the fall (Hain et al. 1981; CETAP 1982; Powers and Payne 1982; Payne et al. 1984, Chu 1986). The areas of Jeffreys Ledge, Stellwagen Bank and the Great South Channel (Subregions Gulf of Maine-southwest and south) have the greatest concentrations of whales during these seasons (Figs. 6a-e). There is a decrease in on-shelf sightings of fin whales in winter. However, fin whales do overwinter in the Gulf of Maine. This is especially apparent on Stellwagen Bank and within the Great South Channel (Fig. 6e).

In the northern hemisphere, fin whales are considered secondary and tertiary, euryphagous carnivores feeding on schooling fishes, euphausids, and copepods depending on seasonal availability (Jonsgard 1966; Mitchell 1974; Sergeant 1966, 1977; Katona et al. 1977; Brodie et al. 1978; Overholtz and Nicholas 1979; Watkins and Schevill 1979; Mayo 1982). In the Gulf of Maine, schooling fishes are the apparent preferred prey, principally Atlantic herring Clupea harengus and American sand eel Ammodytes americanus. Historically, herring were the major prey item in the Gulf of Maine (Katona 1976; Katona et al. 1975; 1977). They still are likely prey in the Gulf of Maine, especially in the northern Gulf of Maine (Mullane and Rivers 1982); however due to a decline in herring stocks since the late 1960's (Grosslein et al. 1980; Anthony and Waring 1980), and a subsequent increase in A. americanus throughout shelf waters of the northeastern United States (Sherman et al. 1981), Ammodytes may now be the dominant food in the southwest-south Gulf of Maine (Jeffreys Ledge, Stellwagen Bank to the Great South Channel). All coastal Massachusetts (Chu 1986) and Maine waters are considered major feeding grounds for finback whales.

Available estimates of abundance for regions of the North Atlantic are summarized in Table 8. Eastern Canada (Nova Scotia to western Newfoundland) has the greatest concentrations, with numbers ranging from approximately 6,000 - 12,000 animals (Mitchell 1972, 1973a, 1974a). Estimates from Iceland waters also are in this range.

Figure 6. Relative distribution and abundance of fin whales in the Gulf of Maine, including Georges Bank (north of 40°00'N latitude) by season.



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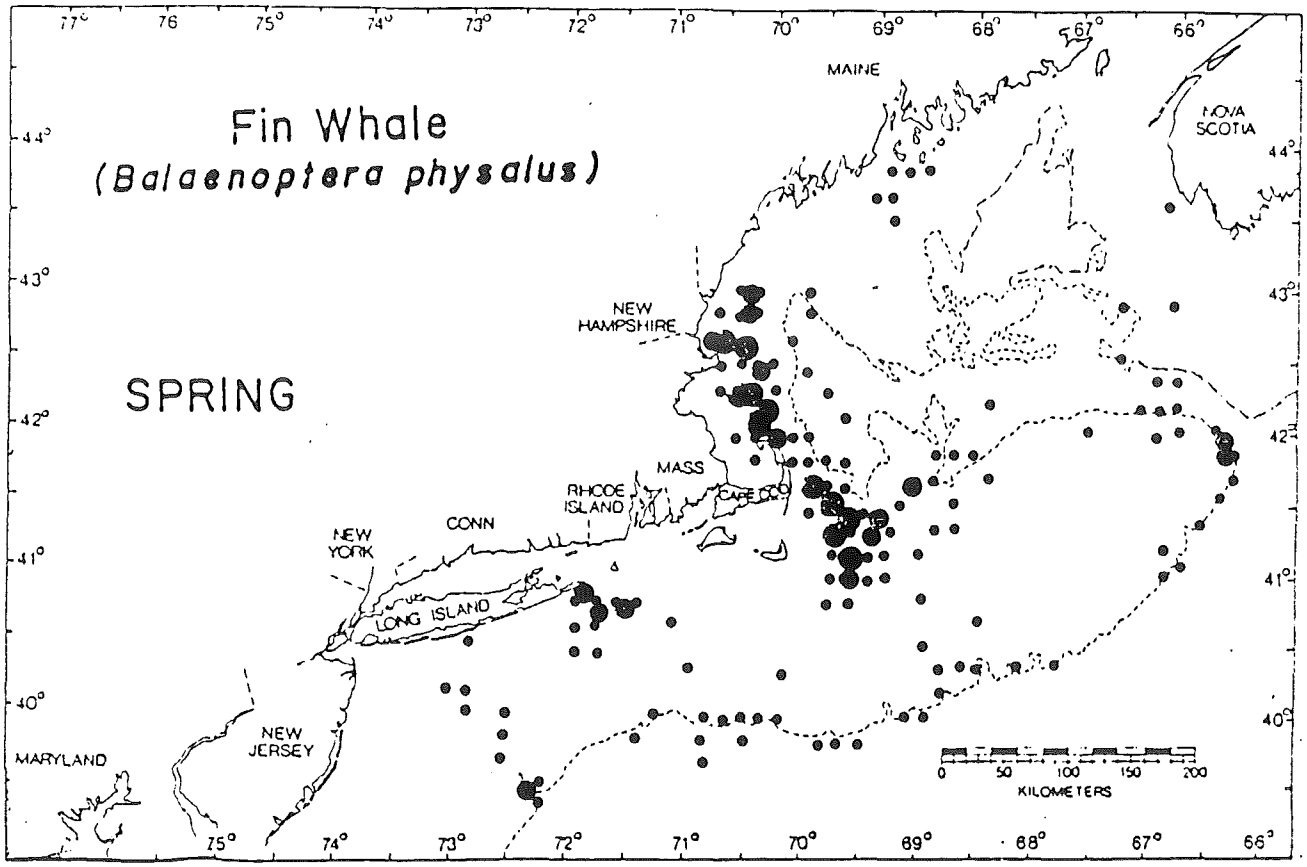
Fin Whale
(Balaenoptera physalus)
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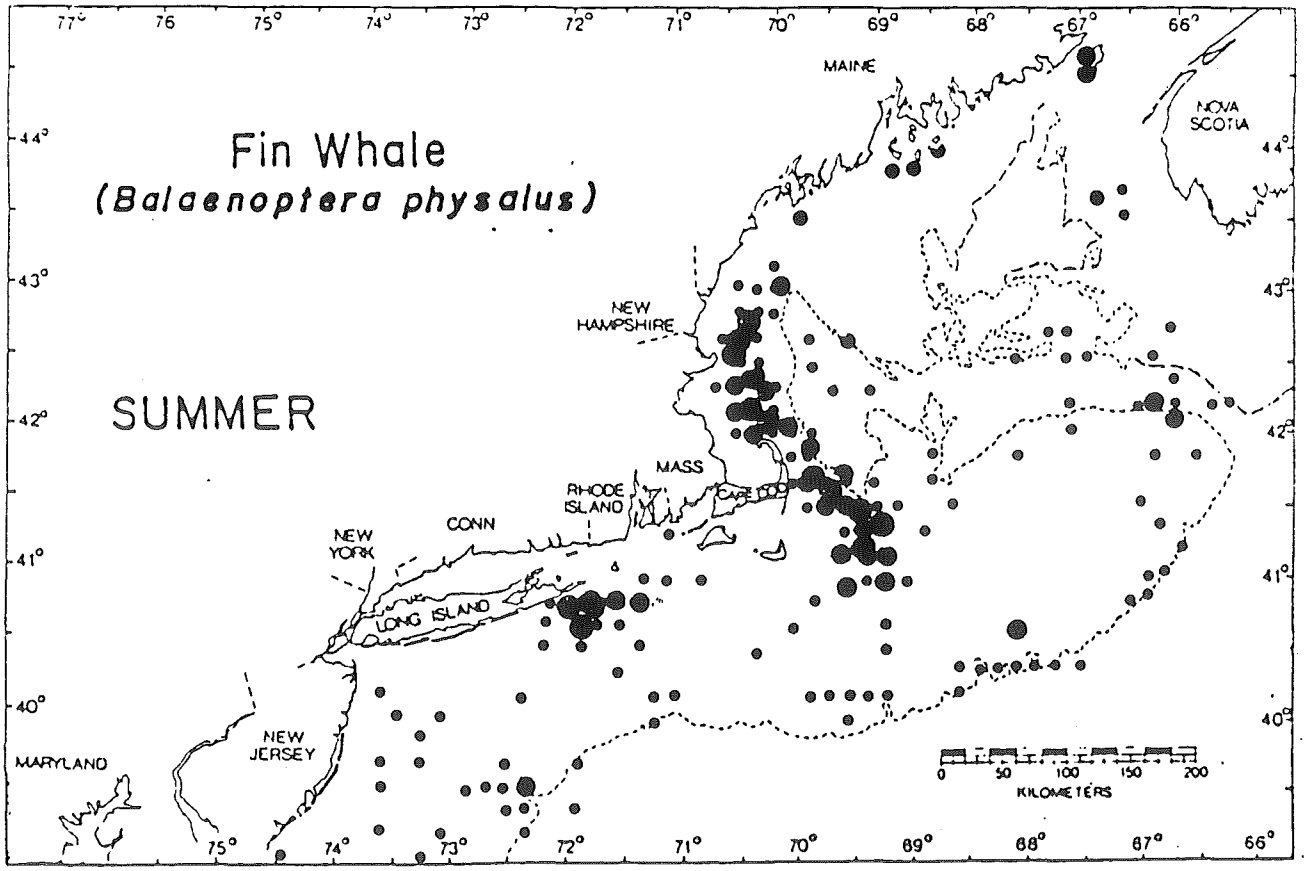
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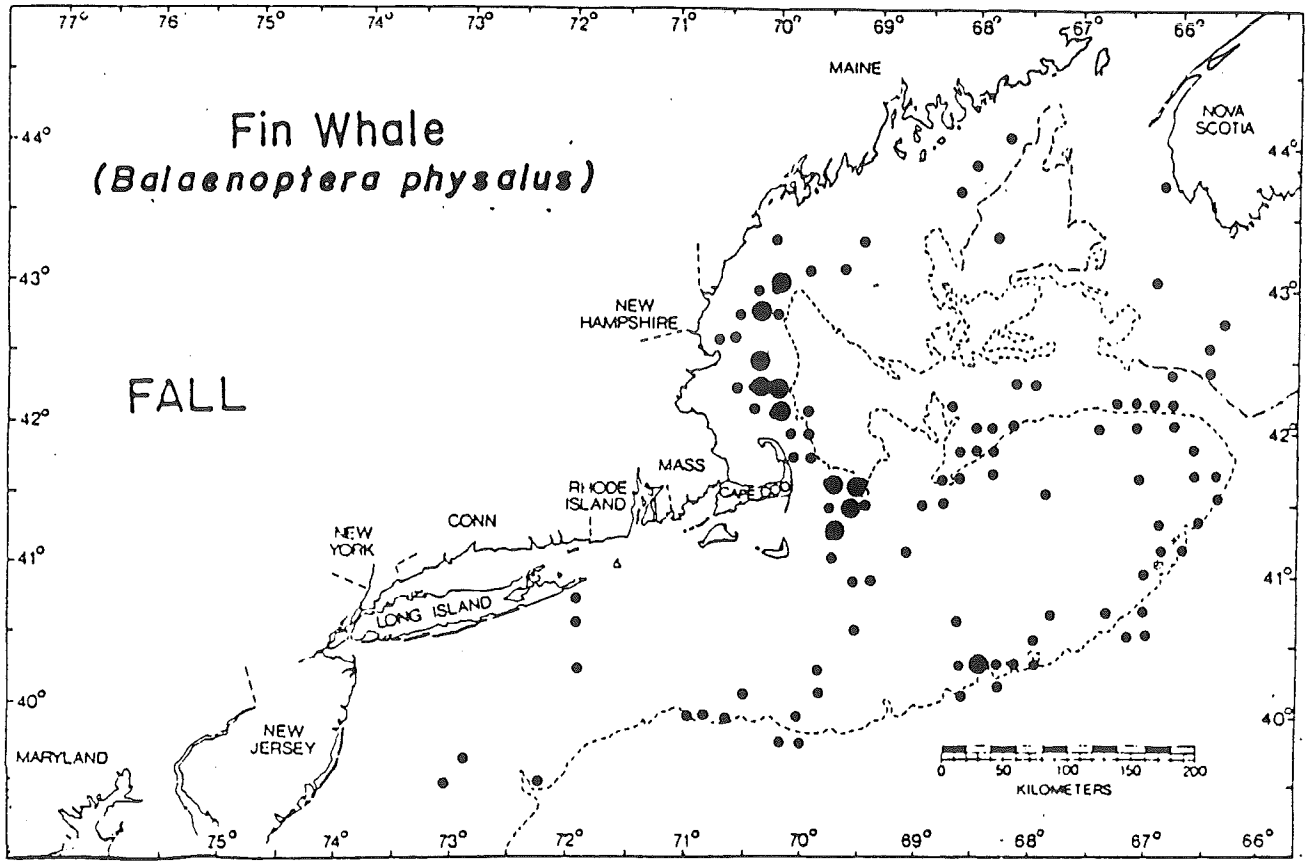
Fin Whale
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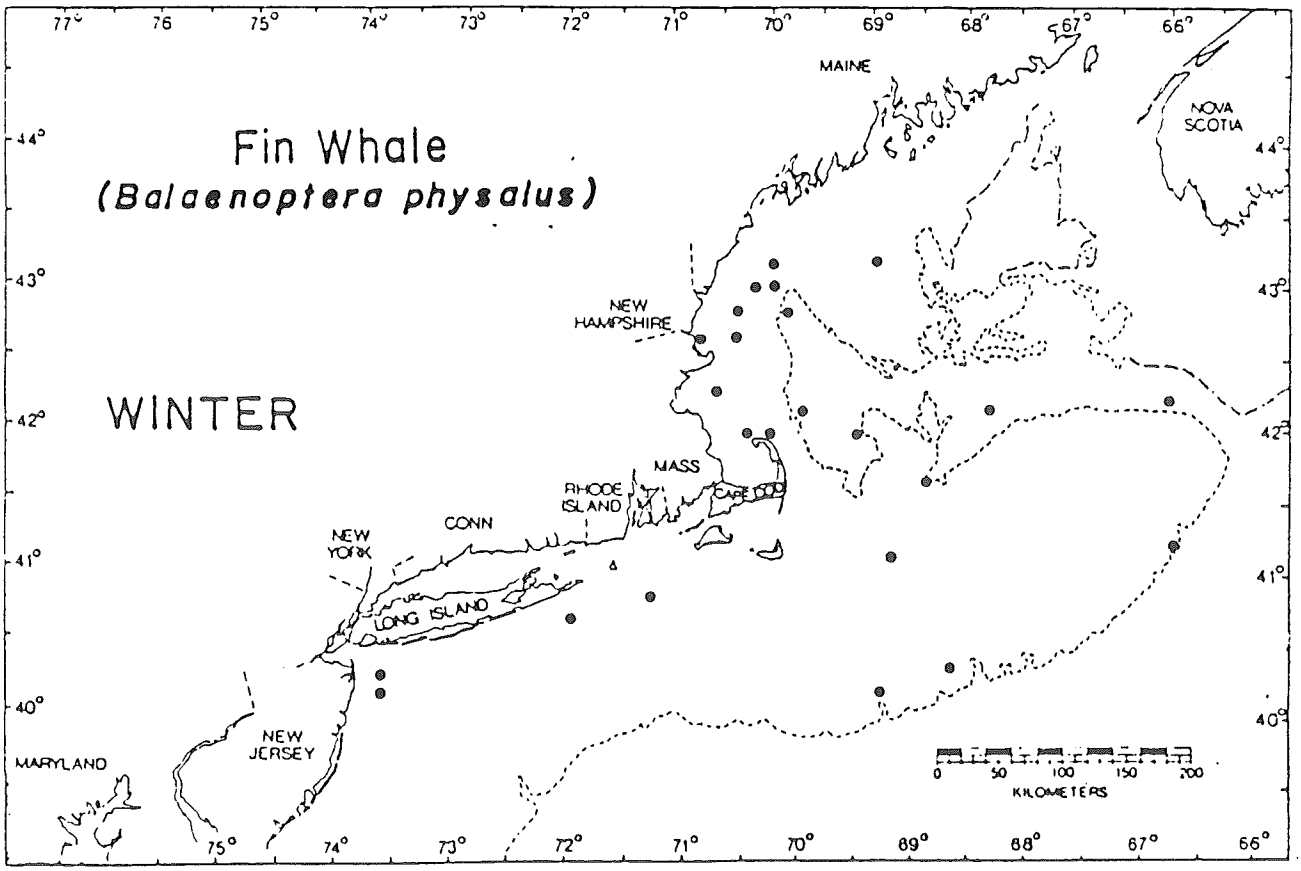
Fin Whale
(Balaenoptera physalus)
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NEW HAMPSHIRE
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NEW JERSEY
MARYLAND
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KILOMETERS

In the Gulf of Maine, the estimated number of fin whales shows clear seasonal fluctuations. Data collected between 1980-85 from shipboard observations (MBO unpublished) result in seasonal estimates between 151 (winter) to 1,862 (summer). These estimates are lower than those obtained from sighting data collected during aerial surveys in 1978-80 which were corrected for the diving behavior of the animals (CETAP 1982). CETAP's (1982) estimates for the Gulf of Maine show a peak in abundance in spring at approximately 3,000 individuals which dwindles to approximately 200 animals in winter. Both data sets show greatest densities occurring from Jeffreys Ledge and Stellwagen Bank south along the 100m contour outside of Cape Cod and into the Great South Channel. Concentrations of fin whales also are found along the boundary between the Gulf of Maine and the northern edge of Georges Bank.

Table 8.

Abundance/Population estimates for fin whales in the North Atlantic.

Region	Method	Numbers	Sources
Newfoundland/ Nova Scotia	Marking	11,610	Mitchell 1974
	Strip-census	7,130	Mitchell 1974
	Catch/effort	6,250	Mitchell 1974
Nova Scotia	Strip-census	2,800	Mitchell 1972, 1974
	Catch/effort	1,180-1,248	Allen 1971, 1973
Eastern Newfoundland and Labrador	Aerial Transect	97-926	Hay 1982
Gulf of St. Lawrence	Strip-census	340	Mitchell 1972, 1974
Eastern Canada	Mark-recapture	6,789	Mitchell 1972, 1974
Iceland	Marking	4,358	
	Total Mortality Rate	8,333	Mitchell 1972, 1974
	Marking	9,000	
Iceland/Greenland	Marking	11,000	
Greenland	Marking	2,000	Mitchell 1972, 1974
Norway/Faeroes	Catch Total	7,234	Sergeant 1977
Spain/Portugal	Catch Total	6,433	Sergeant 1977
Gulf of Maine	Shipboard Survey	151 (winter)	MBO, this report
	Line Transect	1,862 (summer)	MBO, this report
Gulf of Maine	Aerial Survey	200 (winter)	CETAP 1982
	Line Transect (corrected for diving behavior)	3,000 (spring)	CETAP 1982
Gulf of Maine	Aerial Survey	5 (winter)	Scott et al 1981
	Line Transect (no dive time correction)	1,130 (spring)	Scott et al 1981

Blue Whale *Balaenoptera musculus*

Status: **ENDANGERED**

In the western North Atlantic, the blue whale has been reported from pack ice south to the Panama Canal Zone (Leatherwood *et al*. 1976); however their distribution generally is more restricted. The normal range for this species in spring and summer extends from the Gulf of St. Lawrence/Nova Scotia region northward (Sergeant 1966; Sutcliff and Brodie 1977). In fall and winter their precise range is not known, although the population likely moves south into more temperate waters. There are no verified records from south of Cape Hatteras, North Carolina. This species generally is absent from shelf waters; all sightings to date have occurred in deeper slope waters. Only two blue whales (one sighting) were identified off Nova Scotia during the CETAP surveys (CETAP 1982). No blue whales have been sighted in the Gulf of Maine or inside the 200 m contour.

Blue whales feed entirely on krill, and their summer distribution is determined largely by the distribution of their prey species.

Sei Whale *Balaenoptera borealis*

Status: **Endangered**

The sei whale is found in all the world's oceans, excluding tropical and extreme polar seas. Evidence suggests that two stocks of sei whales occur in the northwest Atlantic (Mitchell and Chapman 1977), one off eastern Nova Scotia and another centered in the Labrador Sea. In the western North Atlantic, this species ranges from Greenland and Iceland south to southern New England waters. Sightings in the shelf waters off the northeastern United States occur along the outside of Georges Bank (Fig. 7). Mitchell and Kozicki (1984) tagged 14 sei whales in the winter between Cape Cod and Florida. New England waters are considered the southern end of the feeding range of this species (Kenney 1986). In early June, sei whales begin to move along the continental slope off the eastern United States, arriving on Georges and Browns Bank and in the northeast Channel by mid to late June (Mitchell 1975a; Mitchell and Kozicki 1984). The whales on the Scotian Shelf apparently migrate northward along the continental slope in June and July, and then return southward from mid-September to mid-November (Mitchell and Chapman 1977).

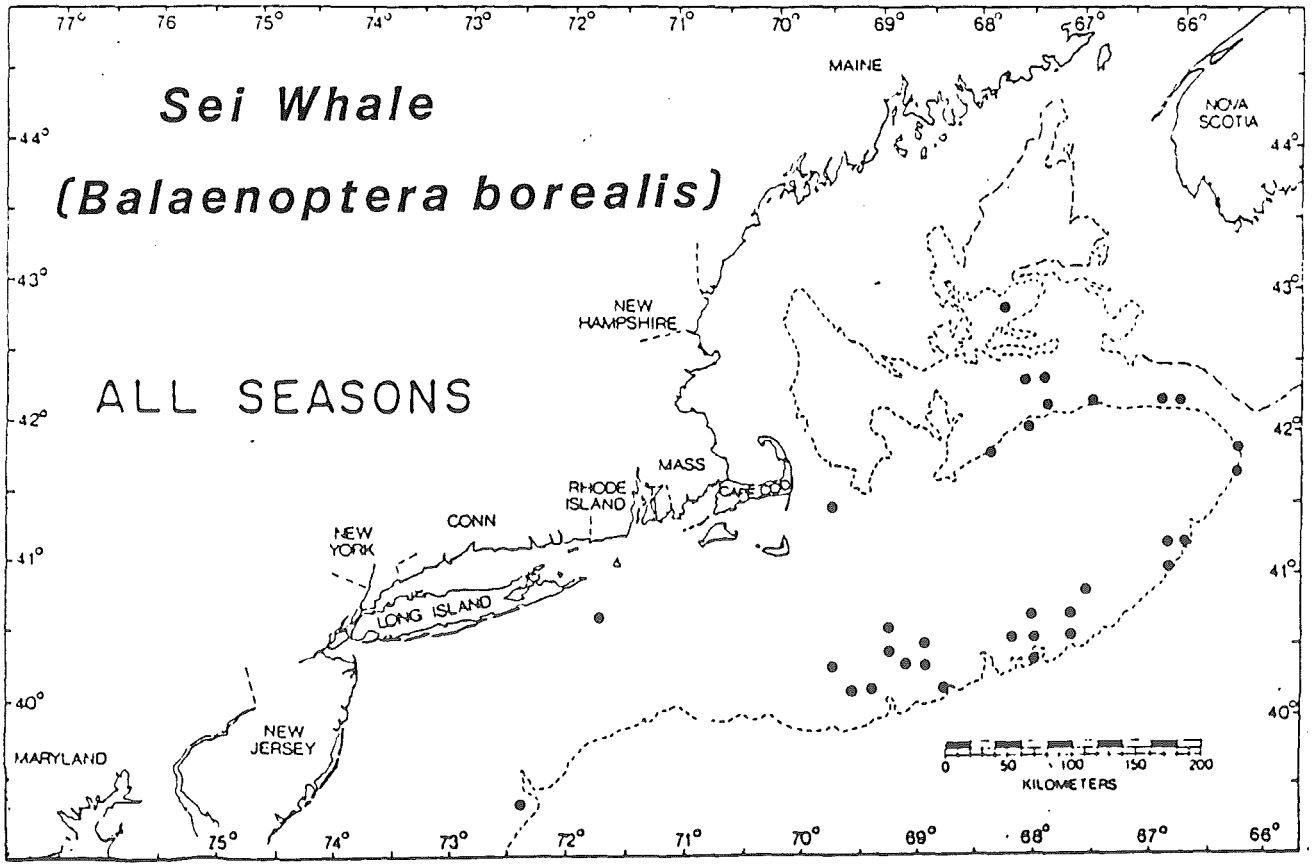
North Atlantic sei whales are "skim" feeders, feeding primarily on copepods and euphausids (Mitchell 1974b). *Calanus finmarchicus* predominates in the diet of this species in the eastern North Atlantic (Jonsgard and Darling 1977).

Sei whales in New England waters are from the same stock as that which occurs off Nova Scotia which contains 1,398 to 2,248 or more whales (Mitchell and Chapman 1977). The number of sei whales in the Gulf of Maine has been estimated to be approximately 100 whales (Scott *et al* 1981), and in the Gulf of Maine including Georges Bank and the lower Great South Channel to be 300 to 500 whales (Scott *et al*. 1981; Kenney 1986).

Figure 7. Relative distribution and abundance of sei whales in the Gulf of Maine, including Georges Bank (north of 40°00'N latitude) for all seasons.

Relative Abundance
cetaceans per 10'x10' block

- 1 - 9
- 10 - 99
- >100



Humpback Whale Megaptera novaeangliae

Status: **Endangered**

Kellogg (1929) suggested two stocks of humpback whales in the North Atlantic which were tied to the continental margins on either side of the ocean. Several individual stocks of humpbacks have been suggested in the northwest Atlantic (Katona et al. 1982). In the northwest Atlantic, the major summer concentrations of humpbacks occur off the coasts of Newfoundland and Labrador, and off the coasts of New England in the Gulf of Maine (Katona et al. 1980; Whitehead et al. 1982). During this period, feeding is their principal activity. The major winter concentrations occur along the Antillean Chain in the West Indies, principally on Silver and Navidad Banks which lie north of the Dominican Republic (Winn et al. 1975; Balcomb and Nichols 1978; Whitehead and Moore 1982). Conception and calving are the primary activities in this region. The migratory routes between regions of winter breeding and summer feeding occur in the deeper, slope waters off the continental shelf (Hain et al. 1981; Kenney et al. 1981; CETAP 1982; Payne et al. 1984, 1986). There are two possible offshore routes (Fig. 8) between these winter and summer areas: 1) Dominican Republic to the Gulf of Maine, and 2) Puerto Rico to Newfoundland. These suggest distinct stocks (Katona et al. 1981). For the Gulf of Maine stock, the Great South Channel has been suggested (Kenney et al. 1981; Payne et al. 1986) as the major exit/entry between the offshore migration routes and the Gulf of Maine feeding areas.

In the northwest Atlantic, the summer range of the humpback extends from western Greenland-Iceland (Kapel 1979; Kapel and Larsen 1982; Perkins et al. 1982, 1985; Whitehead et al. 1983) to Newfoundland-Nova Scotia (Sergeant 1953, 1961, 1966, 1968, 1975; Sergeant et al. 1970; Mitchell 1973b, 1974a; Perkins and Whitehead 1977; Whitehead et al. 1982, 1983; Hay 1985a) and into the Gulf of Maine, including Cape Cod Bay south to the Great South Channel (Hain et al. 1981; Kenney et al. 1981; Watkins et al. 1981; CETAP 1982; Mayo 1982; Mullane and Rivers 1982; Weinrich 1982, 1985; Mayo et al. 1985; Weinrich et al. 1985a, 1985b; Payne et al. 1986). The extent of their winter range in the northwest Atlantic also has been critically examined (Winn et al. 1975; Balcomb and Nichols 1982; Whitehead and Moore 1982; Mattila et al. 1985; Payne and Payne 1985).

Between mid-March and November, humpback whales are located throughout the Gulf of Maine (north of 40°00'N latitude) (Figs. 9a-e) (Hain et al 1981; Kenney et al. 1981; CETAP 1982; Payne et al. 1984; Mayo et al. 1985). CETAP (1982) reported only 10 winter sightings between 1978 and 1981. Payne et al. (1984) confirmed these low figures via shipboard surveys. Within this spatial and temporal framework, concentrations are greatest in a narrow band between 41°00' and 43°00'N latitudes, from the Great South Channel north along the outside of Cape Cod to Stellwagen Bank and Jeffreys Ledge (Fig. 9a). Humpback whales also are reported in the lower Bay of Fundy (Neave and Wright 1968; Kraus and Prescott 1981), and rarely in shelf waters between 40°00'N and Cape Hatteras (Hain et al. 1981; CETAP 1982; Powers and Payne 1983; Powers et al. 1982). They have been reported in coastal waters south of Cape Hatteras to Miami, Florida (Schmidley 1981), although inshore sightings south of Cape Hatteras are rare. The lack of sightings in the mid-Atlantic Bight supports the offshore movement patterns of the humpback whales south of 40°00'N latitude suggested by Winn and Scott (1979) and Katona et al. (1980).

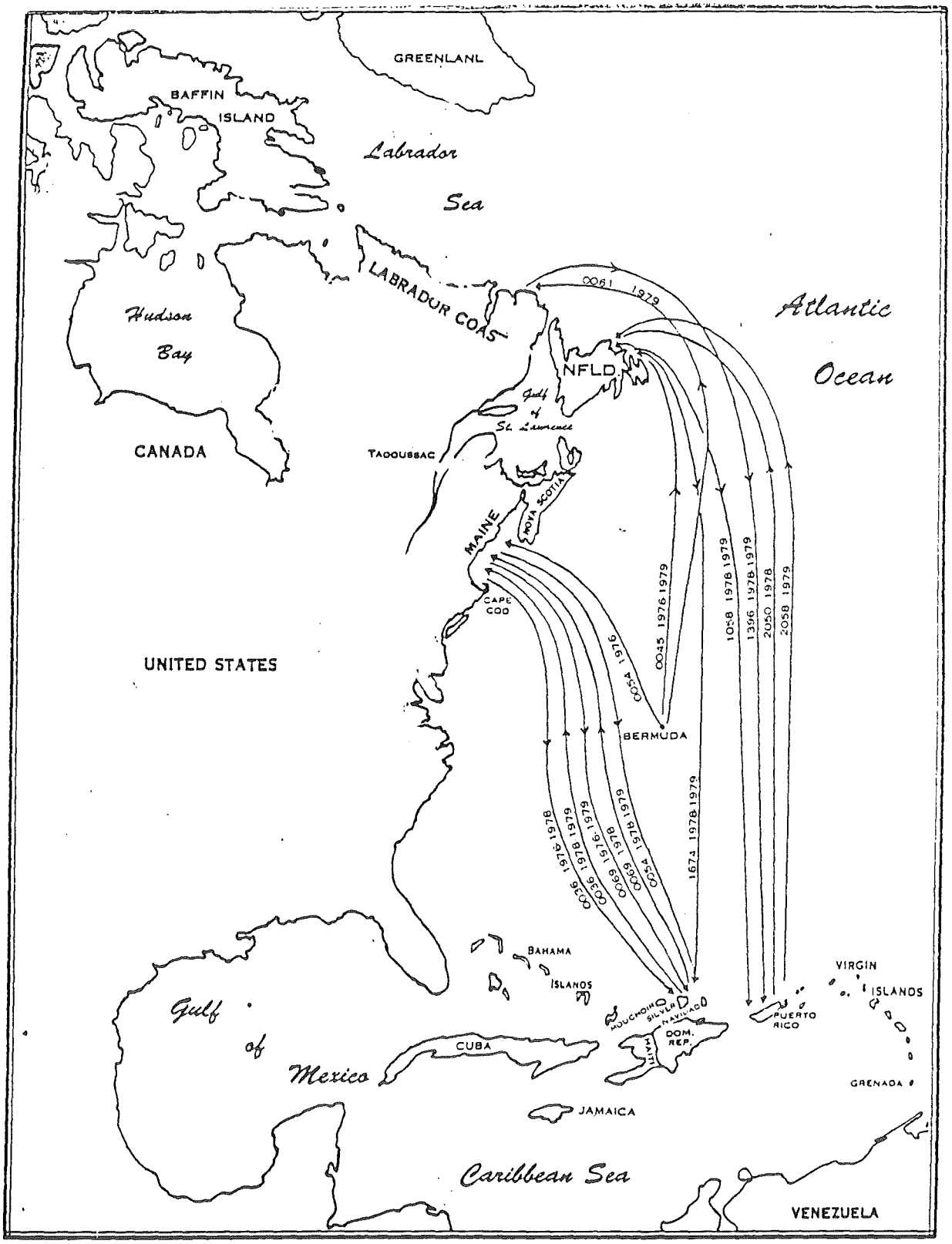


Figure 8. Migrations of individually identified humpback whales in the Gulf of Maine (From Katona et al. 1980).

Figure 9. Relative distribution and abundance of humpback whales in the Gulf of Maine, including Georges Bank (north of 40°00'N latitude) by season.

Relative Abundance
cetaceans per 10'x10' block

- 1 - 9
- 10-99
- >100

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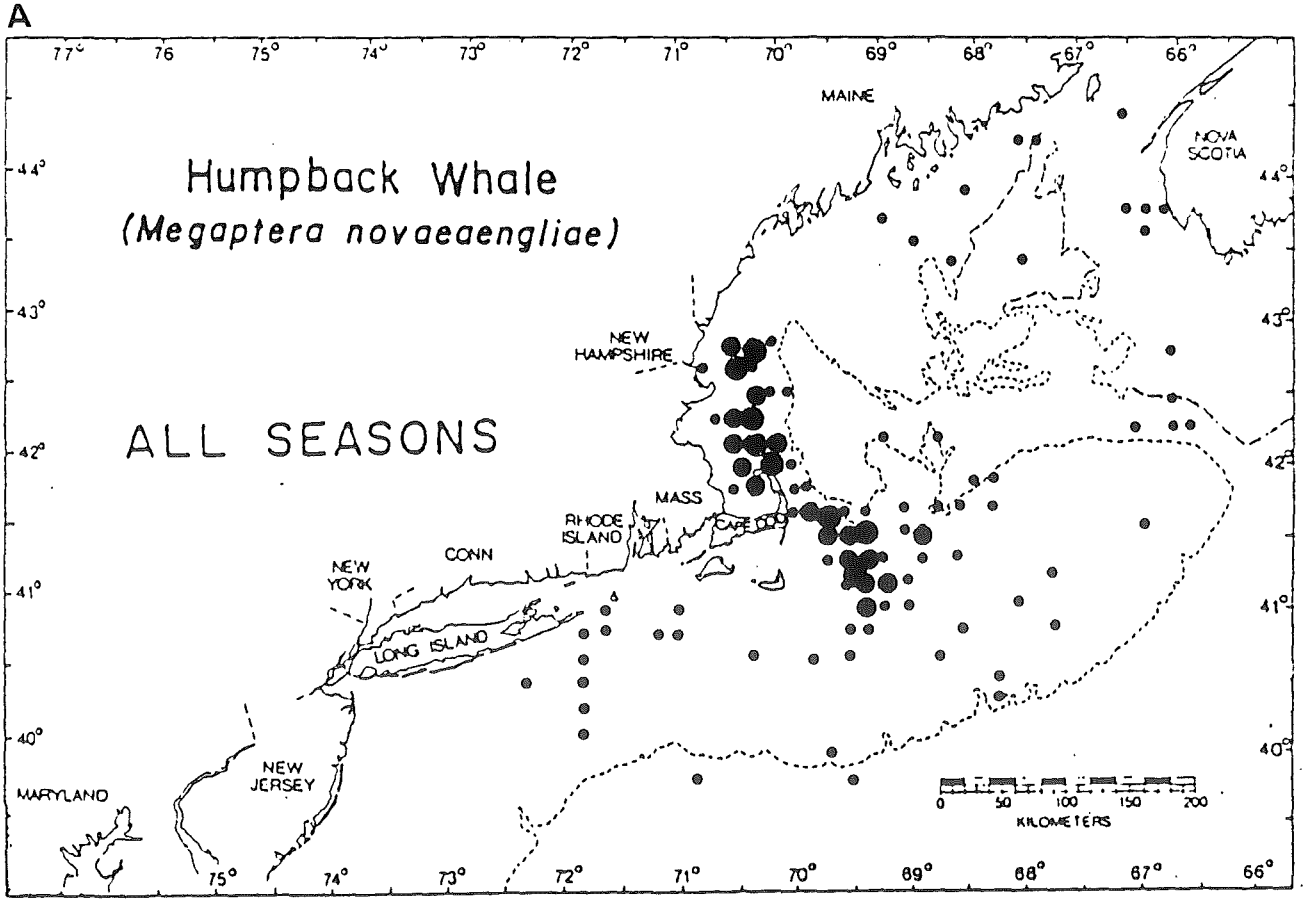

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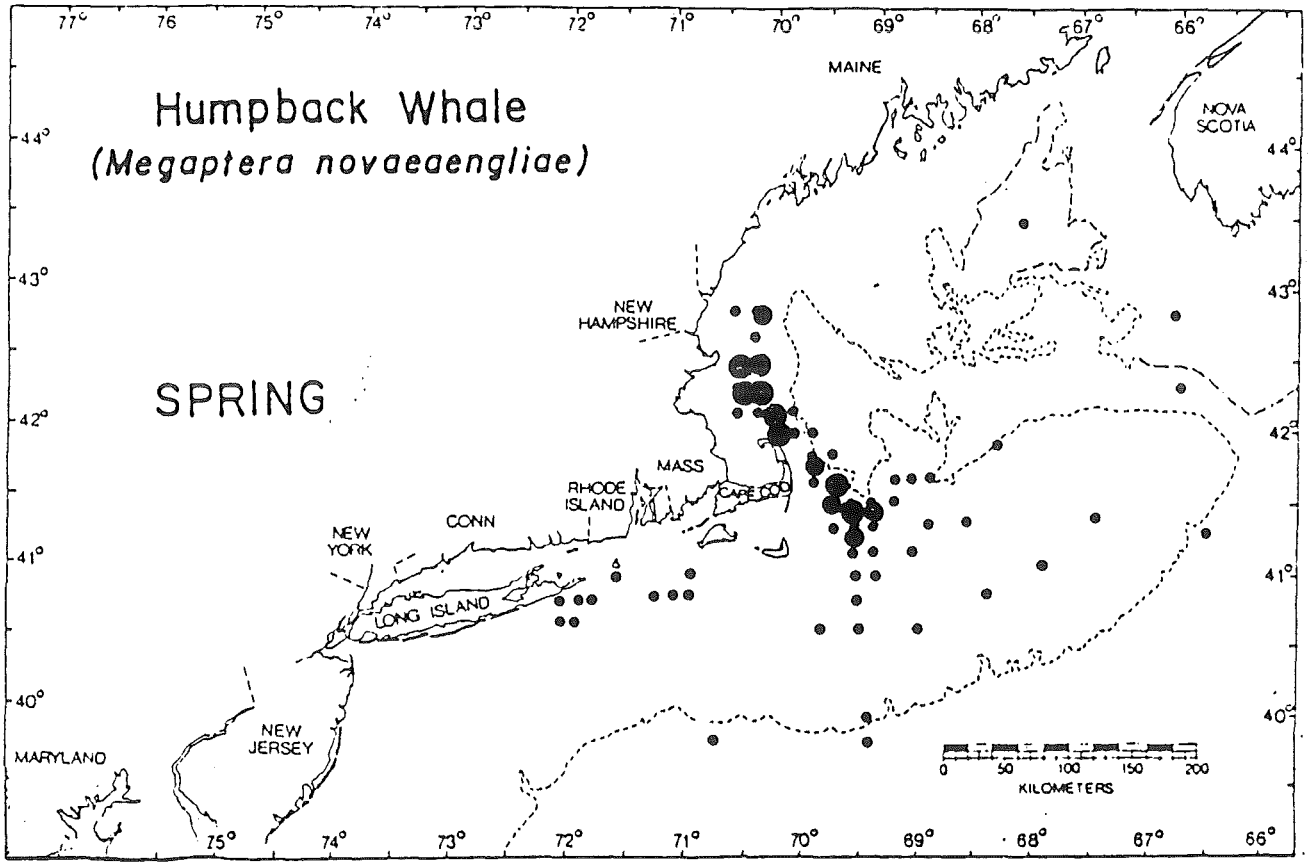
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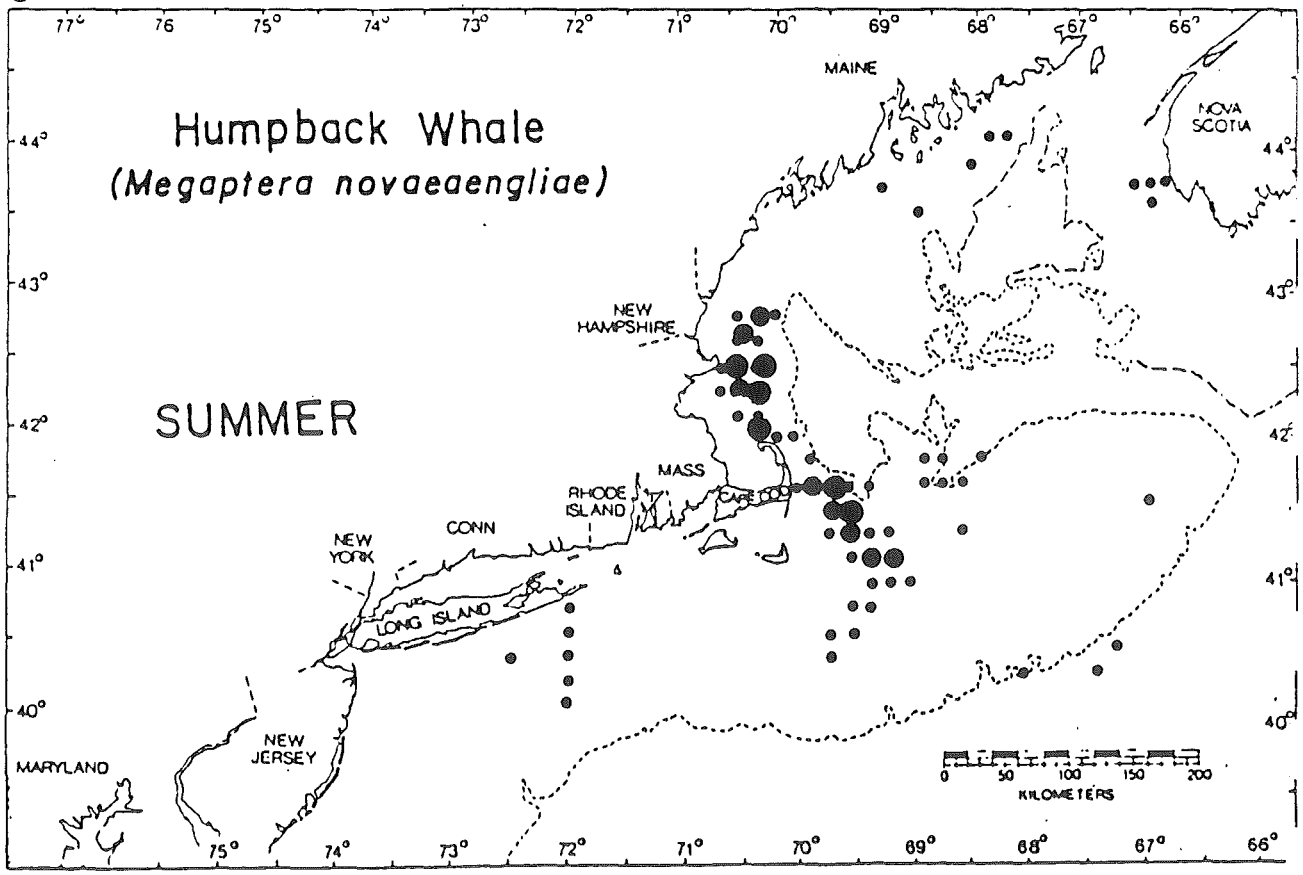
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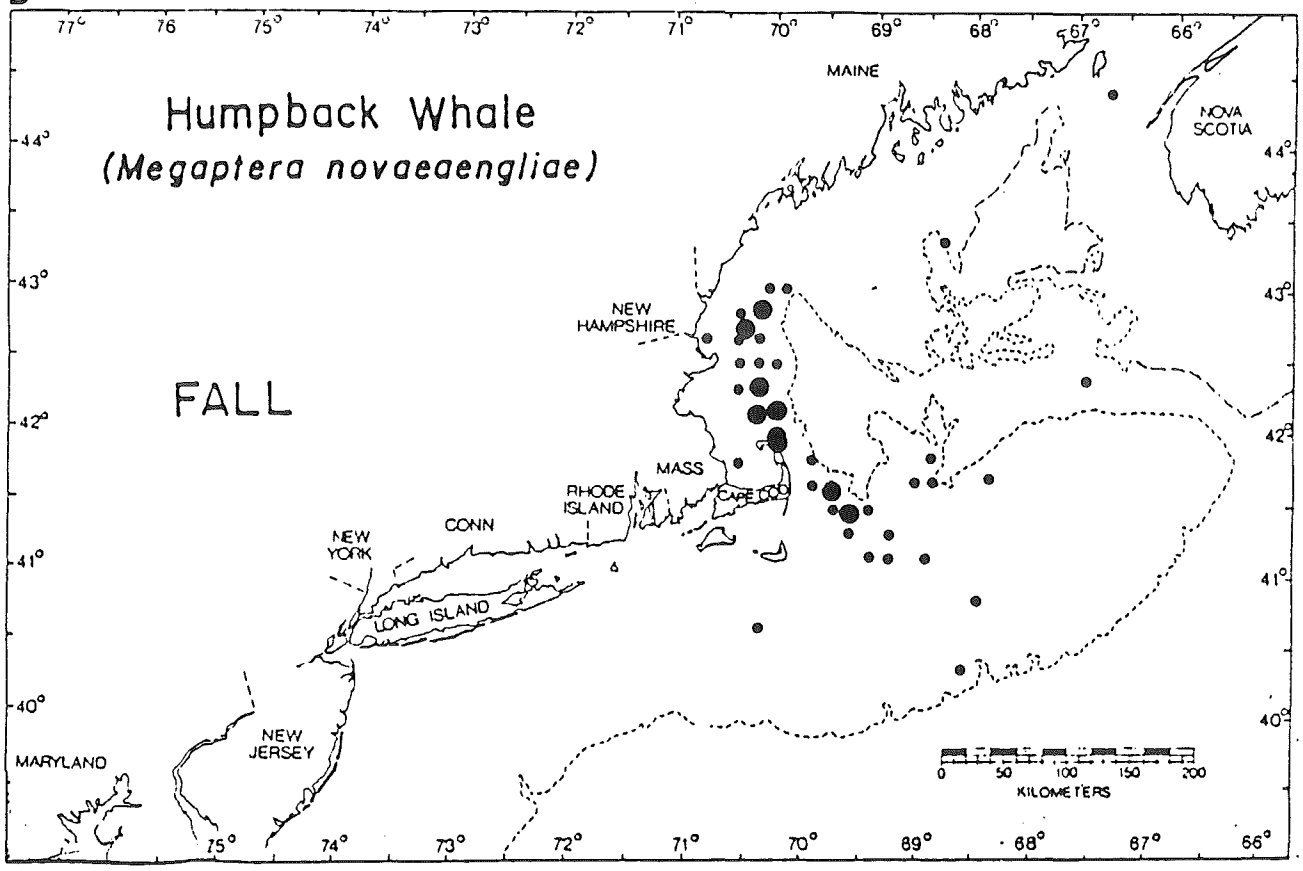
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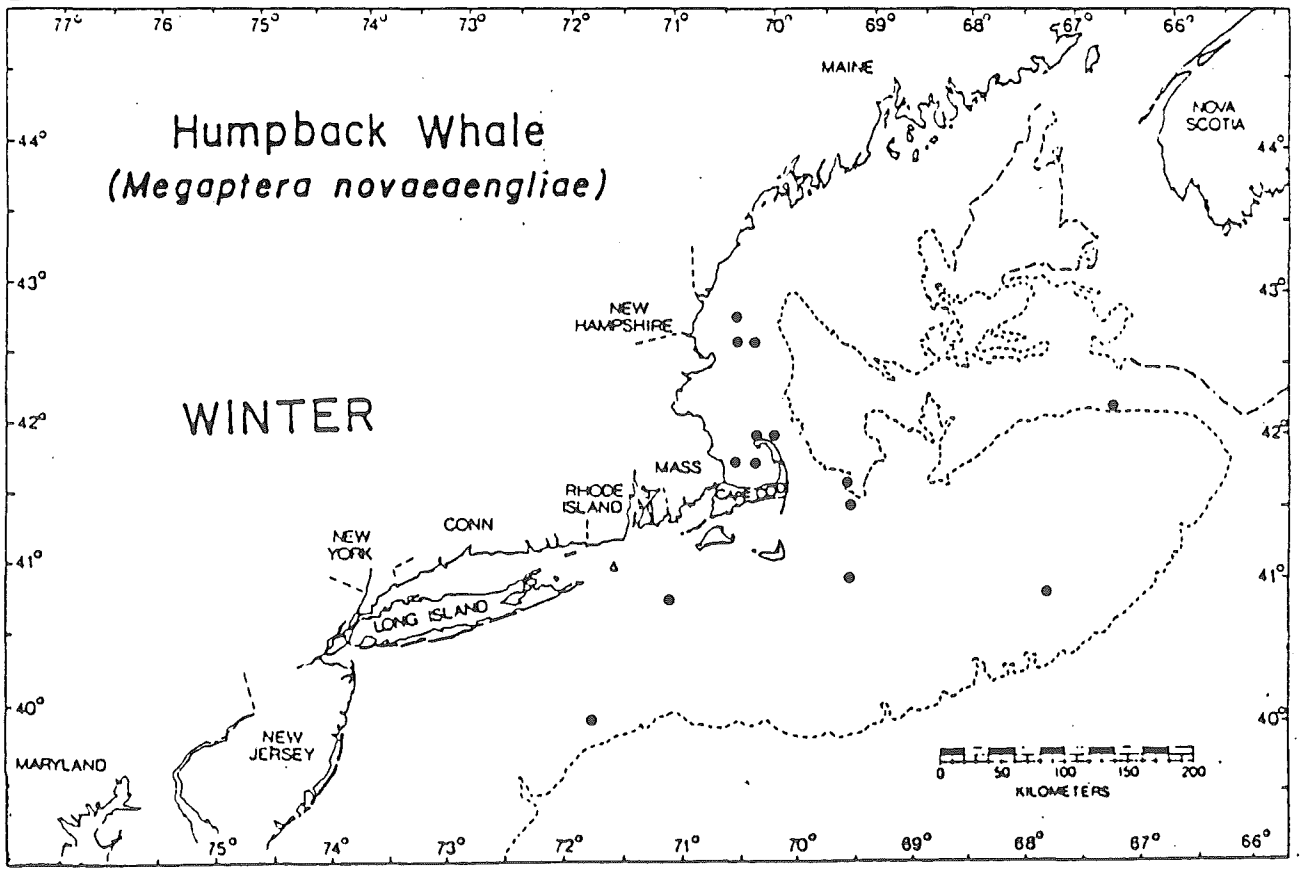
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Humpback whales are secondary and tertiary carnivores and have been described as generalists in their feeding habits (Mitchell 1974b). Whitehead et al. (1980) showed that humpbacks along the northeast coast of Newfoundland monitored the movements of capelin Mallotus villosus, their primary prey species in that region (Mitchell 1973b). Humpbacks in the Scotian Shelf feed on krill and capelin (Mitchell 1973b; Reeves and Brownell 1982). The principal prey of humpbacks in the Gulf of Maine are small, schooling fishes, including: Atlantic herring Clupea harengus, mackerel Scomber scombrus, pollock Pollachius virens, and the American sand eel Ammodytes americanus (Gaskin 1976; Katona et al. 1977; Watkins and Schevill 1979; Kraus and Prescott 1981). In recent years, observations of feeding humpbacks (Hain et al. 1982; Hays et al 1985; Mayo et al. 1985; Weinrich 1985) indicate that sand eel are an important prey item in the Gulf of Maine. Overholtz and Nicolas (1979) suggested that humpback and fin whales were feeding on sand eel on Stellwagen Bank. Hain et al. (1982) identified sand eel in 50% and 75% of the feeding observations on Stellwagen Bank during 1978 and 1979 respectively. Sand eel were the only confirmed prey eaten by humpback whales between 1975-79 on Stellwagen Bank (Mayo 1982). Kenney et al. (1981) and Payne et al (1986) suggest that the observed distribution of the Gulf of Maine humpbacks is due to the distribution of sand eels, although feeding behavior (as described by Hain et al. 1982) and bottom topography also are critical factors in the foraging strategy of humpbacks.

In the northwest Atlantic, humpback whales have been exploited heavily since the 16th century (Mitchell and Reeves 1983). In 1915, only a few hundred humpbacks were said to remain in the northwest Atlantic (Sergeant 1966). This species was officially protected from commercial whaling in 1965 (Sergeant 1966). Most of the recent knowledge on the biology, stock discreteness and population size of humpbacks has been the result of a technique of individual identification based on the markings of the underside of the flukes (tail) which are unique to each individual (Schevill and Backus 1960; Katona and Kraus 1979; Katona and Whitehead 1981; Katona et al. 1982).

Population estimates and abundance estimates for humpback whales in the north Atlantic presently range from 2,000 - 6,000. A summary of current estimates by region is presented in Table 9. In the Gulf of Maine, the estimate for humpback whales based on minimum count (fluke identification technique) ranges from approximately 200-300 individuals (Katona et al. 1984). Abundance estimates from aerial surveys (in the Gulf of Maine between 1978-1980 ranged from 0 (winter) to approximately 600 (summer) for data both corrected and uncorrected for dive times (Scott et al. 1981; CETAP 1982). Estimates from shipboard surveys, 1980-85 range between 30 (winter) to approximately 320 (summer and fall) (MBO, unpubl. data). Mayo et al (1985) provide photographs of the flukes of 216 individual whales photographed between 1976 and 1984.

Table 9. Abundance/population estimates for humpback whales in the North Atlantic.

REGION	METHOD	NUMBERS	SOURCES
Newfoundland	Mark-recapture	1,375-2,075	Whitehead 1982
Newfoundland and Labrador	Mark-recapture	1,535-2,720	Whitehead 1982
	Aerial line transect	235-1,242	Hay 1982
Grand Bank	Mark-recpature	900	Whitehead and Glass 1985
Caribbean	Vessel-strip census	2,000-3,000	Whitehead 1982
	Vessel-strip census	1,018	Winn *et al*. 1975
	Mark-recapture	905	Balcomb and Nichols 1978
Northwest Atlantic	Cummulative catch	1,500	Sergeant 1966
	Cummulative catch	4,200-4,400 (Init. pop. est.)	Mitchell and Reeves 1981
	Vessel-strip census	1,259	Mitchell 1973
	Mark-recapture	2,000-6,000	Whitehead 1982
	Mark-recapture	1,010	Katona *et al*. 1980
		3,000-6,000	Katona et *al*.
Shelf waters of the northeastern United States	Aerial line transect (corrected for dive time)	0 (winter) 555 (spring)	CETAP 1982
	Vessel-strip census	31 (Winter) 340 (Fall)	MBO 1980-85

Northern Right Whale Eubalaena glacialis

Status: **Endangered**

The north Atlantic right whale is one of the most endangered large whales in the world. It has been suggested that the north Atlantic had two stocks of right whales. The first, along the eastern North Atlantic, between the Bay of Biscay and the coast of Iceland (Allen 1908), is thought to have disappeared, or nearly so (Reeves and Brownell 1982). The northwest Atlantic stock occurs from Nova Scotia and Newfoundland (Sergeant 1966; Mitchell 1974b, 1974c; Sutcliffe and Brodie 1977; Hay 1985b), into the lower Bay of Fundy (Arnold and Gaskin 1972; Kraus and Prescott 1981, 1982, 1983; Reeves et al. 1983; Kraus et al. 1984;) and throughout the Gulf of Maine south to Cape Cod Bay and the Great South Channel (Watkins and Schevill 1976, 1979, 1982) in the spring and summer. In the winter, right whales occur from Cape Cod Bay (Watkins and Schevill 1976) south to Georgia and Florida (Moore 1953; Layne 1965; Kraus et al. 1984; Kraus 1986) and into the Gulf of Mexico (Moore and Clark 1963; Schmidley 1981).

The movements and habitat requirements for right whales are subjects of interest to several investigators. Between December and March, small numbers of right whales occur in waters of the Gulf of Maine and western Georges Bank. Another wintering ground for this species occurs in the Georgia-Florida Bight where possibly newborn calves have been observed (Kraus et al. 1984; Kraus 1986). Approximately 10-20 right whales are sighted annually at this location (Fig. 10). Identification of individuals based on callosity patterns on the head of these right whales (Watkins and Schevill 1982; Payne et al. 1983), has linked this wintering group with those whales that move into the Gulf of Maine - lower Bay of Fundy during the spring and summer (see Fig. 10 from Kraus et al. 1984). In the spring, right whale concentrations in the Gulf of Maine occur principally in three locations, the Great South Channel, Cape Cod Bay north to Jeffreys Ledge, and the northern Gulf of Maine - lower Bay of Fundy (see Figs. 11a-e). A few right whales have been reported in Massachusetts waters through the summer, however most of the population spends the summer and fall in the Bay of Fundy and on the Scotian Shelf (Kraus et al. 1984; Kraus 1986). Movements of individual right whales within the Gulf of Maine have been well documented (see Fig. 12 from Kraus et al. 1984).

Right whales feed almost exclusively on copepods and euphausids. Surface feeding or "skimming" is frequently observed in the Gulf of Maine and Cape Cod Bay (Watkins and Schevill 1976; Mayo et al., this report). Feeding whales follow an erratic path when observed from the air or plotted against plankton patches and can be seen to follow "discrete patches of plankton" (Watkins and Schevill 1976, 1979; Mayo et al., this report). Watkins and Schevill (1976) suggest that subsurface feeding is the more typical feeding mode, rather than surface "skimming". Prey items of right whales in the Gulf of Maine and Cape Cod Bay include Calanus finmarchicus and Thysanoessa inermis and juvenile euphausids (Allen 1916; Watkins and Schevill 1976).

Right whales have been protected from commercial hunting since 1935; however "best estimates" for the north Atlantic population are no more than a few hundred (Mitchell 1973a, 1974b; Winn et al. 1981). The largest single sighting (70-100 whales) occurred in 1970 in Cape Cod Bay (Watkins and Schevill 1982). Much of the entire northwest Atlantic population likely moves through the Gulf of Maine on a seasonal basis. Estimates from shipboard surveys for the Gulf of Maine (MBO 1980-85) range from 0 in winter and fall, to 14 in summer and 166 in spring (Table 10).

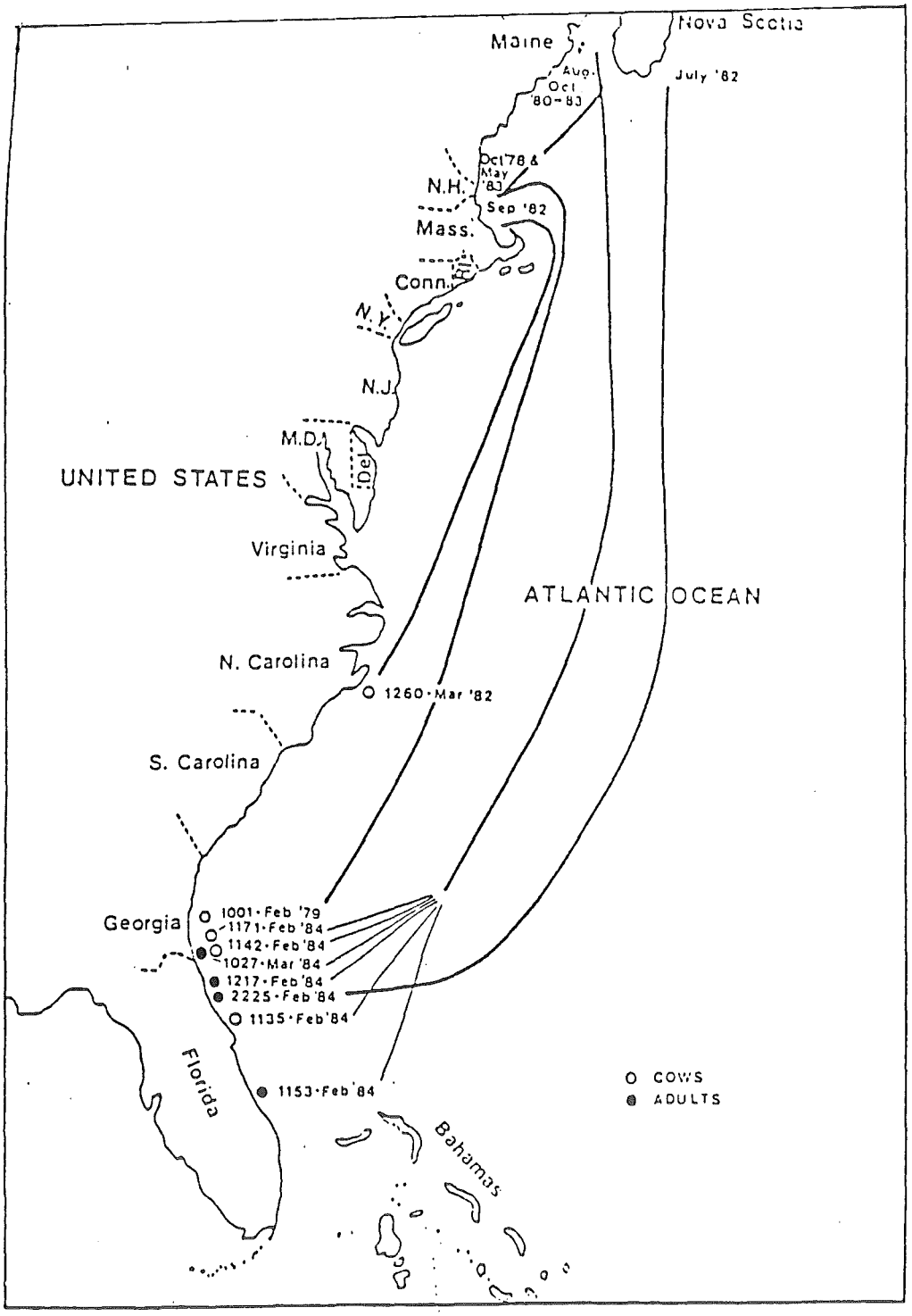
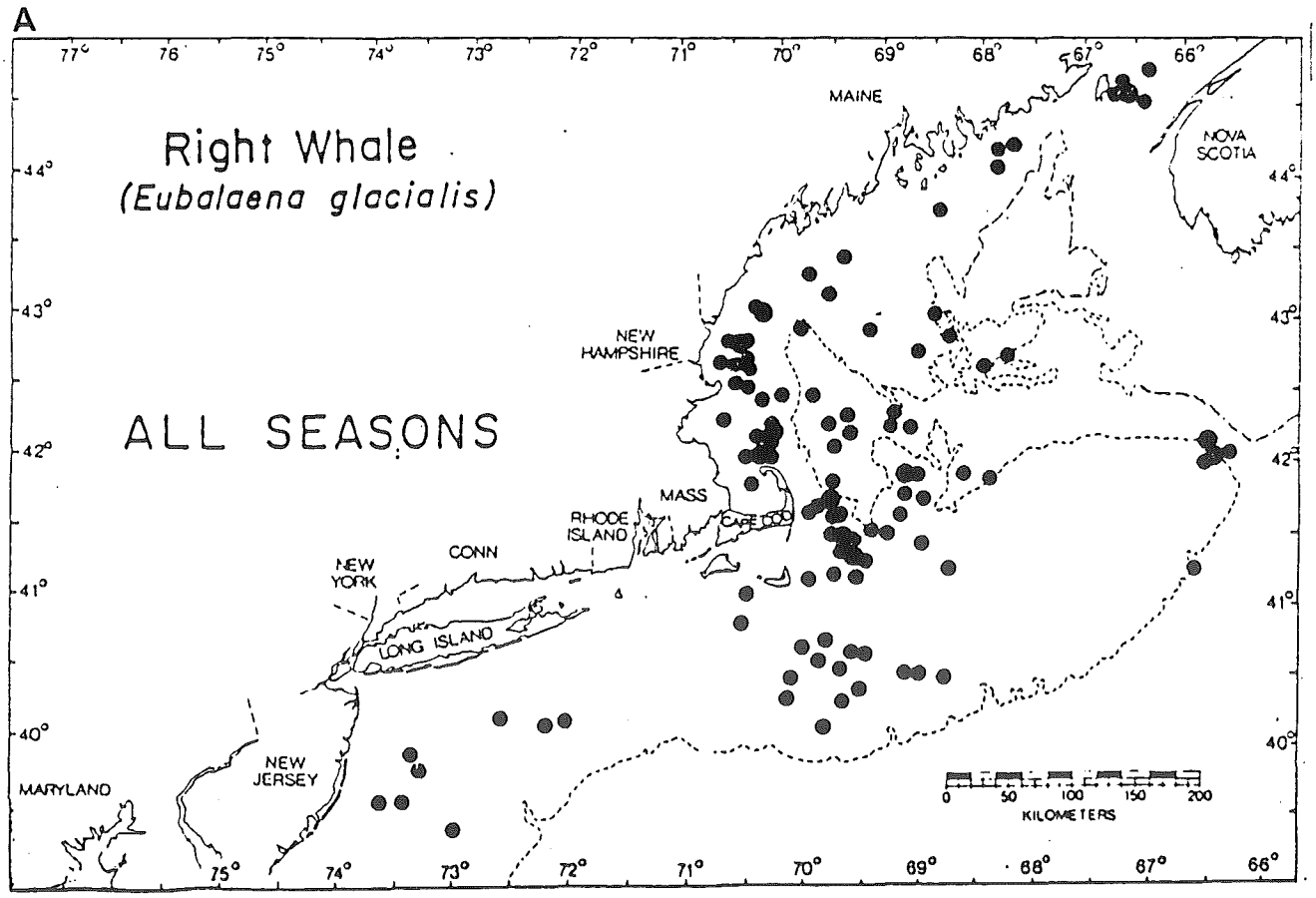


Figure 10. Long distance resightings of right whales in the western North Atlantic 1978-1984 (From Kraus et al. 1984).

Figure 11. Relative distribution and abundance of right whales in the Gulf of Maine, including Georges Bank (north of 40°00'N latitude) by season.



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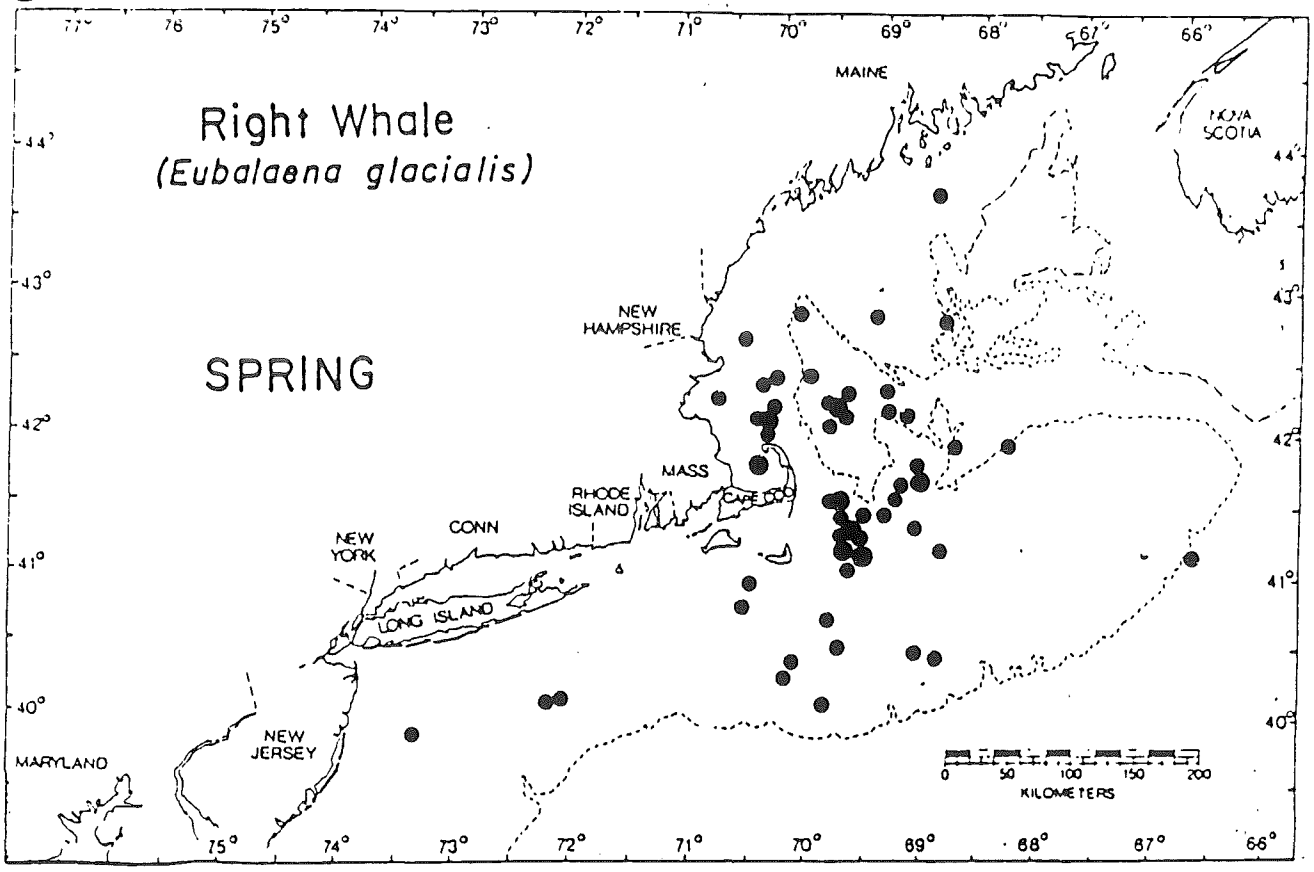
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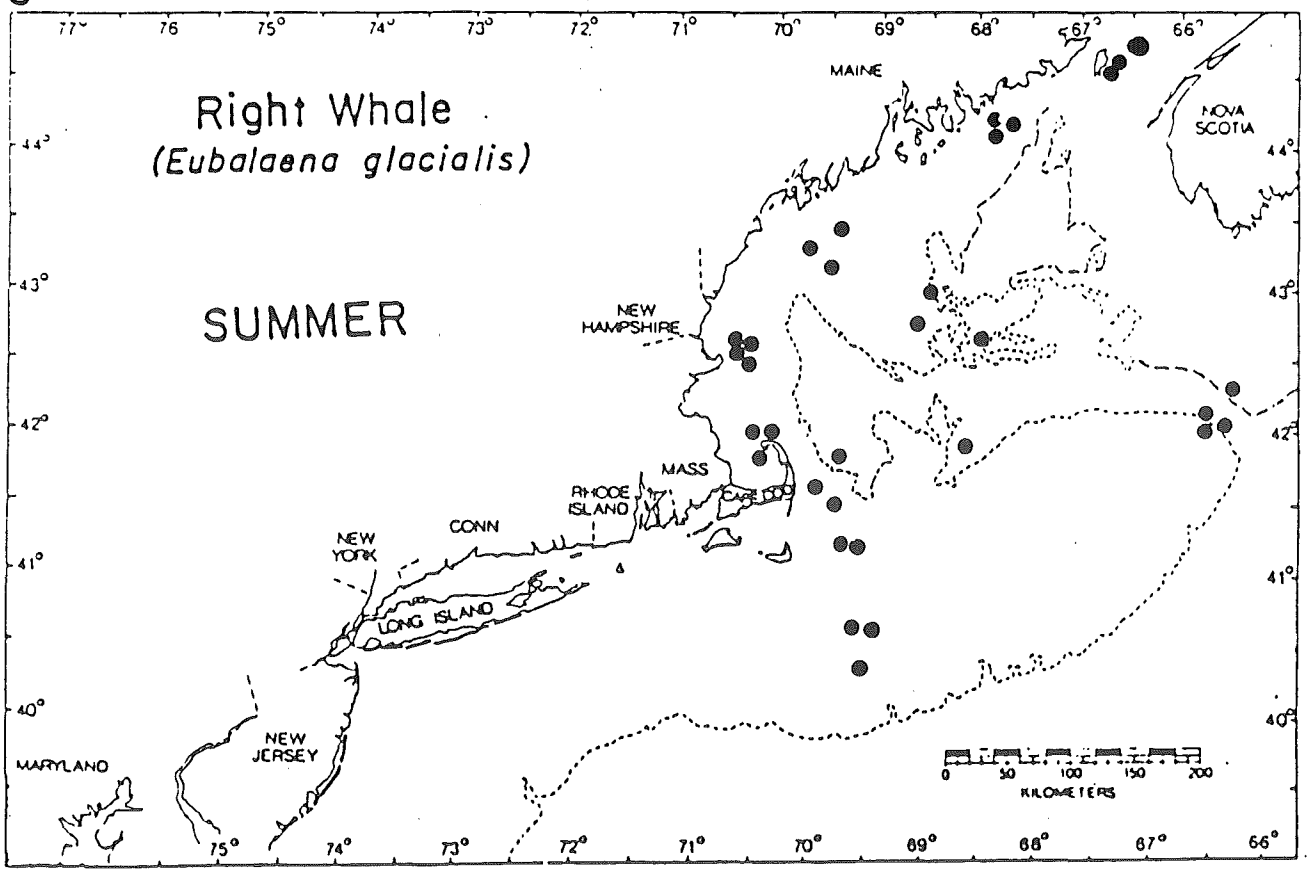
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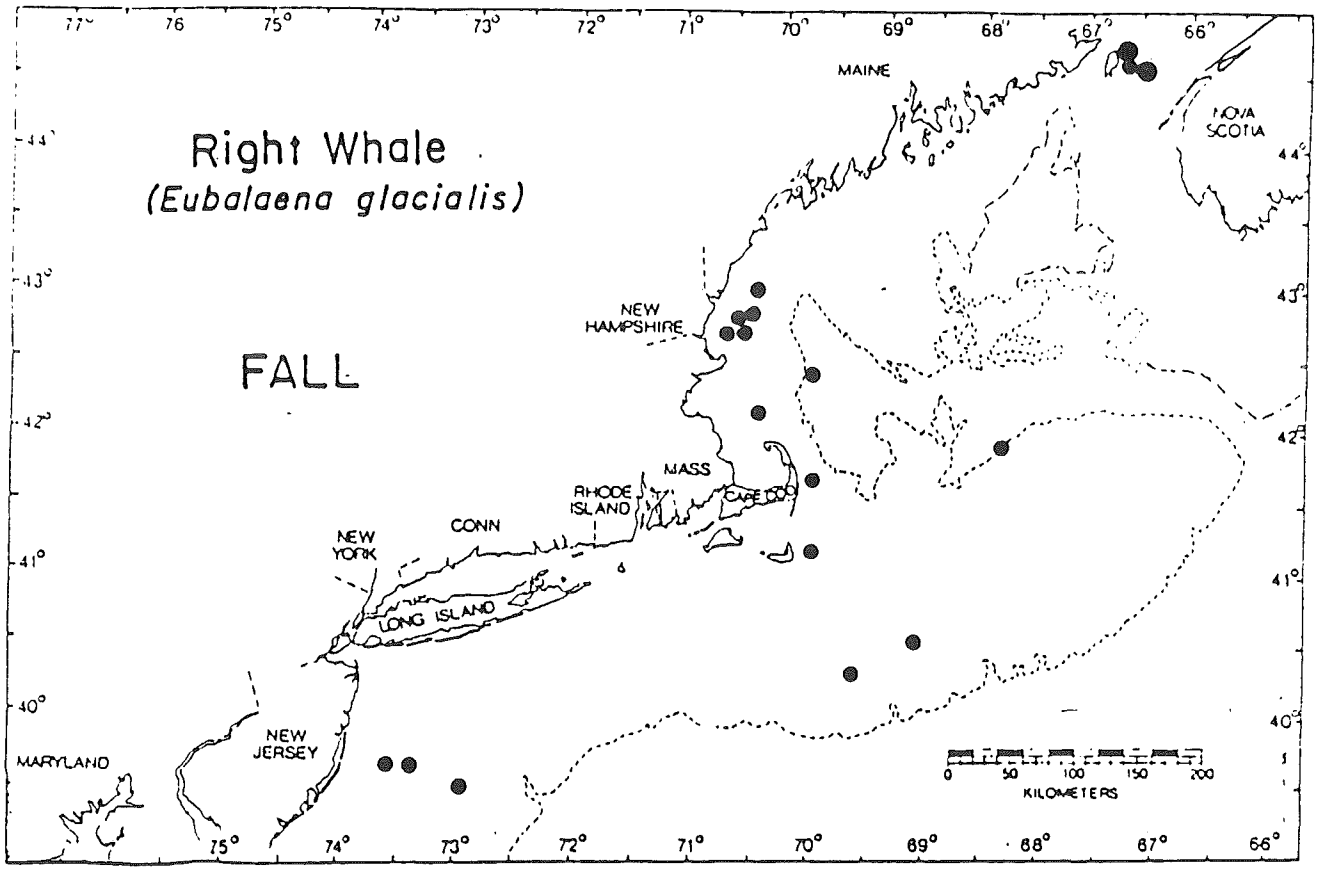
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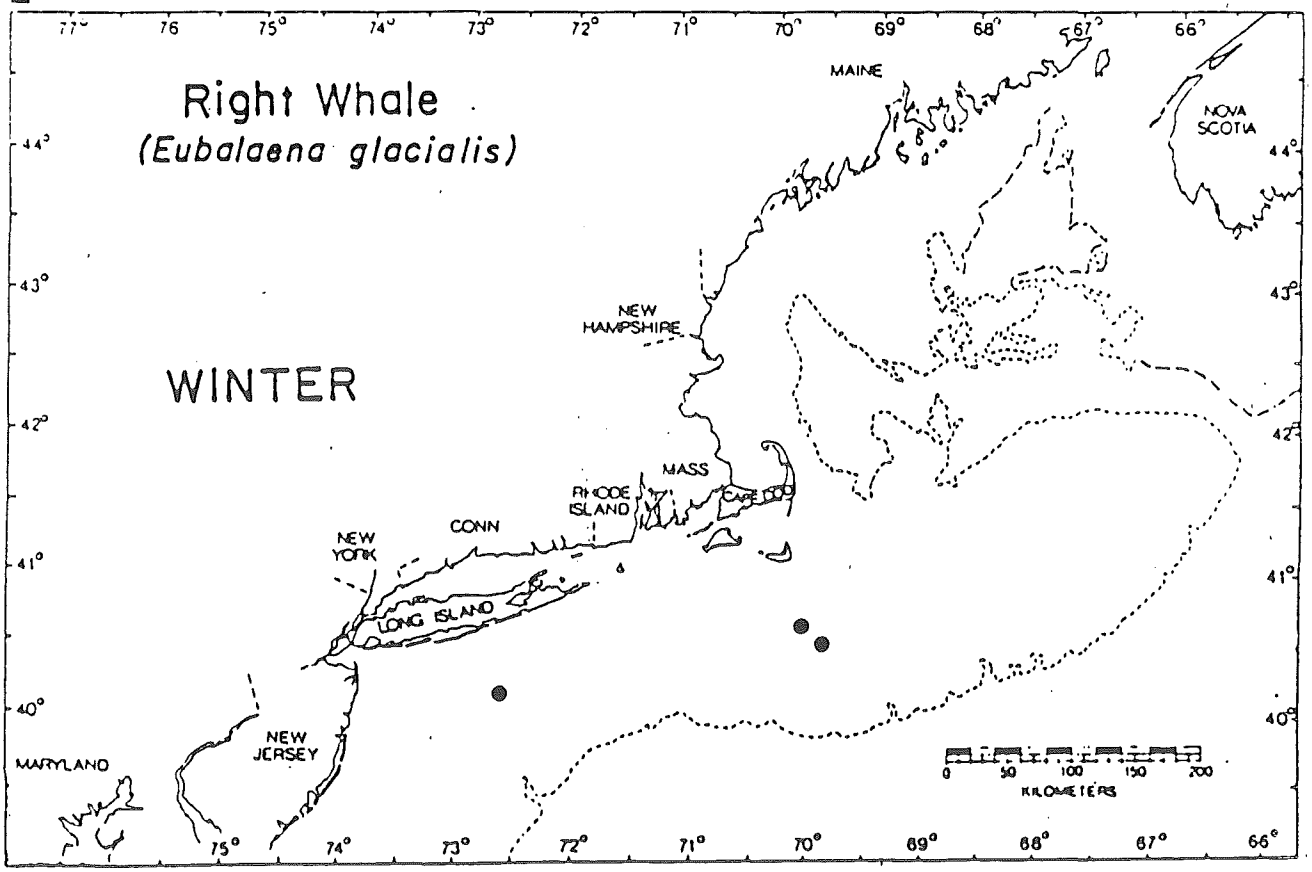
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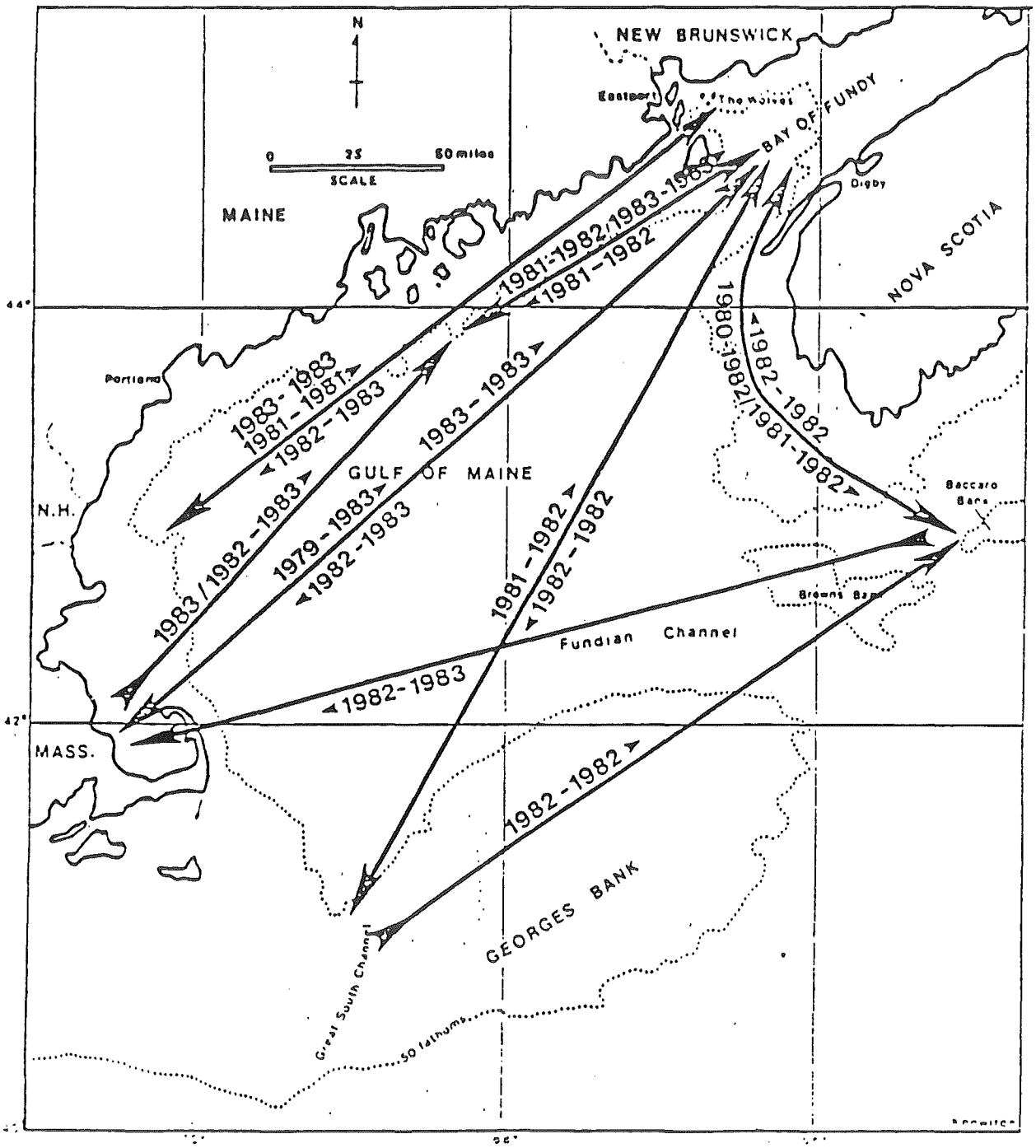


Figure 12. Right whale resightings within the greater Gulf of Maine, 1979-1983 (from Kraus et al. 1984).

Table 10. Abundance/population estimates for right whales in the North Atlantic.

REGION	METHOD	NUMBERS	SOURCES
Bay of Fundy	Aerial line transect	16-25	Kraus and Prescott 1983
	Mark-recapture	69	Kraus and Prescott 1983
Browns Bank	Aerial line transect	21	Kraus and Prescott 1983
	Mark-recapture	42	Kraus and Prescott 1983
	Aerial line transect	46	Stone, 1980
U.S. Shelf Waters	Aerial line transect	432	CETAP, 1982
Northwest Atlantic	Mark-recapture	200	New England Aquarium catalogue
	Aerial line transect	21-418	Winn et al. 1981
Gulf of Maine	Vessel-strip census	0 (winter) 105 (spring)	MBO, this report MBO, this report
	Aerial line transect (corrected for dive time)	0 (winter) 392 (spring)	CETAP 1982 CETAP 1982

Sperm Whale Physeter macrocephalus

Status: **Endangered**

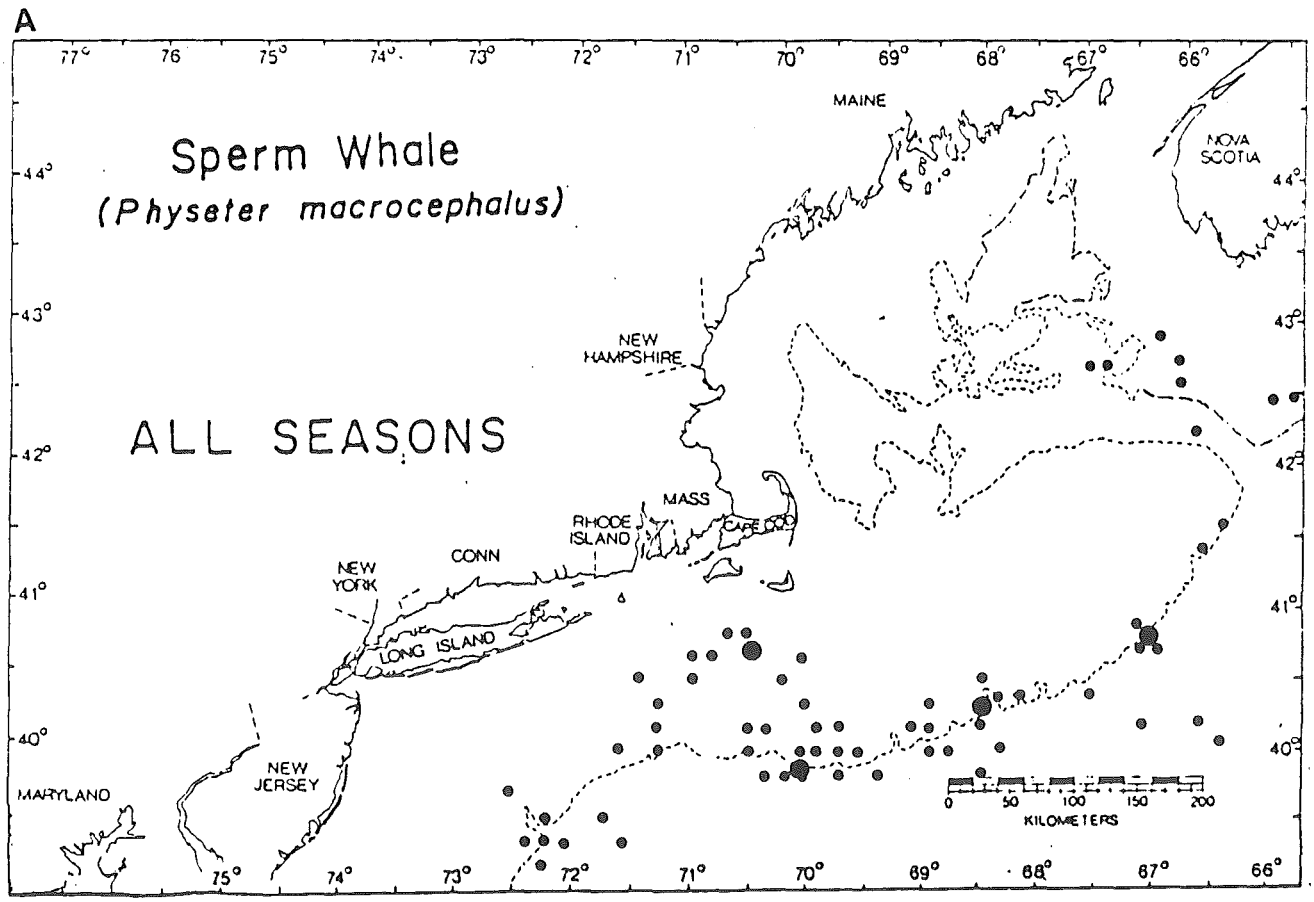
The sperm whale is widely distributed throughout the deep waters of the north Atlantic between 30°00' and 60°00'N latitudes (Brown 1958). Several discrete stocks have been suggested within this range (Mitchell 1974a); however a male tagged off the southeast end of Browns Bank, Nova Scotia in 1966 was killed in the commercial fishery off Spain in 1973 (Mitchell 1975). Most of the whales north of 40°00'N latitude are large males that migrate along the continental shelf edge of eastern North America, from Georges Bank along the Scotian Shelf to the Grand Banks, up to Labrador and Hudson Strait, and then offshore into Davis Strait (Katona et al. 1977; Mitchell and Kozicki 1984). In the northwest Atlantic, sperm whales were fished commercially off Labrador/Newfoundland (Mitchell 1975b) and Nova Scotia (Mitchell 1975b; Sutcliffe and Brodie 1977). Traditional whaling grounds also occurred southeast of the Grand Banks, off the Carolinas to the southwest Caribbean (Gunter 1954; Leatherwood et al. 1976) and in the Gulf of Mexico (Fritts and Reynolds 1981).

The distribution of this species off the east coast of the United States generally is along the shelf-edge and seaward into slope waters in all seasons (Figs. 13a-e) (Hain et al. 1981; CETAP 1982). In winter, sperm whales are concentrated east of Cape Hatteras (Fig. 13d) (CETAP 1982). Between May and November, sperm whales move along the shelf edge south of Nantucket and around the perimeter of Georges Bank (Hain et al. 1981; CETAP 1982; Payne et al. 1984). Within the Gulf of Maine in the fall, occasional sightings occur in the deepwater Northeast Channel between Georges and Browns Bank (Fig. 13d). These on-shelf sightings are temporally related to intrusions of warm,slope water onto the shelf, as well as to movements of squid into shallower shelf waters. Sporadic sightings and strandings occur within the Gulf of Maine, including Cape Cod waters (Katona et al. 1983).

Sperm whales feed primarily on squid (Caldwell et al. 1966; Gambell 1972), mainly deepwater species (Katona et al. 1977). Deep sea fishes and octopus are also taken occasionally (Leatherwood et al. 1976). Within the Gulf of Maine, sperm whales likely feed on the short-finned Illex illecebrosus and the long-finned squid Loligo pealei.

Braham (1984) estimates the North Atlantic stock to be 99,500. Estimates of sperm whale abundance within the Gulf of Maine (Scott et al. 1981; CETAP 1982; MBO, unpublished) are less than 100 individuals. The deeper, central portions of the Gulf of Maine, including Massachsuetts Bay and Cape Cod Bay are considered marginal habitat for this species.

Figure 13. Relative distribution and abundance of sperm whales in the Gulf of Maine, including Georges Bank (north of 40°00'N latitude) by season.



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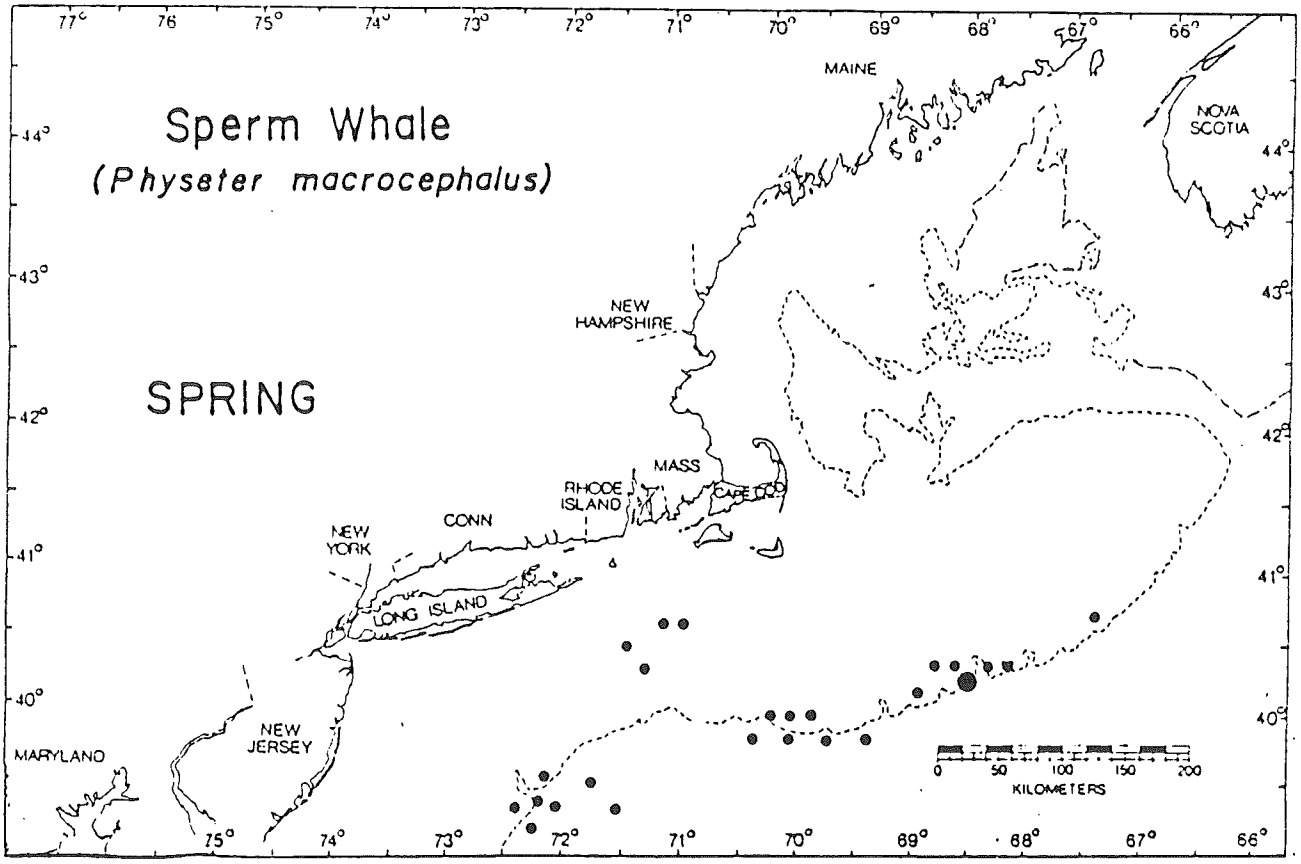
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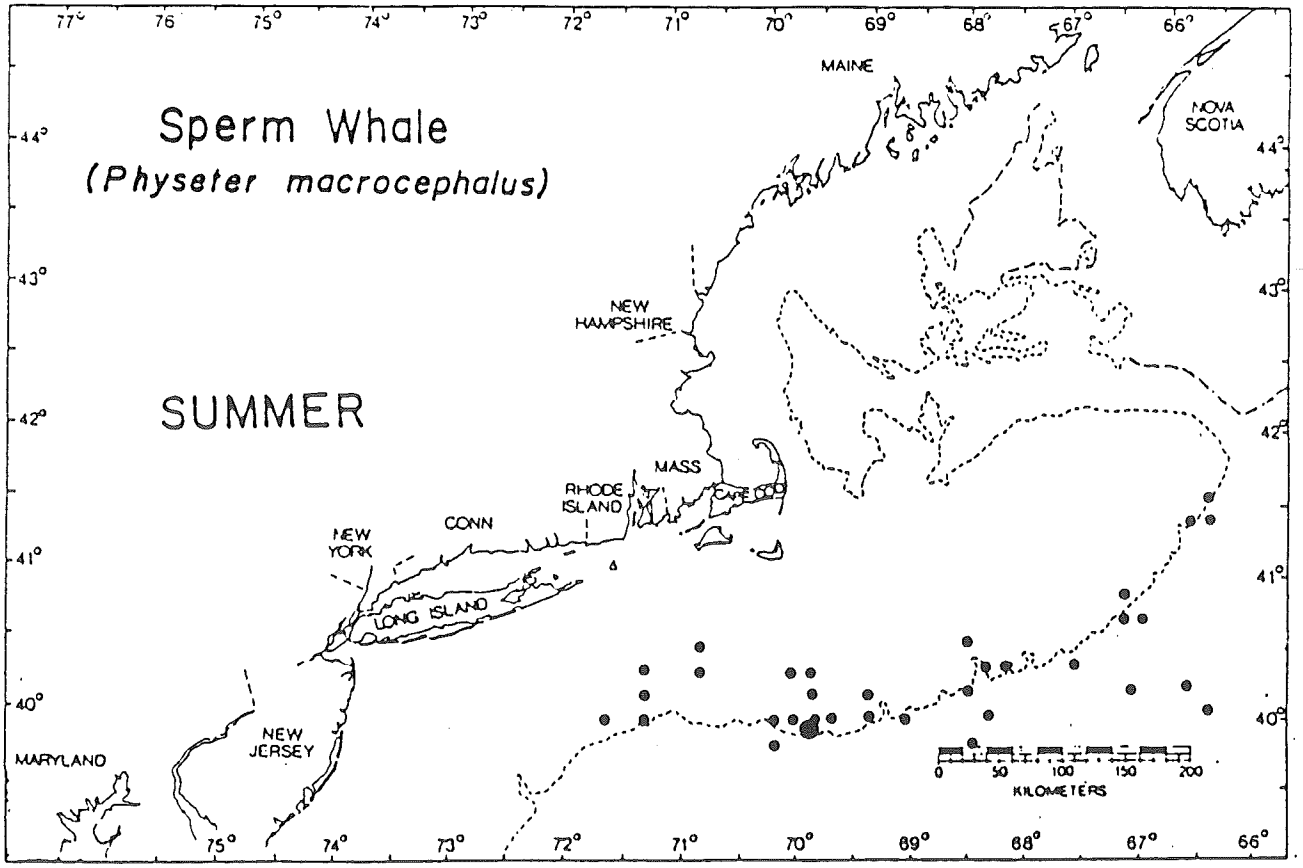
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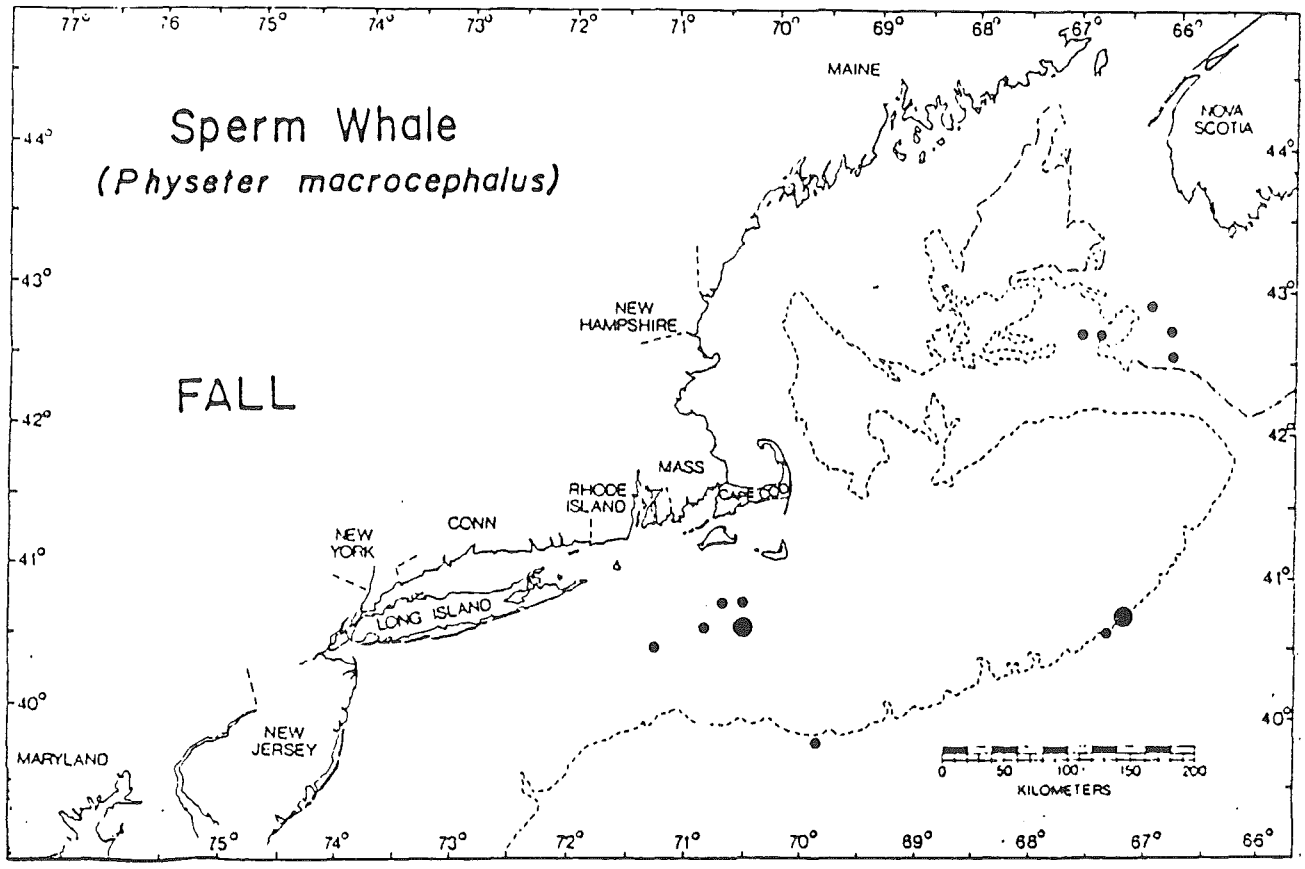
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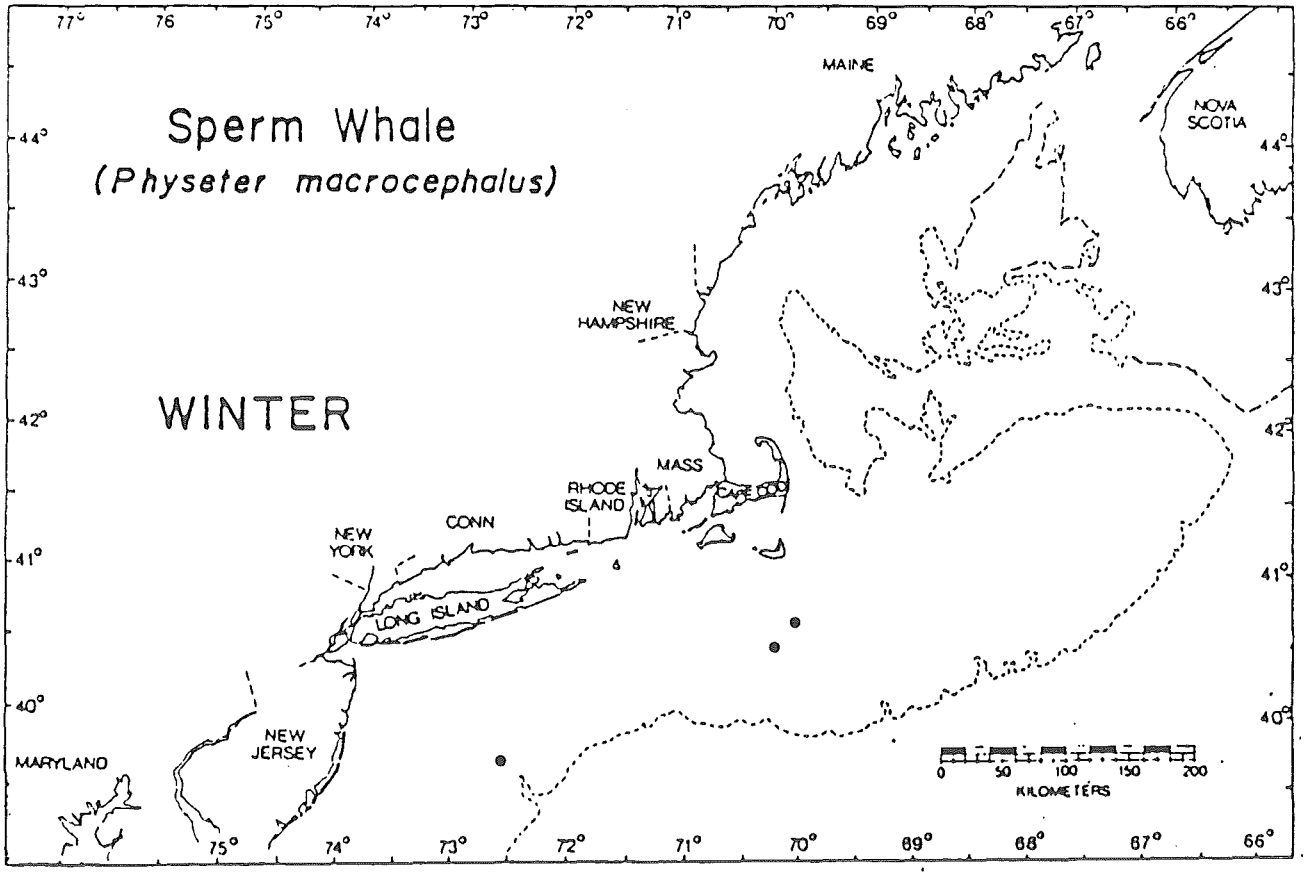
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MARINE TURTLES

Until recently, the distributions of marine turtles off the northeastern United States were known primarily from strandings and reports of opportunisitic sightings at sea (Babcock 1919, Bleakney 1965, Lazell 1976). The first comprehensive study of the spatial and temporal distribution and abundance of sea turtles in this area was conducted by CETAP (Shoop et al. 1981). There are four members of the family Cheloniidae present in our study area: loggerhead Caretta caretta , Atlantic Ridleys Lepidochelys kempi , hawksbill Eretmochelys imbricata , and green turtle Chelonia mydas . The leatherback turtle Dermochelys coriacea (Family Dermochelyidae) is a fifth turtle species found in our study area. Predation on eggs and hatchlings, human disturbance on nesting beaches (McFarlane 1963), excessive demand for turtle products, trawl entanglement, and consumption by local fishermen are all reasons for their current threatened or endangered status (Nat'l. Fish and Wildl. Laboratory 1980a, 1980b, 1980c, 1980d).

Marine turtles feed at several trophic levels from herbivore to tertiary carnivores. With the exception of D. coriacea, marine turtles feed mostly on the bottom and forage close to shores and reefs, generally in waters less than 60 m deep (Shoop et al. 1981). C. mydas is mostly herbivorous, feeding on marine algae and marine grasses (Carr 1952, Nat'l. Fish and Wildl. Laboratory 1980a), although small invertebrates are also consumed (Nat'l. Fish and Wildl. Laboratory 1980a). L. Kempi, E. imbricata and C. caretta are omnivorous and feed on a wide variety of invertebrates, algae and fish scraps discarded by fishing vessels. The hawksbill turtle prefers the sponge Geodia gibberosa (Nat'l Fish and Wildl. Laboratory 1980b), whereas the diet of the Atlantic Ridleys turtle consists mostly of crabs Arenaeus, Callinectes, Calappa, and Hepatus (Nat'l. Fish and Wildl. Laboratory 1980c). Leatherback turtles are open water or pelagic carnivores feeding principally on jellyfish (Carr 1952, Nat'l. Fish and Wildl. Laboratory 1980d) and favor Cyanea in the Gulf of Maine (Lazell 1976).

SPECIES ACCOUNT

Loggerhead Turtle Caretta caretta

Status: **ENDANGERED**

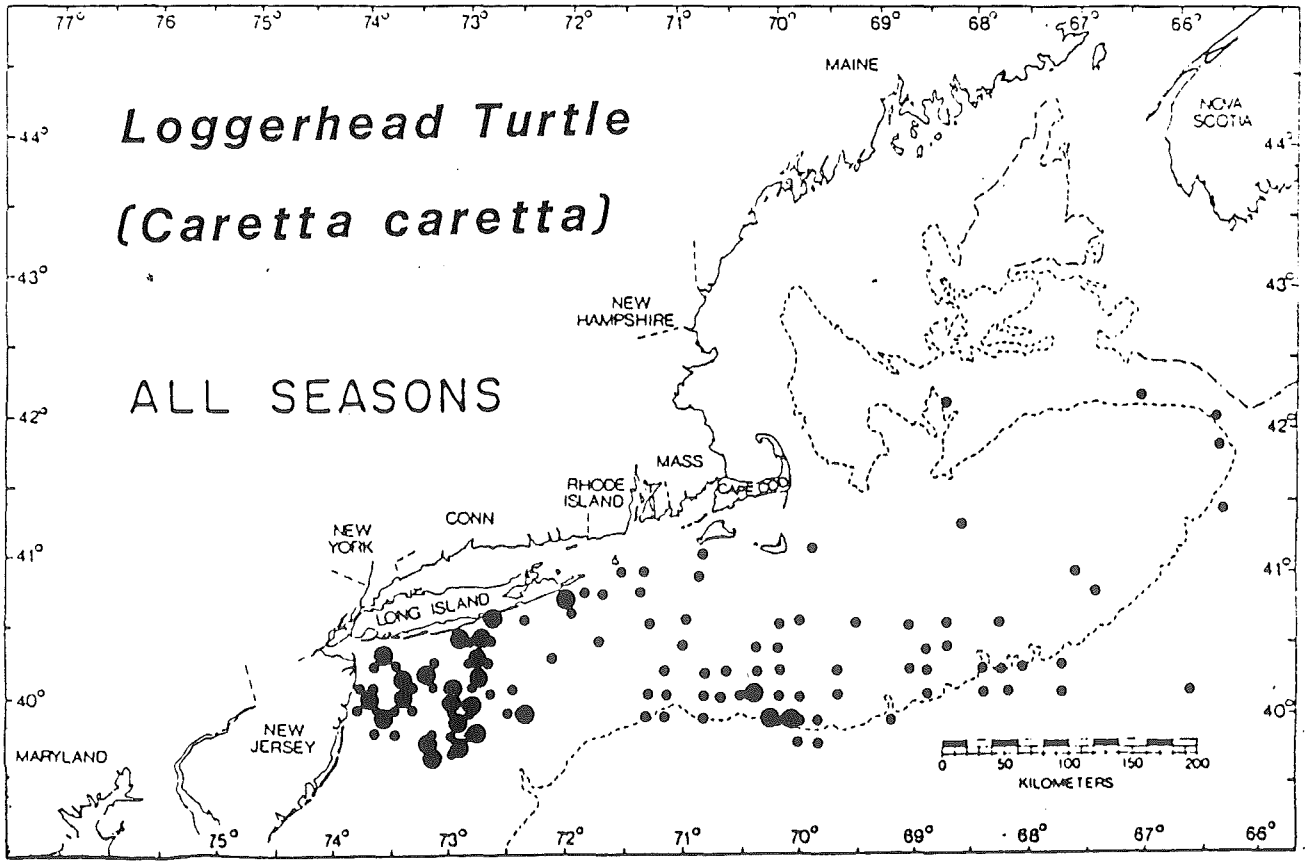
The loggerhead turtle is the most widespread and numerous sea turtle along the eastern seaboard (CETAP 1982; Payne and Ross 1986). Its range during the winter and early spring is south of 37°00'N latitude on estuarine rivers, coastal bays and shelf waters of the southeastern United States. Their distribution is the most restricted during the winter months (sightings generally occur south of Cape Hatteras), prior to spring and early summer nesting. Their distribution is most widespread in summer and fall coinciding with a northward dispersal phase which follows the peak nesting period (at this time sightings occur throughout shelf waters north to Massachusetts). Their offshore distribution (beyond the edge of the continental shelf) in summer also extends north along the eastern United States to appproximately 42°00'N latitude (Fig. 14).

Loggerheads are generally absent in shelf waters north of Cape Cod, including Cape Cod Bay and the Gulf of Maine. Prolonged exposure to water temperatures lower than 10-15°C may cause dormancy, cold-stunning or death. The northward dispersal following nesting results in limited sightings along outer Cape Cod and the islands mid-summer through fall. Sporadically loggerheads become trapped inside Cape Cod Bay in late-fall and winter, resulting in cold-stunning and death. Generally, Massachusetts is at the northern range limit for this species, therefore these waters are considered marginal habitat (Payne and Ross 1986).

Figure 14. Relative distribution and abundance of loggerhead turtles in the Gulf of Maine, including Georges Bank (north of 40000'N latitude) for all seasons.

Relative Abundance
cetaceans per 10'x10' block

- 1 - 9
- 10-99
- >100



Atlantic Ridleys Turtle Lepidochelys kempi

Status: **ENDANGERED**

The Ridleys sea turtle has the most restricted breeding range of any sea turtle, nesting within a few hundred miles of Rancho Nuevo on the southern coast of Tamaulipas, Mexico (National Fish and Wildlife Lab. 1980c). Their adult life is spent in the Gulf of Mexico; however, as juveniles they appear as far north as New England either by actively swimming or drifting in the Gulf Stream (Lazell 1976; Shoop 1980; Prescott 1986). Juvenile Ridleys which turn up in Massachusetts generally are 10" to 12" long and weigh up to seven pounds (Prescott 1986). Waters off southern New England are important feeding areas for Ridleys turtles and are considered important habitat for this species (Lazell 1980). Each fall as water temperatures drop in Cape Cod Bay between 12 and 30 immature Ridleys strand on Cape Cod (Prescott 1986).

Green Turtle Chelonia mydas

Status: **ENDANGERED**

Green turtles are found worldwide in waters warmer than 20°C, although juveniles sometimes are found in cooler waters (Nat'l. Fish and Wildlife Laboratory 1980a). Green turtles are rare summer stragglers as far north as Cape Cod Bay (CETAP 1982; Shoop and Ruckdeschel 1986a). Individuals in Massachusetts waters are usually juvenile and probably from the endangered Florida breeding population. Gulf of Maine sightings are extremely rare (CETAP 1982).

Hawksbill Turtle Eretmocheyls imbricata

Status: **ENDANGERED**

The Hawksbill turtle is scattered throughout the world's tropical oceans, though it is infrequently observed north of Florida on the Atlantic coast. A single juvenile carapace, presumably from somewhere on Cape Cod, is the only museum record of this species for New England (Shoop and Ruckdeschel 1986b). They are considered absent from Gulf of Maine waters, including Cape Cod Bay.

Leatherback Turtle Dermochelys coriacea

Status: **ENDANGERED**

The leatherback is the largest and most distinctive of the sea turtles. It is widespread in the oceans of the world (Nat'l. Fish and Wildlife Laboratory 1980d). Leatherbacks nest on tropical beaches, after which, the adults move into temperate waters to feed. This is the second most common turtle along the eastern seaboard of the United States, and the most common north of 40°00'N latitude (Gulf of Maine, including Georges Bank and Cape Cod Bay).

The leatherback is a strongly pelagic species. The large flippers and streamlined body allow prolonged, fast swimming. Their large body size and a special arrangement of blood vessels in the skin and flippers enable them to retain heat generated during swimming. Leatherbacks maintain body temperatures several degrees above the temperature of the surrounding water, facilitating their travel to cool temperate waters where food is abundant.

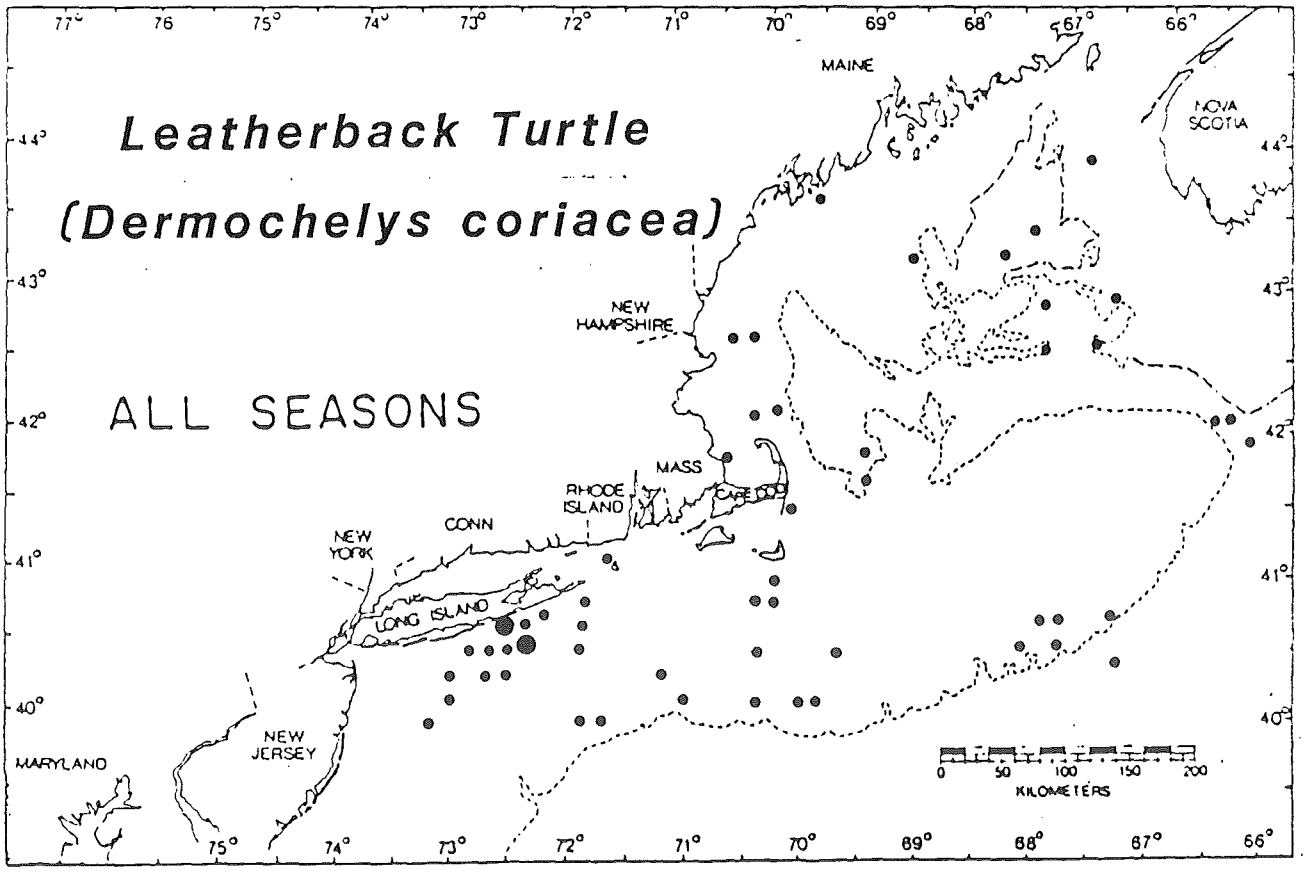
However, their physiological adaptations to pelagic life make leatherbacks poorly suited to deal with obstructions in shallow waters. They regularly become engangled in fishing nets and lobster pot lines. Leatherbacks possess a limited ability to maneuver and cannot swim backward to disentangle themselves. Leatherbacks are reported to have died of intestinal blockage after eating floating plastic bags, which they presumably mistake for jellyfish, their desired prey. They are also occasionally killed by collisions with boats.

Adults migrate extensively throughout the Atlantic basin. There are numerous records of leatherbacks in New England and as far north as Nova Scotia (Fig. 15) and Newfoundland (Ross 1986). Sightings off Massachusetts are most common in the late summer months (July - September) (Shoop et al. 1981, CETAP 1982), and the leatherbacks seen here are usually of adult size. The leatherback's seasonal migration is the reverse of that of the Loggerhead. Leatherback turtles move northward beyond the shelf-break, possibly to within the Gulf Stream; therefore there are few sightings in the spring months (CETAP 1982). They first appear in the Gulf of Maine (north of 42°00'N latitude) in late May to June, and from 42°00'N to approximately 38°00'N in shelf waters from June through October (Shoop et al. 1981). Sightings of leatherbacks peak during the summer, most in the southern New England coastal regions (CETAP 1982). They are not seen above Cape Hatteras in winter.

Figure 15. Relative distribution and abundance of leatherback turtles in the Gulf of Maine, including Georges Bank (north of 40°00'N latitude) for all seasons.

Relative Abundance
cetaceans per 10'x10' block

- 1 - 9
- 10 - 99
- >100



III. AREAL AND TEMPORAL DISTRIBUTION AND BEHAVIOR OF RARE AND ENDANGERED MARINE MAMMALS AND TURTLES IN WATERS WITHIN AND ADJACENT TO THE FOUL-AREA DISPOSAL SITE (FADS)

M. T. Weinrich, L. A. Selzer and P. M. Payne

SPECIES ACCOUNTS

Humpback Whales *Megaptera novaeangliae*

Use of the northern Stellwagen waters (including the waters surrounding the FADS) by humpbacks varies both annually and seasonally. Concentrations of whales are greatest in the summer and early fall and lowest in winter and early spring (Figs. 16a-e) with certain exceptions. August 1985, saw little use, although this is a month in which many humpbacks are resident on northern Stellwagen, during 1985. Similarly, spring of 1984 involved a higher than normal abundance of humpbacks.

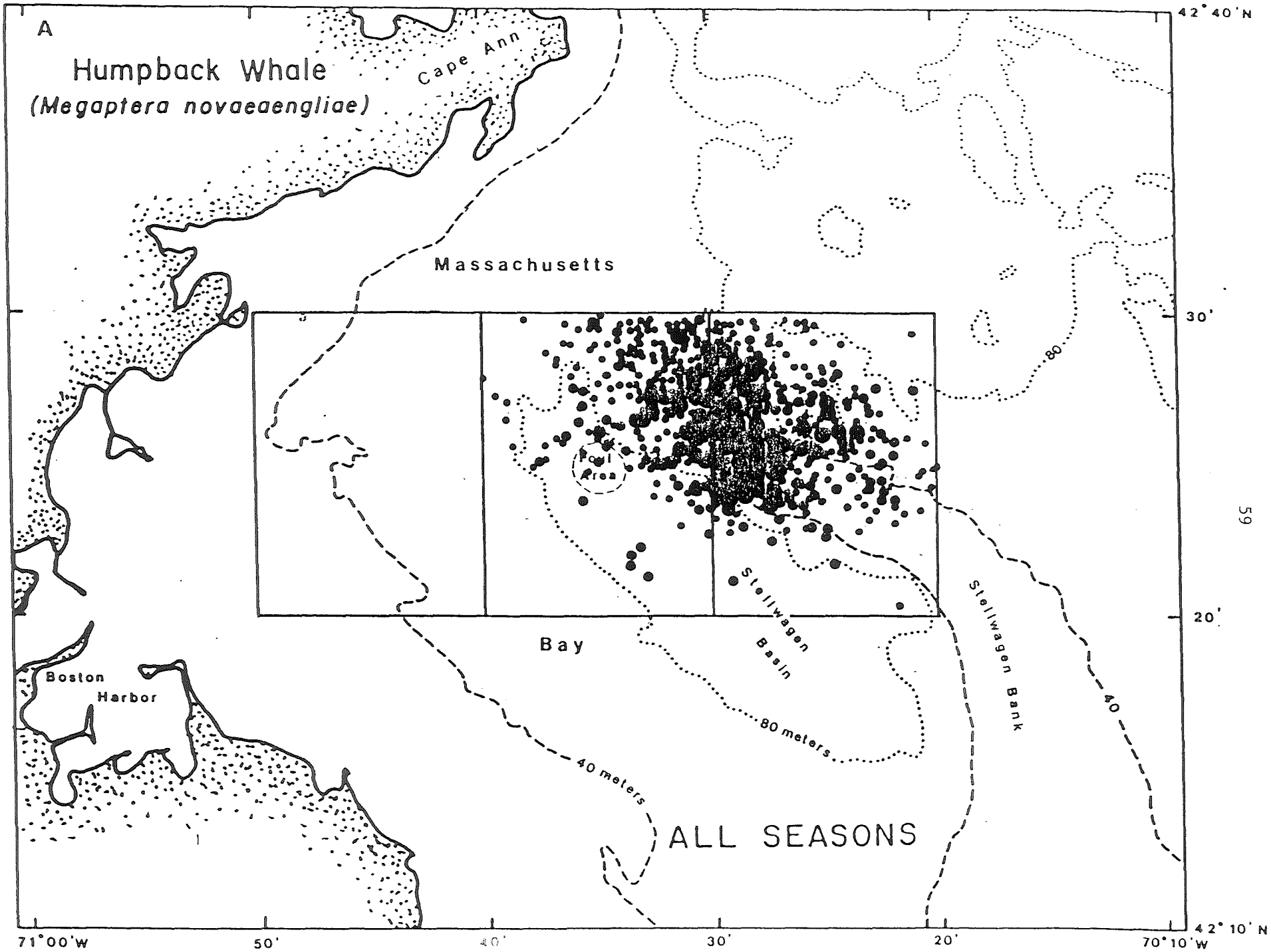
One of the most important uses of Stellwagen Bank by cetaceans is for feeding (Fig. 17). However, the intensity of surface feeding behavior on northern Stellwagen is quite variable. During 1980, 1981, as well as brief periods in 1982 through 1985, feeding on Stellwagen was very active. Groups of up to 100 humpbacks were commonly found feeding on sand eel. Most members of the groups were adults, and most were using the bubble cloud feeding style described by Hain *et al*. (1982) and Mayo *et al* (1985) . Prey, when identified, were sand eel on all but eight observations; those eight involved feeding on dense concentrations of euphausiids. Although humpbacks 1-3 years old were seen surface feeding at times, they were observed feeding much less often than adults. It is the impression of the Cetacean Research Unit (CRU) that these young whales engage in more sub-surface feeding. Feeding was observed less frequently in the immediate vicinity of the FADS than on northern Stellwagen Bank.

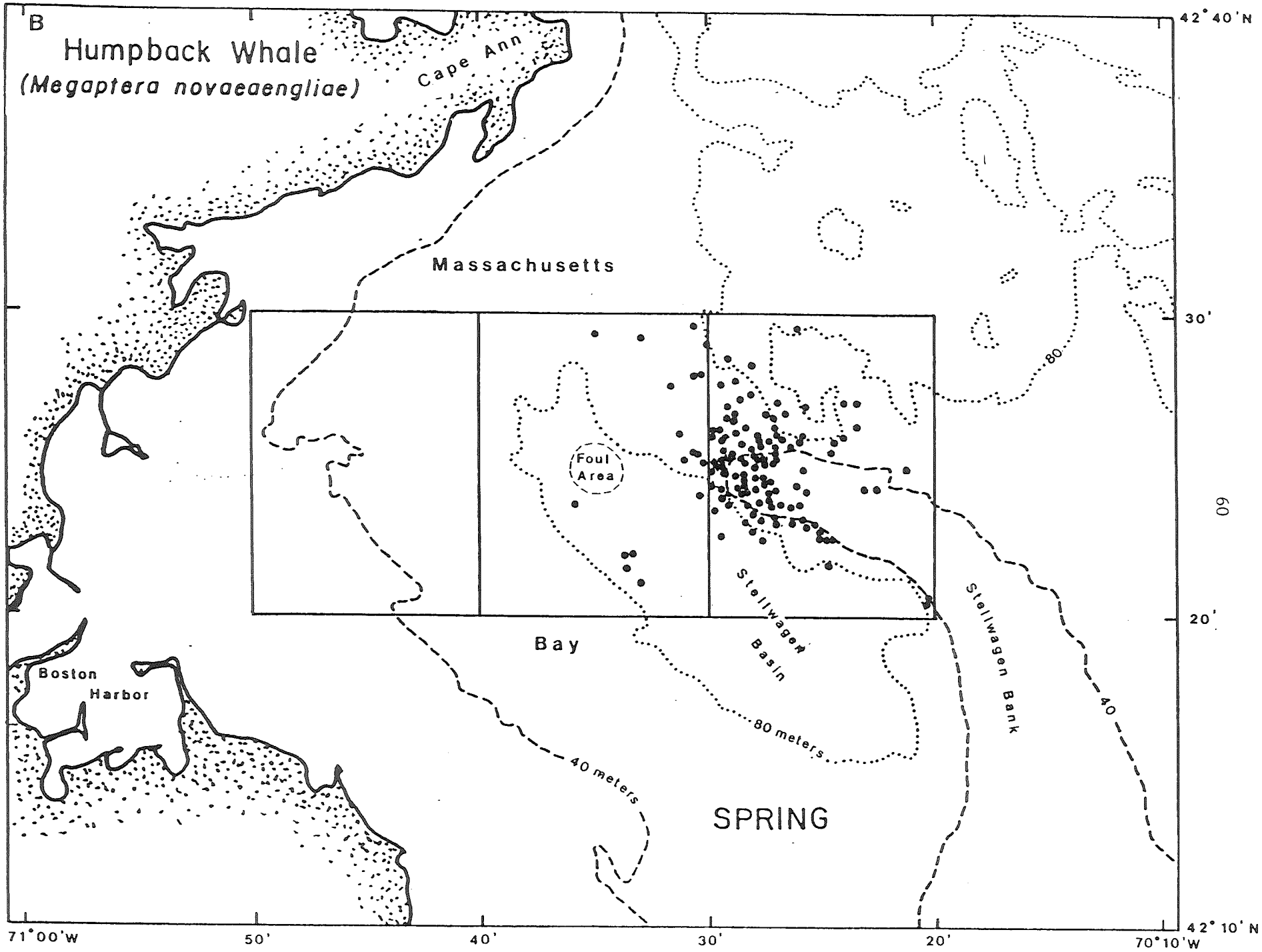
In 1982 and 1983, southern Jeffreys Ledge was the site of similar feeding groups. This area received some use by feeding humpbacks in the fall of 1984 as well.

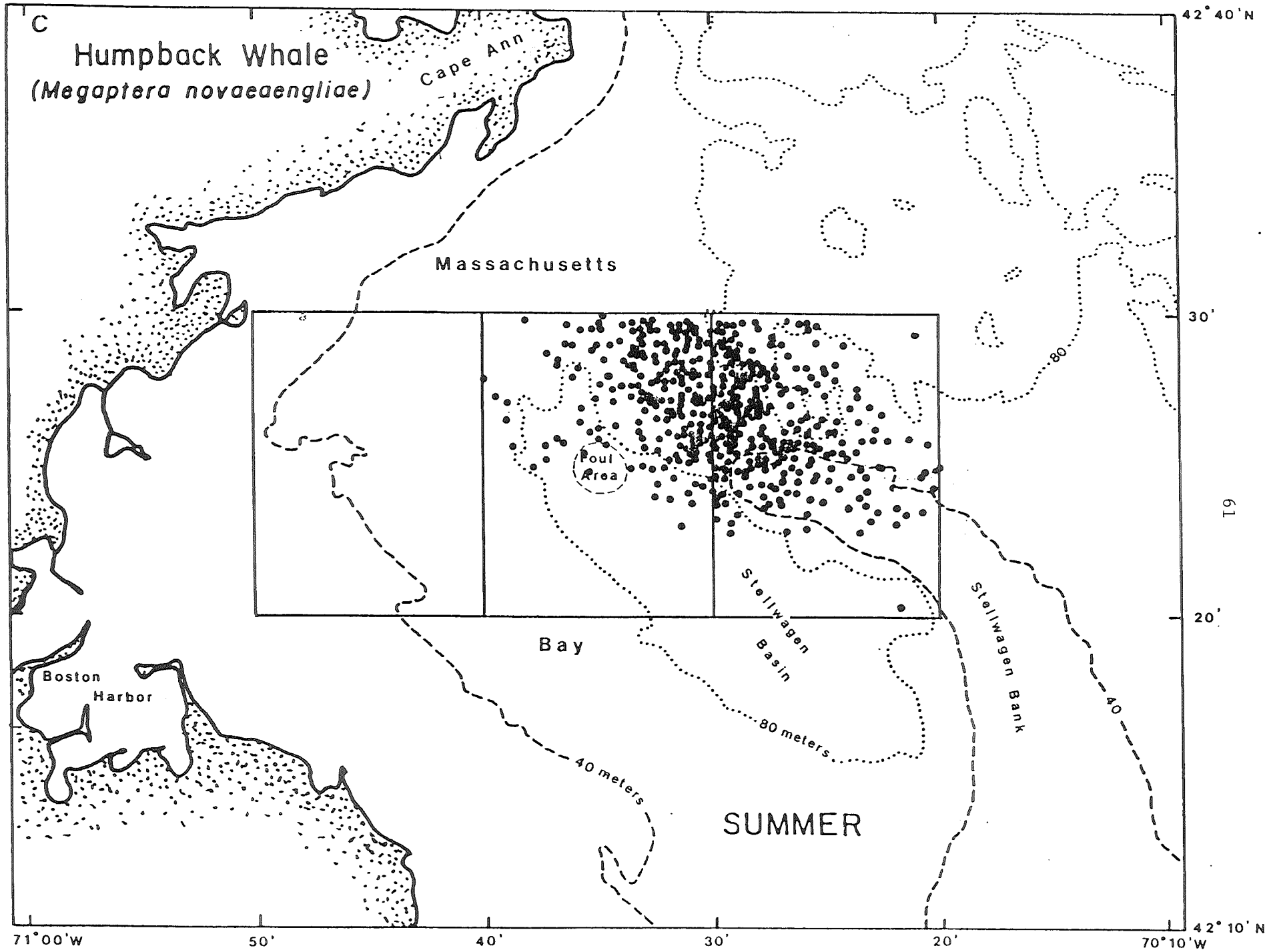
The short-term movements of humpback whales within the northern Stellwagen system appear to be dictated primarily by prey availability. Some locations on Stellwagen consistently receive high use, while other areas in the immediate vicinity of Stellwagen receive high use only periodically. For example, in October of 1985, the immediate area of the FADS was the location where most of the humpbacks in the vicinity were found.

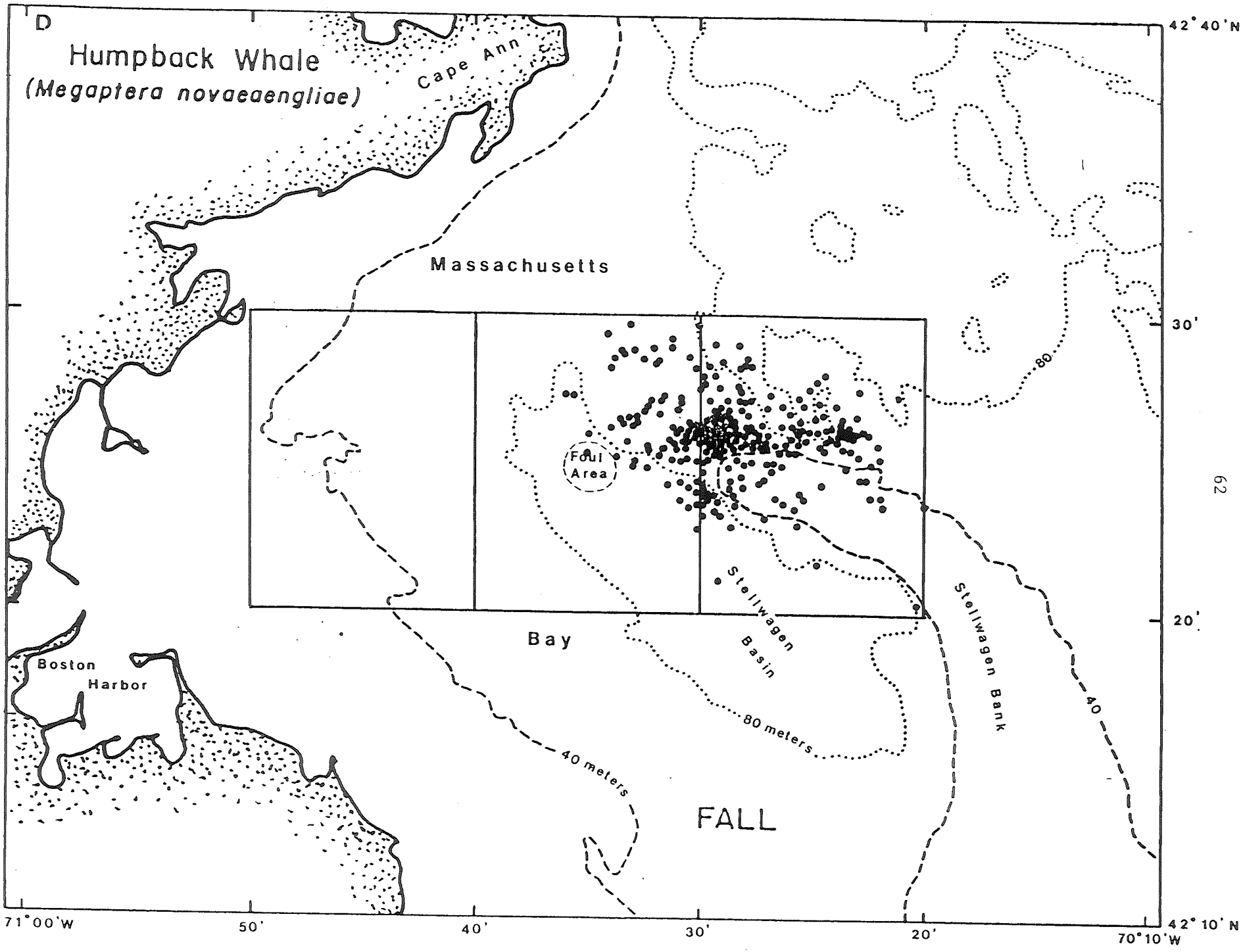
Figure 16. Sightings of the humpback whale within the waters of the Foul-Area Disposal Site study area by season.

Sources: Data from the Cetacean Research Unit; Hain et al. 1981; Payne et al. 1984; MBO unpubl. data, 1985-1986; Gulf of Maine Cetacean Sighting Network 1975-1981.


A
Humpback Whale
(Megaptera novaeaengliae)
Cape Ann
Massachusetts
Bay
Boston
Harbor
Stellwagen
Basin
Stellwagen Bank
80 meters
40 meters
80
40
ALL SEASONS
42° 40' N
30'
20'
42° 10' N
71° 00' W
50'
40'
30'
20'
70° 10' W


B
Humpback Whale
(Megaptera novaeaengliae)
Cape Ann
Massachusetts
Foul Area
Stellwagen Basin
Stellwagen Bank
Bay
Boston Harbor
80
40
80 meters
40 meters
SPRING
42° 40' N
30'
20'
42° 10' N
71° 00' W
50'
40'
30'
20'
70° 10' W


C
Humpback Whale
(Megaptera novaeaengliae)
Cape Ann
Massachusetts
Bay
Boston
Harbor
Poul
Area
Stellwagen
Basin
Stellwagen Bank
80
40
80 meters
40 meters
SUMMER
42° 40' N
30'
20'
42° 10' N
71° 00' W
50'
40'
30'
20'
70° 10' W


D
Humpback Whale
(Megaptera novaeaengliae)
Cape Ann
Massachusetts
Bay
Boston
Harbor
Foul
Area
Stellwagen
Basin
Stellwagen Bank
80
40
80 meters
40 meters
FALL
42°40'N
30'
20'
42°10'N
71°00'W
50'
40'
30'
20'
70°10'W

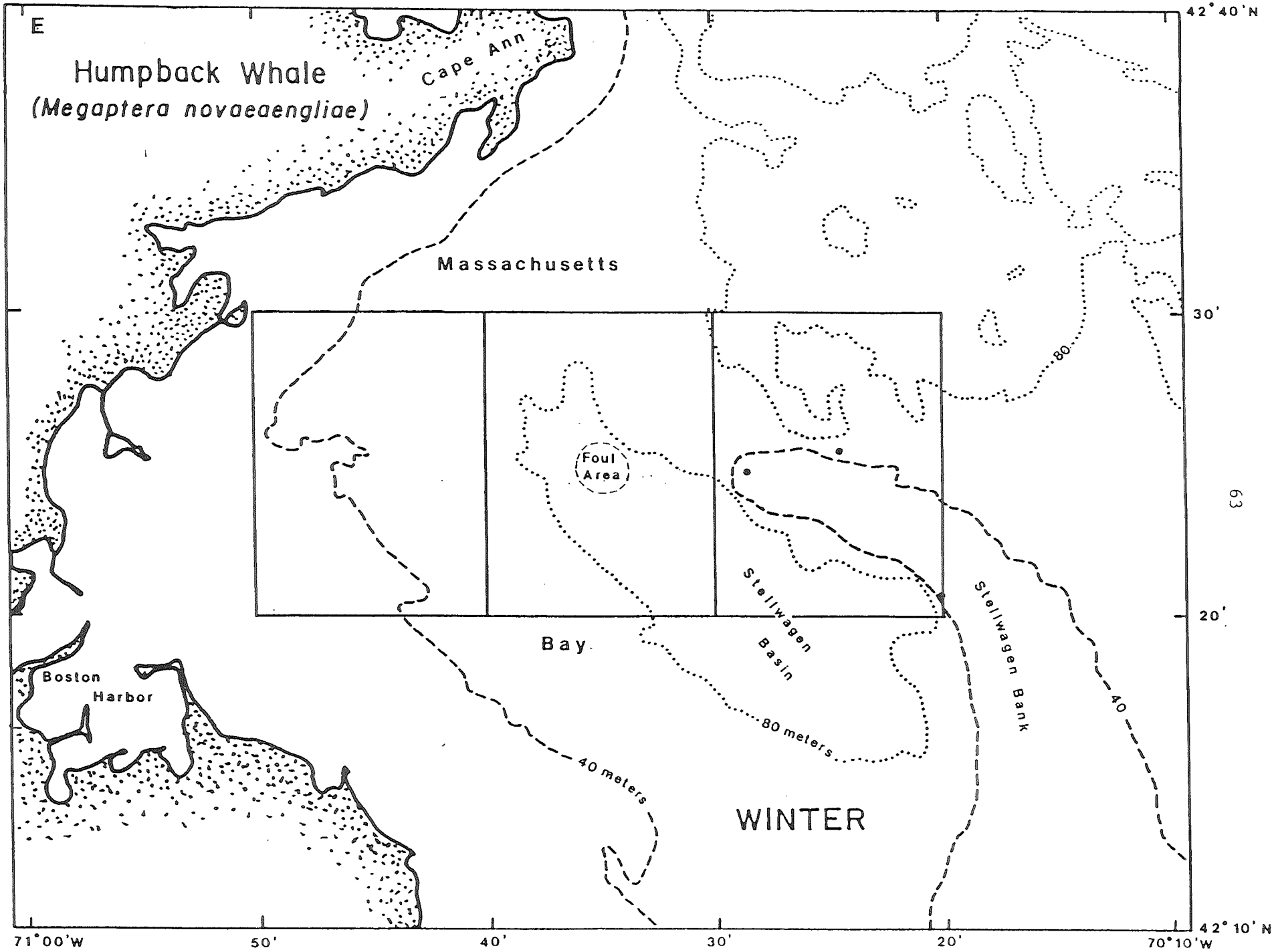
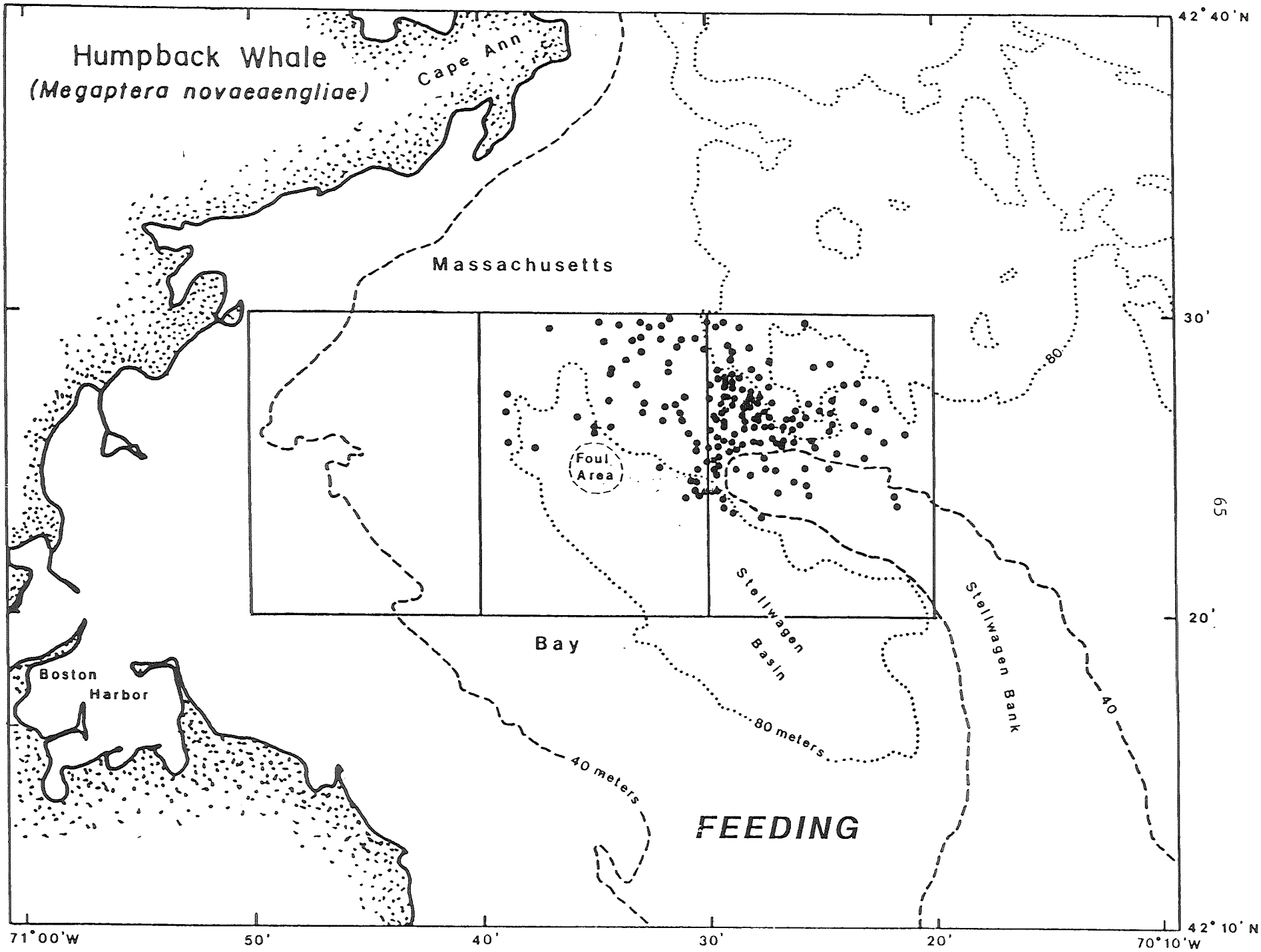

E
Humpback Whale
(Megaptera novaeaengliae)
Cape Ann
Massachusetts
Foul Area
Stellwagen Basin
Stellwagen Bank
Bay
Boston Harbor
80
40
80 meters
40 meters
WINTER
42° 40' N
30'
20'
42° 10' N
71° 00' W
50'
40'
30'
20'
70° 10' W

Figure 17. Sightings of surface-feeding by humpback whales within the waters of the Foul-Area Disposal Site study area for all seasons.


Humpback Whale
(Megaptera novaeaengliae)
Cape Ann
Massachusetts
Bay
Boston
Harbor
Foul
Area
Stellwagen
Basin
Stellwagen Bank
80
40
80 meters
40 meters
FEEDING
42° 40' N
30'
20'
42° 10' N
71° 00' W
50'
40'
30'
20'
70° 10' W

A diurnal pattern was observed for humpbacks of the FADS area which involved a period of daybreak and morning feeding, dispersal, then regrouping again later in the day; however, exceptions to this general pattern are common. This feeding pattern is consistent with the daily grouping patterns of sand eel (Meyer et al. 1979). Mid-day observation periods usually recorded a more dispersed distribution of humpbacks, with more time spent resting or engaging in social behavior.

Different age and sex classes generally use the area at different times. Juveniles (those animals less than four years old) most often are seen in the spring and fall, and in the summer if adults are not present in large numbers. An influx of adults into the area often spurs an emigration of juveniles (Weinrich et al. 1985).

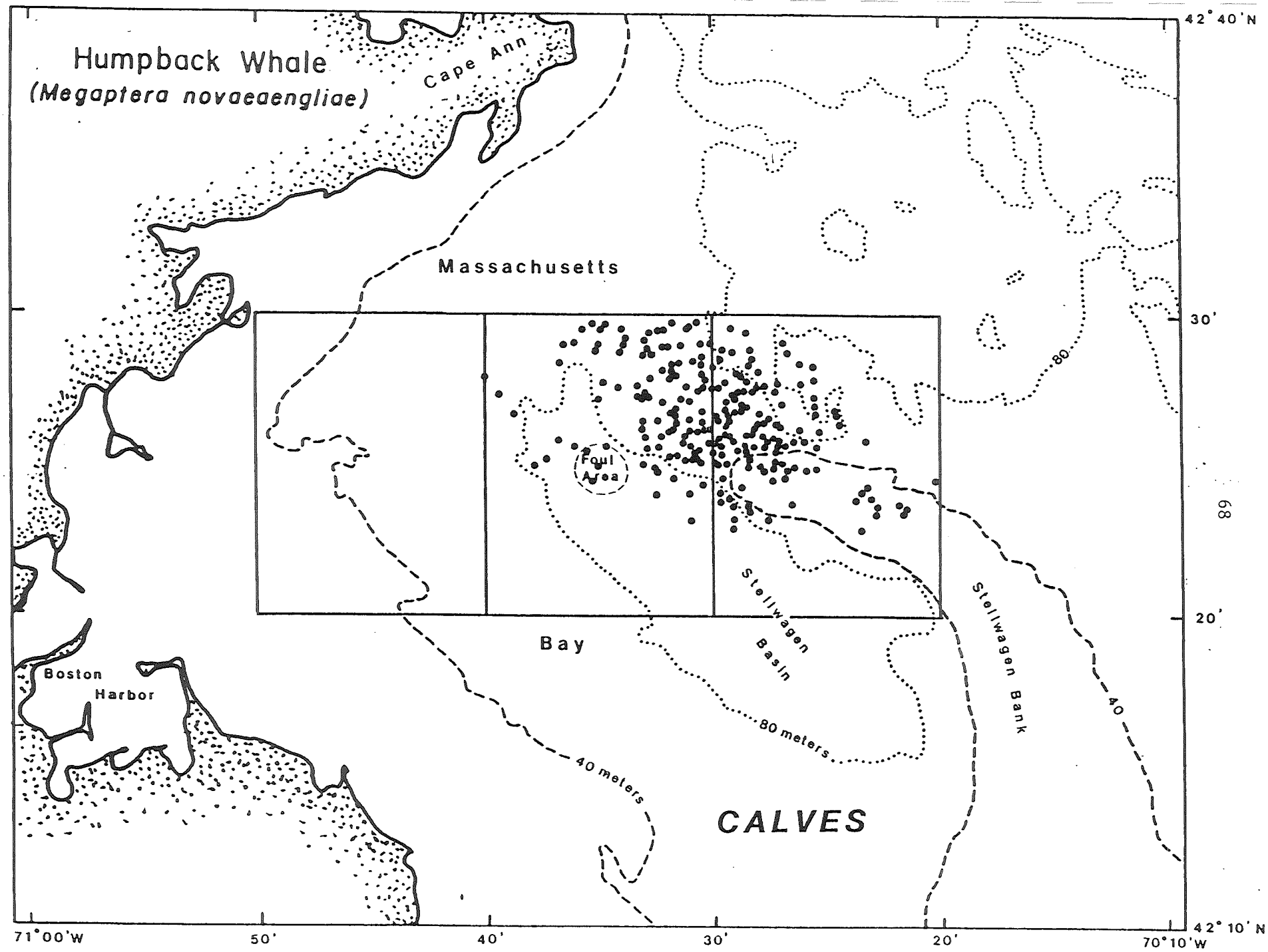
Cow/calf pairs occur in a relatively consistent pattern each year, with most sightings occurring from July through October (Fig. 18). The majority of sightings occur during July and August, although some also are sighted through the fall.

Humpbacks are often found in groups of two to three individuals. Many of these small groups may aggregate in one area, especially when feeding. Groups generally are unstable, however, breaking apart and rejoining frequently. Persistent bonds exist between mothers and their calves, and only infrequently between certain adults (Weinrich, 1985).

The number of humpbacks identified in the waters of northern Stellwagen Bank and southern Jeffreys Ledge varied annually. Between 1979 and 1985, a total of 298 different humpbacks have been identified by CRU in this area via photographic marking. Humpbacks are considered resident in this area if they are resighted consistently within a period of not less than four consecutive weeks in any year. Of the 298 animals identified, 112 have been resident in at least three years, and 55 have been resident in only one or two years; 131 are listed as transients that have never demonstrated residency. Among these, are 62 animals first identified in 1985 that cannot be classified as returning residents, short term residents, or transients due to the relatively short sighting period. When these animals are factored out, the numbers are 112 returning residents, 102 transients, and 22 short term residents.

Humpback use of the three 10 minute blocks surrounding the FADS varies greatly. The inshore quadrat receives little use; the middle quadrat, containing FADS, receives moderate use; the offshore quadrat is used heavily by humpbacks. Of the 298 humpbacks identified by CRU, approximately 90% have been seen within the three 10' quadrats surrounding the FADS.

Figure 18. Sightings of humpback whales with calves within the waters of the Foul-Area Disposal Site study area for all seasons.


Humpback Whale
(Megaptera novaeangliae)
Cape Ann
Massachusetts
Bay
Boston
Harbor
Foul
Area
Stellwagen
Basin
Stellwagen Bank
80
40
80 meters
40 meters
CALVES
42° 40' N
30'
20'
42° 10' N
71° 00' W
50'
40'
30'
20'
70° 10' W

Fin Whales Balaenoptera physalus

Fin whales are found in the waters of northern Stellwagen Bank year-round. Although there is an overall decrease in the number of fin whales within the Gulf of Maine in winter, CETAP (1982) found little, if any, decrease in the number of fin whales present in Massachsuetts Bay.

Fin whales are more widely distributed within the FADS study area than are humpback whales (Figs. 19 a-e). However, like humpbacks, fin whales will aggregate to feed; concentrations of up to 50 fin whales have been observed in the northern Stellwagen area. Fin whales have shown a relatively consistent pattern of habitat use between years. Surface feeding behavior by fin whales has been observed. Prey, when observed on Stellwagen, has been sand eel in all except one observation. Fin whales on Jeffreys Ledge, however, appear to feed consistently on euphasiids (S. Mercer, pers. comm.).

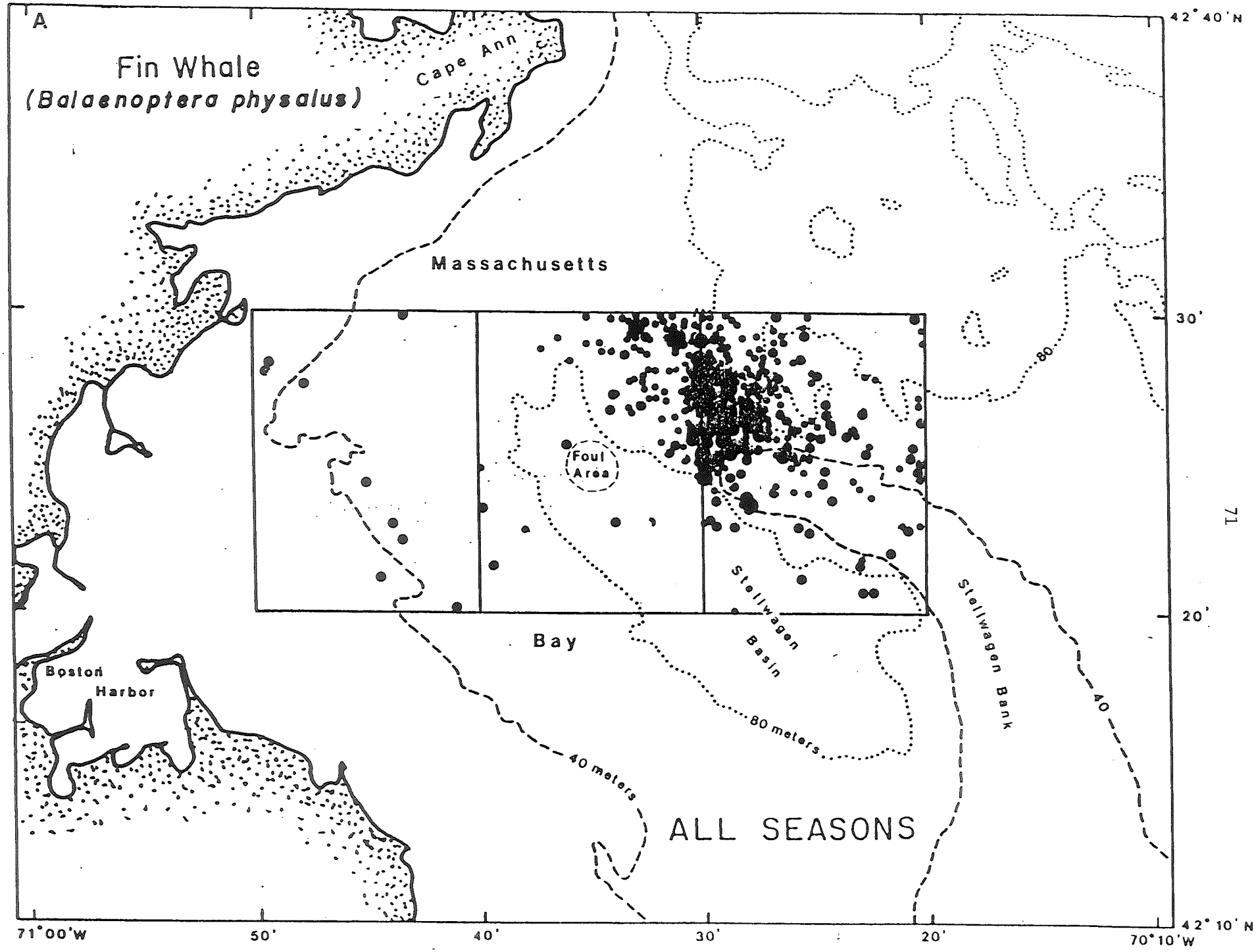
Fin whale cow/calf pairs were most frequently observed from late spring to summer. Approximately 10 to 15 fin whale cow/calf sightings have occurred each year. Most sightings occur on the northern edge of Stellwagen's tip (within FADS), although some sightings have occurred inshore toward Gloucester.

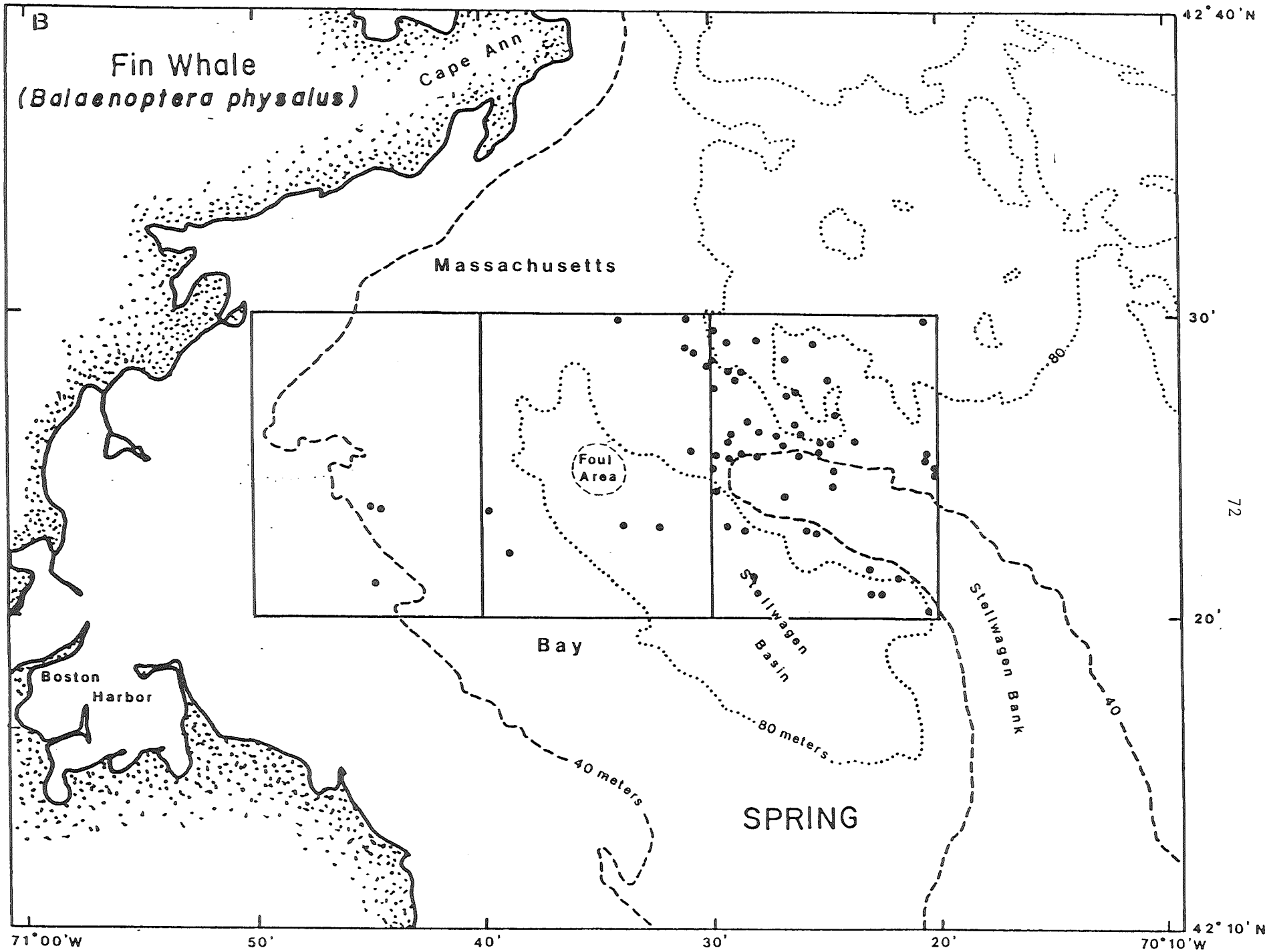
Residence time of individually identified fin whales is minimal. Most animals were sighted for a period of one to seven days. Individual movements were widespread within the Gulf of Maine within a season. Fin whales photographed at northern Stellwagen and southern Jeffreys have been matched to photographs taken as far away as Bar Harbor, Maine, and the Great South Channel.

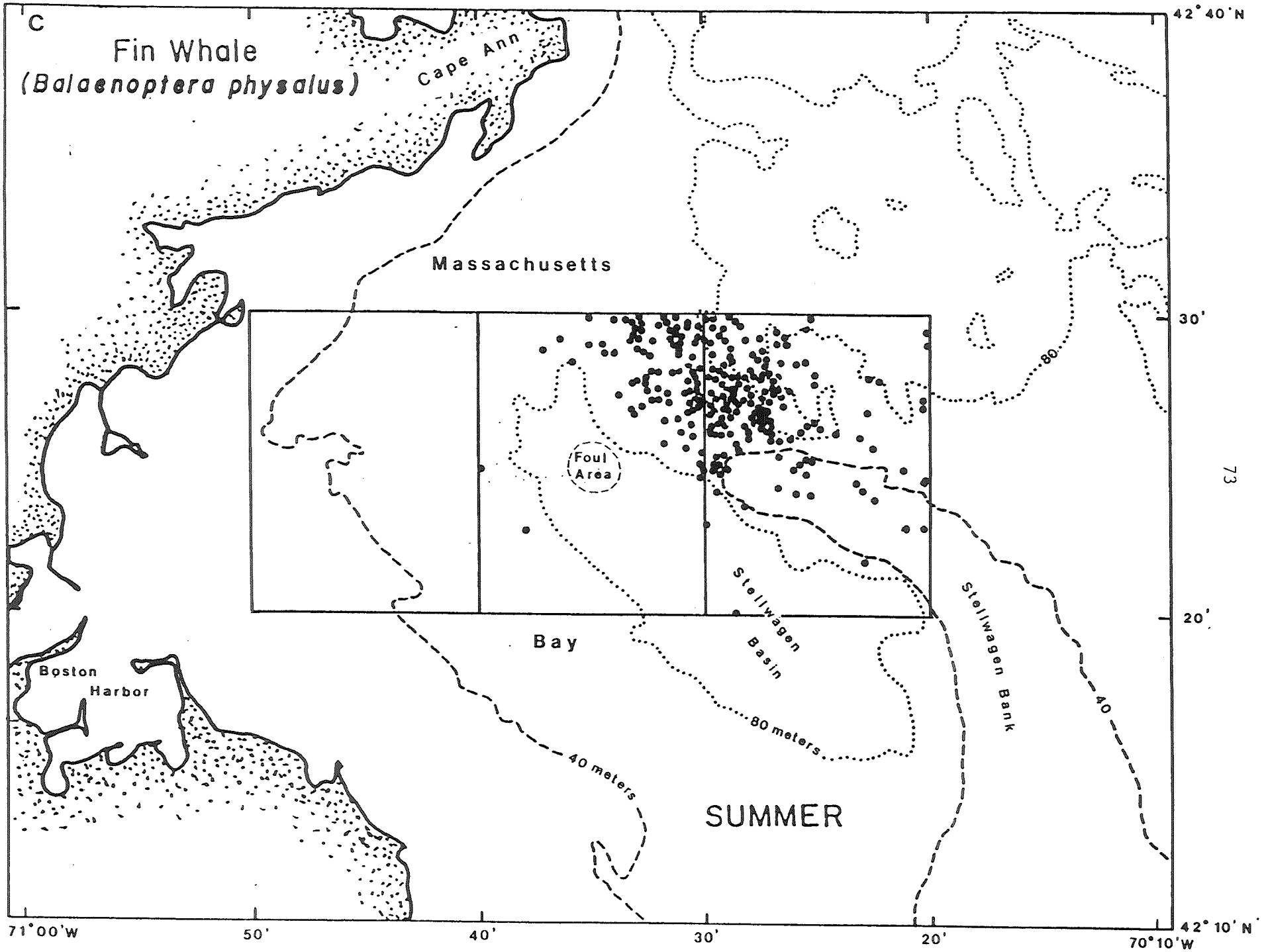
Among the three 10' blocks surrounding FADS, the offshore block receives the highest use, particularly on the western side. The middle block, containing FADS, receives moderate to heavy use. Not enough data has been collected from the inshore block to reliably estimate fin whale use, but low-moderate use is suggested.

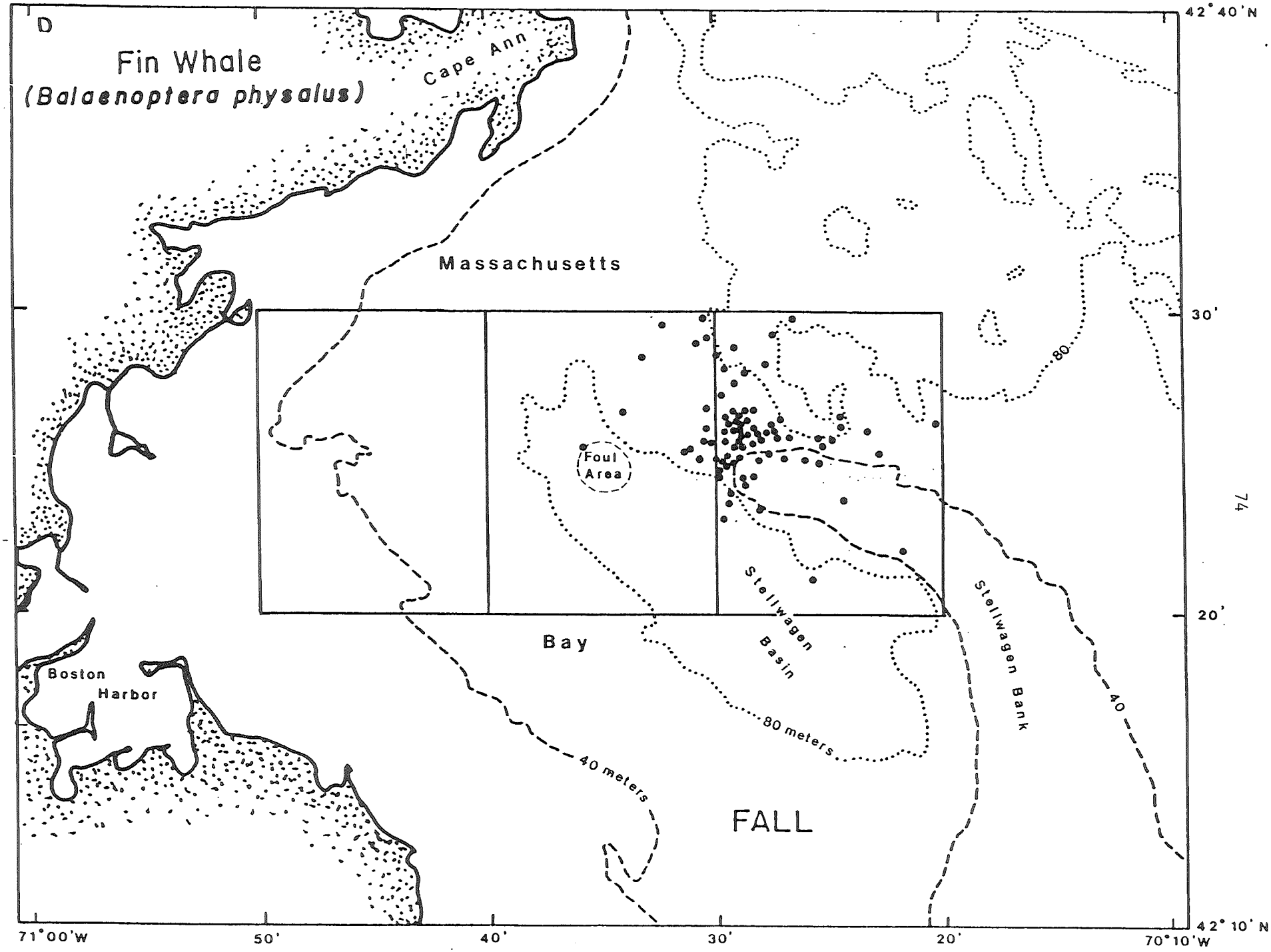
Figure 19. Sightings of fin whales within the waters of the Foul-Area Disposal Site study area by season.

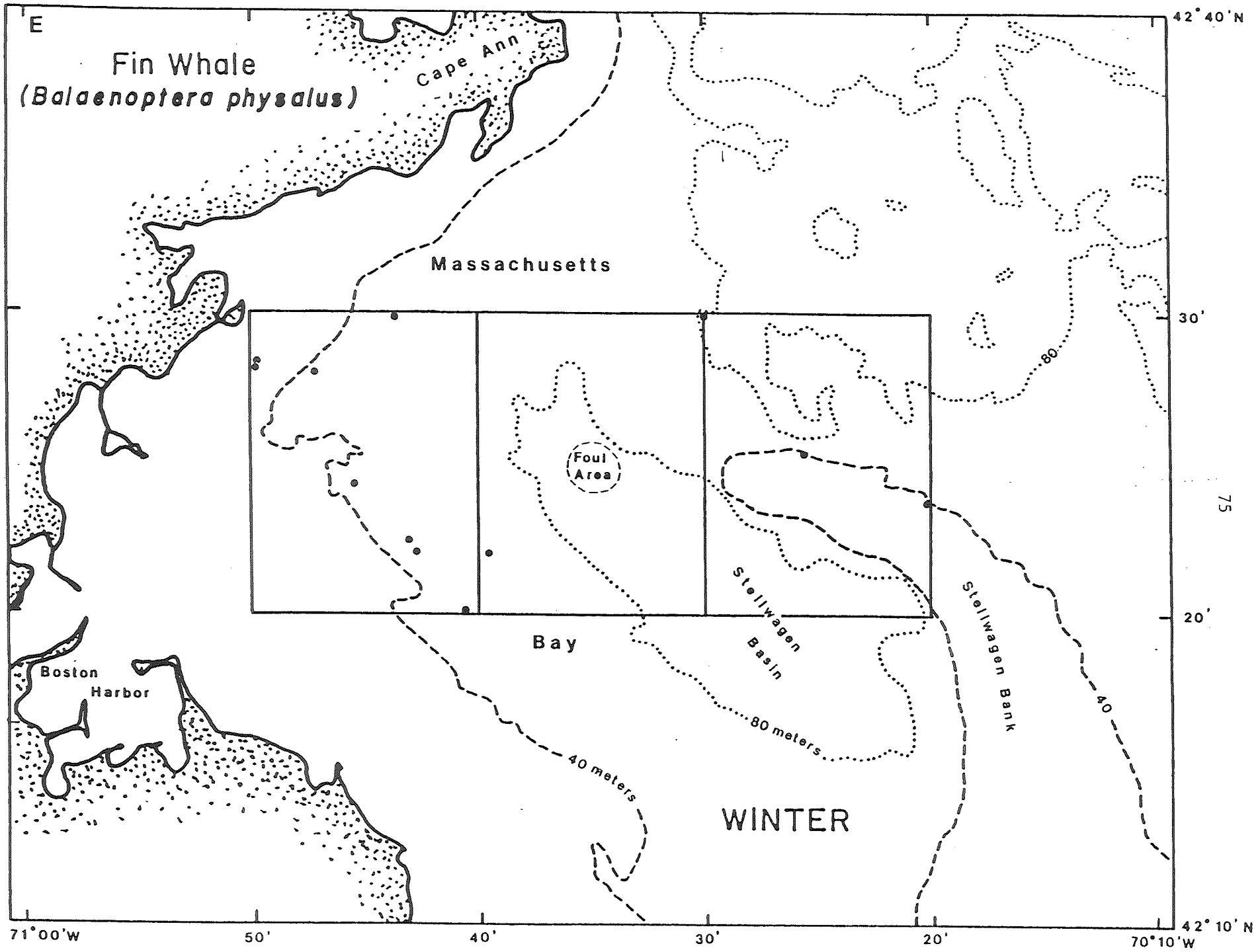
Sources: Data from the Cetacean Research Unit; Hain et al. 1981; Payne et al. 1984; MBO unpubl. data, 1985-1986; Gulf of Maine Cetacean Sighting Network 1975-1981.


A
Fin Whale
(Balaenoptera physalus)
Cape Ann
Massachusetts
Foul Area
Bay
Stellwagen Basin
Stellwagen Bank
80
40
80 meters
40 meters
Boston Harbor
ALL SEASONS
42° 40' N
30'
20'
42° 10' N
71° 00' W
50'
40'
30'
20'
70° 10' W


B
Fin Whale
(Balaenoptera physalus)
Cape Ann
Massachusetts
Bay
Foul Area
Stellwagen Basin
Stellwagen Bank
80
40
80 meters
40 meters
Boston Harbor
SPRING
42° 40' N
30'
20'
42° 10' N
71° 00' W
50'
40'
30'
20'
70° 10' W


C
Fin Whale
(Balaenoptera physalus)
Cape Ann
Massachusetts
Bay
Foul Area
Stellwagen Basin
Stellwagen Bank
80
40
80 meters
40 meters
Boston Harbor
SUMMER
42° 40' N
30'
20'
42° 10' N
71° 00' W
50'
40'
30'
20'
70° 10' W


D
Fin Whale
(Balaenoptera physalus)
Cape Ann
Massachusetts
Bay
Foul Area
Stellwagen Basin
Stellwagen Bank
80
40
80 meters
40 meters
Boston Harbor
FALL
42° 40' N
30'
20'
42° 10' N
71° 00' W
50'
40'
30'
20'
70° 10' W


E
Fin Whale
(Balaenoptera physalus)
Cape Ann
Massachusetts
Foul Area
Bay
Stellwagen Basin
Stellwagen Bank
80
40
80 meters
40 meters
Boston Harbor
WINTER
42°40'N
30'
20'
42°10'N
71°00'W
50'
40'
30'
20'
70°10'W

Right Whales Eubalaena glacialis

Right whales are known to occur in the northern Stellwagen Bank and southern Jeffreys Ledge regions; however information on their occurrence, movements and behavior is limited (Fig. 20). Most sightings have occurred in the spring, during March to April, although a second peak in sighting frequency occurs in July. Right whales were not recorded within the FADS study site during the MBO or CETAP surveys.

Survey coverage of the region by CRU during early spring was limited to one year, 1985. In that year, during mid-April, a considerable number of right whales were observed approximately one mile south of quadrant II. During four days of effort between 18 and 21 April, 20 - 30 individuals were observed at that location. They were most concentrated on 18 April. Behaviors observed included courtship, breaching, and apparent juvenile play behavior (rolling, hanging with mouth opened, and investigating the vessel). Two mother/calf pairs were identified.

During the same period, lower numbers of right whales were seen on northern Stellwagen (east of FADS). Right whales were observed on two of four cruises to northern Stellwagen during the period between 8 April and 24 April. A total of seven animals were identified, including two mother/calf pairs. Both mother/calf pairs were also seen in the large concentration south of quadrant II. Behaviors seen on northern Stellwagen included breaching, and possible nursing.

Although survey effort on northern Stellwagen Bank during April by CRU was limited prior to 1985, one right whale was seen during the only cruise taken in April of 1983, and two were observed during a cruise in March of 1982. Throughout the spring months, northern Stellwagen is an important area for right whales, although not used as consistently or by the same numbers that frequent Cape Cod Bay during the same period (see Mayo et al., this report). Although surface feeding is frequently observed in Cape Cod Bay, it was not observed on northern Stellwagen.

The second period of right whale sightings takes place in July. Effort by CRU has concentrated on northern Stellwagen; hence the lack of sightings in other areas does not indicate absence. During this period most animals were travelling to the north or northeast, apparently in a migratory pattern. This corresponds to known movement patterns of right whales between Cape Cod Bay and the Bay of Fundy. Many of the animals sighted in the vicinity if the FADS have been resighted in the Bay of Fundy within four to six weeks (S. Kraus, pers. comm.). Mother/calf pairs were most frequently observed during July; 55% of the nine sightings during this period have been mothers with calves.

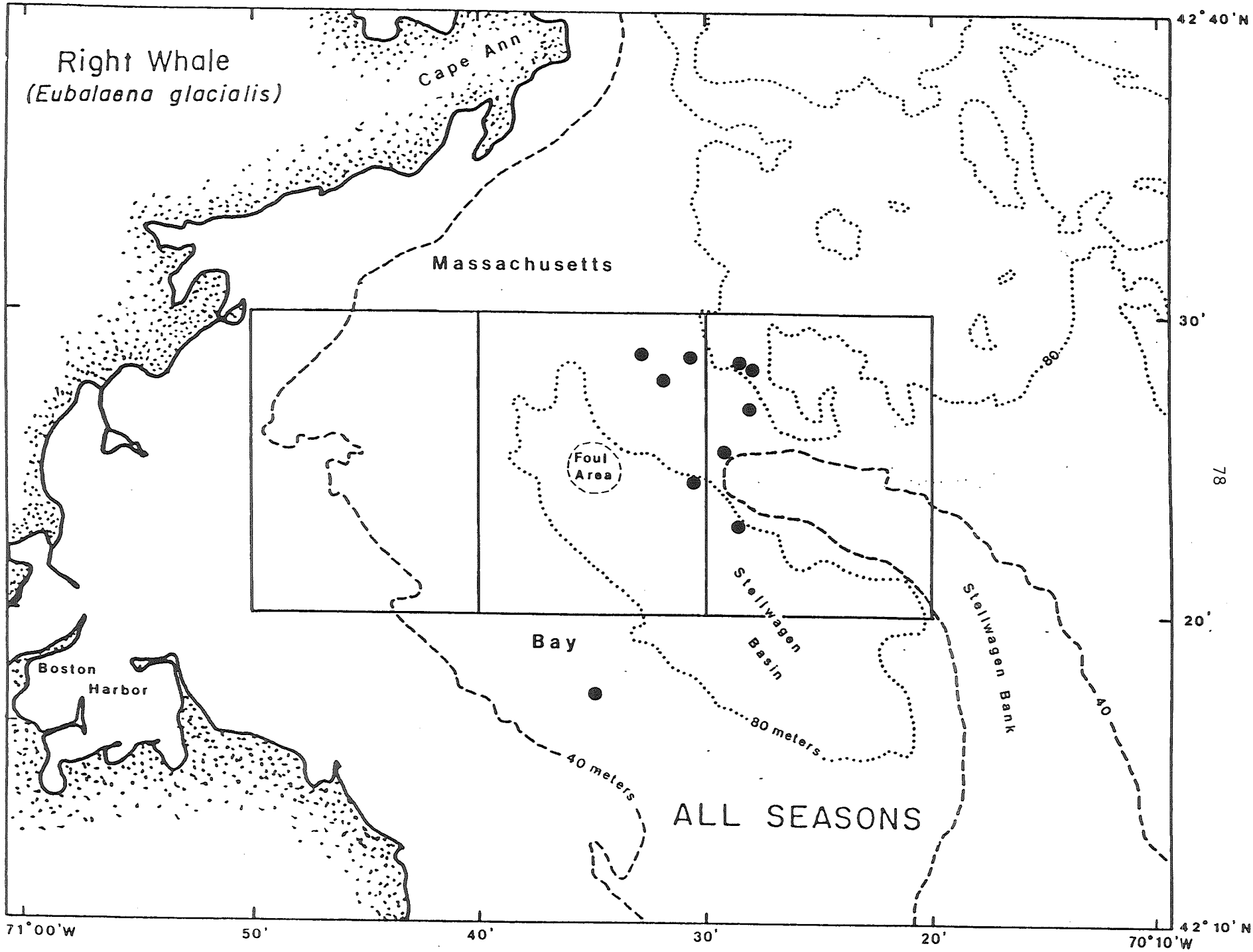
Right whales make another appearance in the fall, during October and November. At this time they are seen rarely on northern Stellwagen, but are seen with some frequency on Jeffreys Ledge (S. Mercer, pers. comm.).

Sei whales (Balaenoptera borealis)

Sei whales have been sighted twice on northern Stellwagen. In both cases, a lone sei whale was seen in a fin whale aggregation. Sei whales are considered accidental visitors to the inshore region.

Figure 20. Sightings of right whales within the waters of the Foul-Area Disposal Site study area for all seasons.

Sources: Data from the Cetacean Research Unit; Hain et al. 1981; Payne et al. 1984; MBO unpubl. data, 1985-1986; Gulf of Maine Cetacean Sighting Network 1975-1981.


Right Whale
(Eubalaena glacialis)
Cape Ann
Massachusetts
Foul Area
Stellwagen Basin
Stellwagen Bank
Bay
Boston Harbor
80 meters
40 meters
80
40
ALL SEASONS
42°40'N
30'
20'
42°10'N
71°00'W
50'
40'
30'
20'
70°10'W

IV. TH RIGHT WHALE (EUBALALNA GLACIALIS) IN CAPE COD AND MASSACHUSETTS BAY - RELIMINARY OBSERVATIONS ON DISTRIBUTION, OCCURRENCE AND BEHAVIOR

Mayo, C. A. Carlson, M. K. Marx and C. L. Danton

The right whale (Eubalaena glacialis) is considered one of the world's most endangered large mammals and certainly its rarest whale. With an estimated 1800 remaining in the world's oceans in a habitat which covers perhaps 50% of the globe, the density of right whales in their remaining "high-use" habitats may be so low as to preclude normal rates of reproduction. The North Atlantic population of right whales, apparently neither increasing nor decreasing in number, has been estimated at fewer than 300 individuals. Because of the pressing need to investigate this rare cetacean, in 1984 the Center for Coastal Studies commenced a study of the right whale in the waters of Cape Cod. This preliminary report on our studies during the past four years relates to investigations supported by many organizations, including the World Wildlife Fund - U.S., the National Marine Fisheries Service, the Ellis L. Phillips Foundation, the Phipps Florida Foundation, the Island Foundations, the W. Alton Jones Foundation, Sippican Ocean Systems, Inc., the Center for Coastal Studies, and the Office of Naval Research .

We wish to express our appreciation to the organizations funding the research, and to the staff of the Center for Coastal Studies for an unusual and often uncompensated effort to accomplish the tasks in these preliminary investigations. The work was carried out using research vessel Halos (provided through a personal contribution) and zodiac inflatables (provided through anonymous contribution and by the Whale Protection Fund). We express our appreciation for their assistance to Stephen Chelminski, Bill Rossiter, Roger Payne, and Scott Kraus. Special appreciation is extended to Bill Stahl and Birgit Kriete for assisting with the analysis of zooplankton samples.

BACKGROUND

Two representatives (by some these are considered two species) of the genus Eubalaena , formerly Balaena , are found throughout the temperate waters of the world's oceans. The right whale of the northern hemisphere, E. glacialis generally occurs between 20 degrees (Townsend, 1935; Omura, 1958; Klumov, 1962) and 60 degrees (Townsend, 1935) north latitude. The right whale of the southern hemisphere(E. australis or glacialis)occurs in a range extending between 30 and 60 degrees south latitude (Matthews, 1937; Mermoz, 1980; Townsend, 1935). The two populations, while displaying some meristic differences, are closely related and are similar in both habit and habitat. The right whales of both hemispheres make limited north-south migrations, preferring the colder, high latitude waters in the summer and the warmer, sub-tropical or temperate waters in the winter. In general, they have historically been found residing in banks and in bays throughout their range (Allen, 1908; Allen, 1916; Townsend, 1935; Matthews, 1937; Gaskin, 1968; Donnelly, 1969; Cummings, et al, 1974; Payne, 1976; Watkins and Schevill, 1976; Reeves, et al, 1978; Castello and Pinedo, 1979; Mermoz, 1980; Aguilar, 1981; Kraus, 1985; Mercer, 1985; Best, pers. comm.).

The western North Atlantic range the right whale extends from as far south as Florida, to Quebec and Newfoundland in the north (Reeves, 1978; Beamish, 1981; Mead, in press). Although they were once common throughout the range (Reeves, 1978) their numbers were severly depleted by intensive hunting beginning in the 1500's by the Basques based in Newfoundland (Scammon, 1874; Aguilar, in press). In the early 1600's American whaling began, taking place along much of the eastern coast of the United States. Catches by American whalers were recorded from Florida (Burghard, 1935; Moore, 1953), Georgia, the Carolinas

(Holder, 1883, True, 1904; Stick, 1958), Delaware Bay (Cope, 1865, True, 1904; Weiss, 1974; Lipton, 1975), New Jersey coast (Weiss, 1974; Lipton, 1975), Long Island (Allen, 1908), Cape Cod, Nantucket, Martha's Vineyard and Cape Anne (Allen, 1916). The hunting continued until the early 1900's when, due to the scarcity of the whales, the last of the right whale fisheries closed (Reeves, 1978). Although the North Atlantic right whale has been protected since 1937 under the International Convention on the Regulation of Whaling, their numbers have not increased and only a few hundred remain (CeTAP, 1982).

Aggregations of right whales may still be observed in several locations along the shores of North America. At least part of the population over-winters along the coast from North Carolina to Florida (Kraus, 1984, Winn, 1984; Mead, in press) and in Cape Cod Bay. During the spring, Great South Channel (CeTAP,1982) and Cape Cod Bay are consistently inhabited by this species. From June through October the right whale distribution appears to be centered on the southern Scotian shelf in the vicinity of Browns and Bacarro Banks, and in the Bay of Fundy (CeTAP, 1982; Kraus, 1982; Kraus, 1983; Winn, 1984; Kraus, 1985). Little is known about the migration routes between these areas.

Around the world, productive embayments appear to be especially important habitats for right whales. In Argentina right whales aggregate to court and calve in Gulfo Nuevo and Gulfo San Jose (Cummings, 1974; Payne, 1976;Mermoz, 1980). Significant numbers of mothers and calves were seen in False Bay, Table Bay, and Algoa Bay on the coast of South Africa (Best, pers.comm.). Mothers and calves have also been seen in the Bay of Fundy, as was feeding and socializing (Kraus, 1985). The bays of Campbell Island in New Zealand (Gaskin, 1968) and the coastal coves from South Carolina to Florida have been well documented as a principle calving areas (Reeves, 1978). In Cape Cod Bay right whales have been observed skim feeding, socializing, and courting since the early 1950's (Watkins and Schevill, 1976; Mayo, 1985).

This report to the Manomet Bird Observatory summarizes the preliminary information on the distribution, food, feeding, and general behavior of the right whales observed during studies of the Massachusetts and Cape Cod Bay region by the Center for Coastal Studies between 1983 and 1985. General comments on the winter and spring observations during the 1986 season will also be included.

METHODS

In 1978 the Center for Coastal Studies began an effort to document the occurrence and distribution of North Atlantic right whales in the coastal waters of Massachusetts. The work undertaken was divided into four parts: (1) intensive shore and aircraft sighting to locate right whales (seasonally 1984-1986), (2) a track survey to collect oceanographic data in right whale habitats and to obtain right whale density information (1984-1986), (3) a photoidentification study to determine the demographics of the right whale populations observed in 1978-1986, and (4) a study of the food, feeding, and general behavior of the whales observed in 1984-1986.

- Shore and Air Surveys

Generally, survey tracks were run along predetermined lines (Figure 21) to permit density estimation. Shore stations were observed by members of the staff at clear view locations indicated on Figure 1. Aircraft searches, though restricted by weather, were flown generally along track lines used by the vessel.

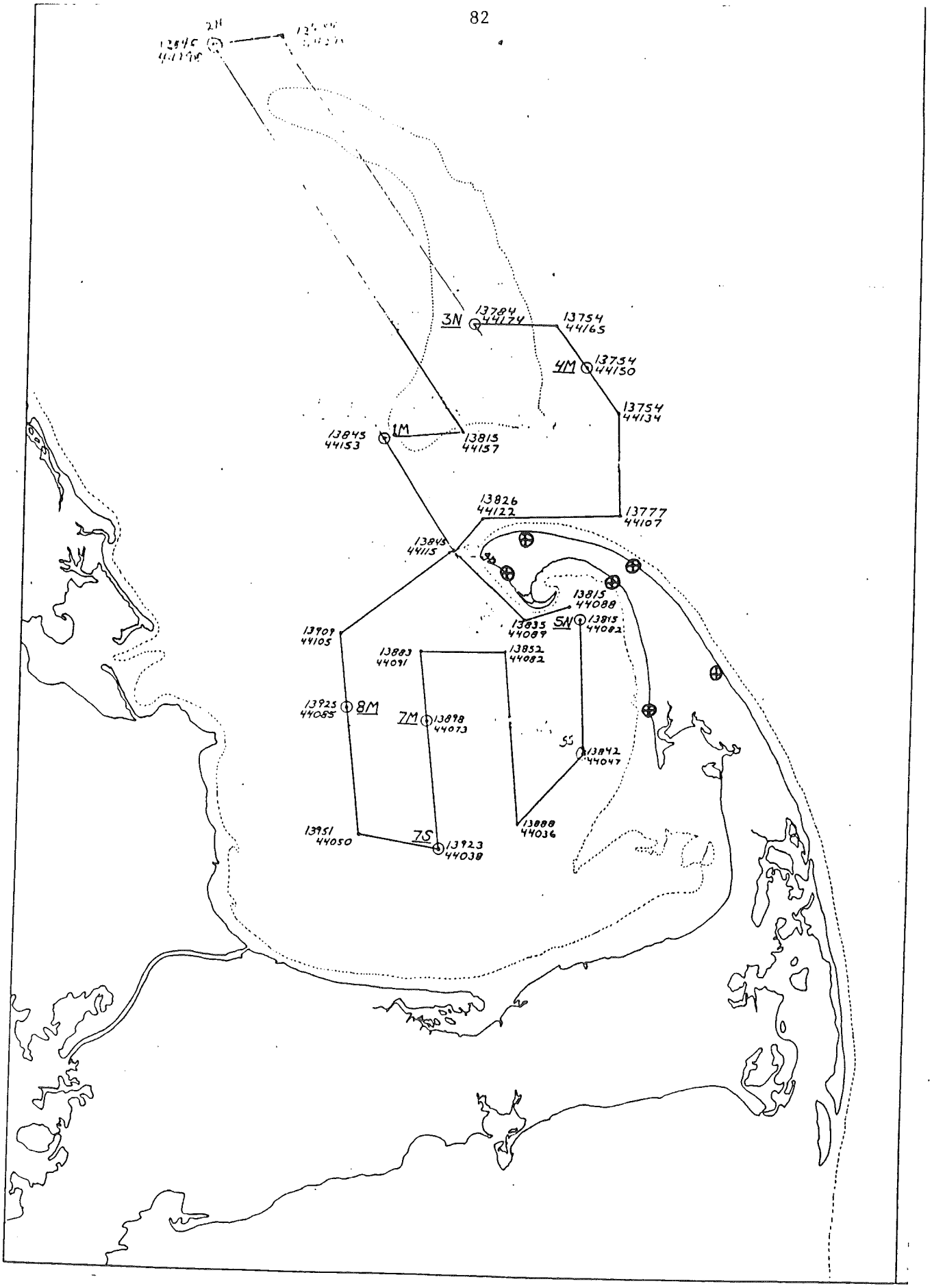


Figure 21. Study sampling tracks and shore observing locations (⊕).

- Photodocumentation

The whales were photographed to permit individual identification as described by Payne et.al. (1983). The photographic equipment included 35mm, single lens reflex, Pentax motor drive cameras fitted with 200 to 400mm lenses. All photographs taken during the study were imprinted with data-back codes to permit later filing.

- Feeding and Behavior Documentation

Documentation of surface behavior employed a video cassette recorder with notes inserted on the audio channel of the VCR tape. Both along the ocean survey tracks and in areas of right whale feeding and intensive habitat use, information on the physical and biological environment was recorded. Samples of the zooplankton were collected using a conical 471 micron net towed at the surface. This plankton net was fitted with a calibrated, General Oceanics flow meter to permit accurate density estimates. Phytoplankton samples were taken by dip and counted by using a Palmer Maloney cell. Information on the characteristics of the environment (meteorology and sea conditions) were recorded as part of the data collection process normally employed by the Center for Coastal Studies. Surface water current tracking in the right whale feeding areas was undertaken for the first time in 1985 using drogues. The drogues were generally deployed at the beginning of a feeding observation and recovered at the end to permit an estimate of the effects current on the movement of the zooplankton patch.

-Photoidentification

Approximately 10,000 photographs of the individually distinctive characteristics of right whales were taken during the 1984-1985 observation period. While those photographs are still under intensive analysis, some information may be gleaned from the data base.

(1) Most, if not all, of the whales observed in 1985 have not been confirmed as whales present in the region in 1984.

(2) Many whales in each of the two grouping areas were observed repeatedly through 1985, suggesting residency.

(3) Between 4 and 6 newborn calves were observed in the study area both in the Cape Cod Bay and Stellwagen Basin locations.

(4) One female with calf, observed in the study area in April, was also seen in the spring of 1983 with a calf, indicating an unexpectedly short two year reproductive cycle. Payne (pers. comm.), from his Valdez study, describes two year calving as unusual in the South Atlantic.

(5) Preliminarily it appears that the two grouping areas, Cape Cod Bay and Stellwagen Basin, are populated by somewhat different individuals, suggesting that there was not a free exchange between the two grouping areas.

(6) Based on these observations we conservatively estimate that between 30 and 45 right whales were observed during 1985. Most of those whales were seen on more than one cruise.

- Habitat Use: Behavior

Observations of right whale behavior have been made from the shore and from vessels. All of the broad categories of behavior have been observed in the study area including: social behavior which has been categorized by some researchers as courtship or sexual activity, skimming feeding, nursing and nursery behaviors with first year calves, resting behavior (for which we have coined the term "logging"), long diving patterns which most researchers assume are associated with deep feeding, and active surface traveling. We are endeavoring to compare the two 1985 residency areas relative to the principal behaviors observed, however, such comparisons are not available at present. The consensus of the CCS observers is that the whales seen in the Stellwagen Basin site during April displayed relatively more intense social behavior with greater underwater vocalization, than those observed within Cape Cod Bay. The observed social behavior, because of the degree of physical contact and the number of whales involved, strongly suggests that such behavior was sexual in nature. Surface skimming was not observed in the region of the Stellwagen Basin, therefore feeding could not be confirmed; however, very long period dives and occasional surfacing with mouth partly agape indicates that feeding in the Stellwagen Basin is likely taking place at depth. Nursery and related behaviors were observed primarily in the Stellwagen Basin area in mid- and late April. All calves observed in 1985 appeared to be less than 6 months old.

When right whales were found, research vessel Halos was used to either follow the whales while videotaping or to approach the whales to obtain the requisite photographs of individually distinctive callosity patches. Inflatable boats were used in conjunction with research vessel Halos to expand the areas of search and to collect identifying photographs. On several occasions one or more of the inflatables were used to record underwater sound while video recording was conducted from Halos.

RESULTS

-General Distribution of Right Whales

The information collected during the past 8 years suggests the following broad patterns of distribution and occurrence of right whales. Right whales were observed during January and February by shore observers in 1979, 1981, 1982, 1984, and 1985. Distribution patterns from vessel observations in 1984 and 1985 are presented in Figs. 22 and 23. Observations in 1984 suggest two centers of right whale distribution; one, previously studied, on the eastern side of Cape Cod Bay and a second, discovered during early April 1985 surveys, in the Stellwagen Basin west of the central part of Stellwagen Bank. Preliminary information from the individual identification studies suggests that the whales did not freely exchange between the two areas, but remained in somewhat discreet groups during the 1985 observing period.

In 1985, the first right whale calves were seen in the Stellwagen Basin area during the second week of April while in 1984 calves were seen in early April in Cape Cod Bay. The late arrival of calves supports previous observations that first year calves are not seen within the study area before 1 April.

Preliminary distributional information suggests that the right whales are grouped in dispersed aggregations of 15 to 25 individuals and that these groups may represent important socializing and feeding units within the population. First analysis of the data indicates that up to 25 whales resided in each of the habitats studied, in the Stellwagen Basin and in eastern Cape Cod Bay during the 1985 season.

The distribution observed in 1984 with most of our observations in the eastern fringe of Cape Cod Bay and the lack of whales in the Stellwagen Basin during 1984 is explained as an artifact of our sampling pattern and does not indicate that no whales were present there prior to 1985. Although our analysis has not been completed, it appears that most of the whales in 1985 were, as in 1984, found in a residency condition, not migrating through the region but remaining in localized aggregations for periods of weeks or months.

It should be pointed out that the collection of information in 1985 was limited by lack of funding and by inclement weather, which prevented vessel operation. Therefore, the distribution pattern suggested here may prove to be more complicated or substantially different when more information is collected. From shore sighting and vessel observations being recorded during 1986, there is a strong suggestion that whales enter the study area significantly earlier (possibly mid- December) than indicated in our 1984-1985 data.

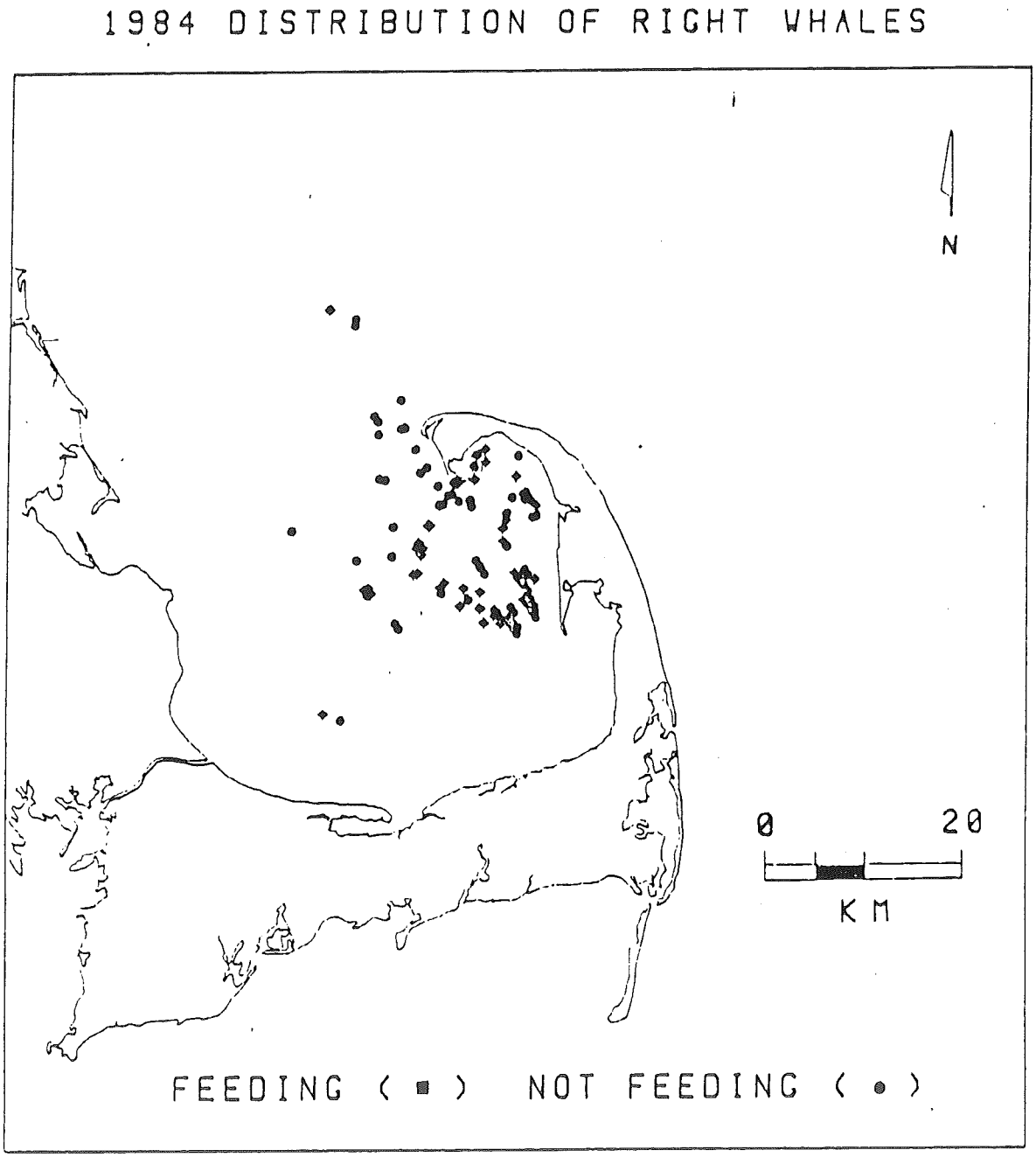


Figure 22. Right whale observations in 1984.

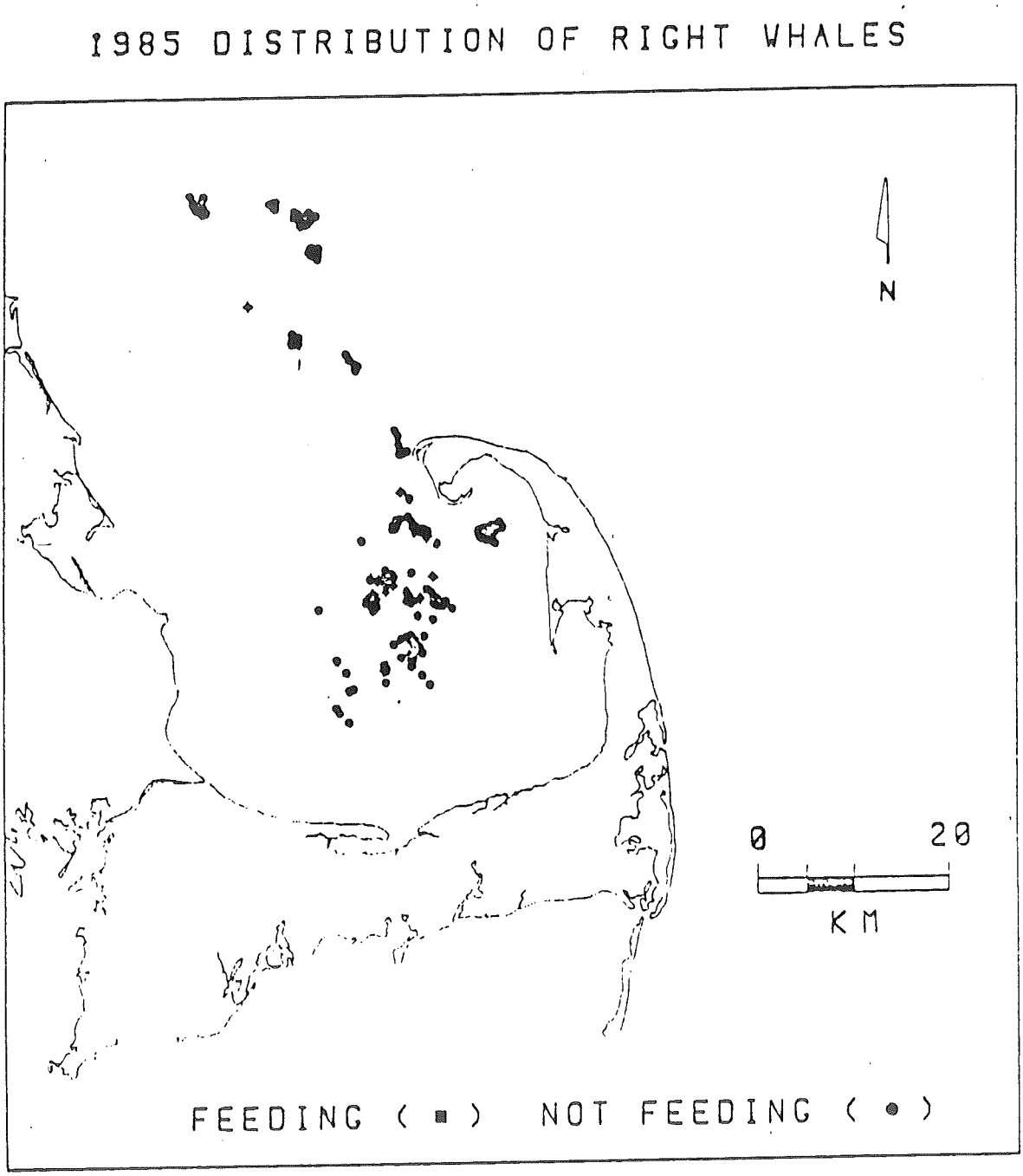


Figure 23. Right whale observations in 1985.

-Preliminary Habitat Use Studies: Feeding

The following preliminary results of our feeding studies were presented in a paper in the Sixth Biennial Conference of the Society for Marine Mammalogy, held in Vancouver, British Columbia in November, 1985. The feeding studies conducted in Cape Cod Bay were originally designed to interpret the potential effects of altered zooplankton patch characteristics on the fitness of right whales. To that end, skim feeding whales were studied and the zooplankton consumption and caloric needs were estimated

Right whales in Cape Cod Bay usually forage at or near the surface of the sea in a behavior known as "skimming" (Figure 24). Such behavior, not commonly found throughout most of their world-wide range, permits us to confirm open-mouth filtration and to study prey density by sampling the zooplankton in the immediate vicinity of the feeding path. Our analysis of that feeding path depends on a combination of data collection including (1) five hours of videotape of whales feeding, to study associated swimming patterns, (2) collection of 57 plankton samples from within 0 to 10 meters of the feeding path and where whales were not feeding and, (3) an estimate of feeding rates based on path length and vertical mouth gape area.

From our phytoplankton studies in the winters of 1984 and 1985 we conclude that the phytoplankton community supporting the food web in Cape Cod and Massachusetts Bays, of which the right whales are part, is dominated by five genera of diatoms likely consumed by the zooplanktonic prey of the right whales (Figure 25). In 1984 the dominant genera of phytoplankters where Chaetoceros and Thalassiosira in that order; while in 1985 the genera Leptocylindrus and Chaetoceros were the dominant primary producers. The zooplankton for both years was dominated by the calanoid copepods Calanus finmarchicus and Pseudocalanus minutus, with a significant contribution to total zooplankton by barnacle larvae of both naupliar and cyprid stages.

Although the qualitative characteristics of the zooplankton over the region appear to be relatively stable, the density of zooplankton is dramatically variable as exemplified by an individual cruise summary (Figure 26). This summary documents the large density differences typical of samples collected within several kilometers of one another in the right whale feeding areas.

Patchiness of the zooplankton community in the study area may, more than any other characteristic of the system, affect the distribution and habitat use of right whales in the region as shown by summary plankton density diagrams (Figures 27-29). Plankton sample densities collected near the feeding whales observed in 1984 spanned 1063 to 12,800 and average 5729 zooplankters/M3 while those taken (1) from non-feeding locations and (2) at stations where whales were not present average 1094 and 2036 zooplankters/M3 respectively. Zooplankton samples from 1985 similarly demonstrate the selection of dense patches by feeding right whales. A summary of the 1984 and 1985 zooplankton concentrations suggests that right whales during the period of our study foraged at the surface in locations where the zooplankton density was greater than 1000 organisms/M3. The only exception among the 23 samples taken in 1985 was sample H785, which was likely due to a meter error. In later discussions we will use the value of 1000 zooplankters/M3 as a threshold concentration for

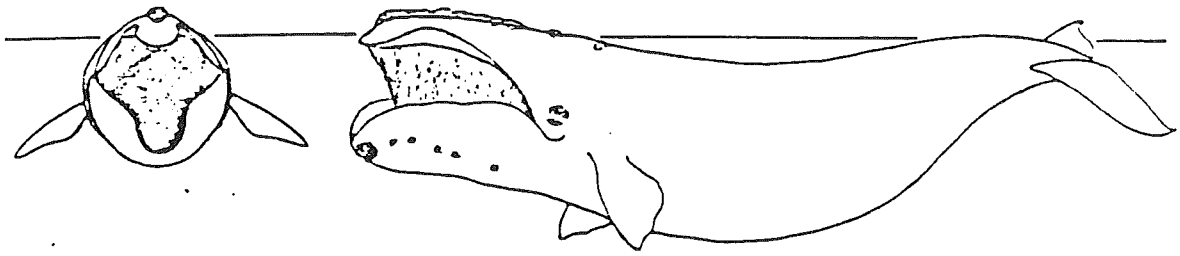


Figure 24. Right whale skim feeding (graphics by M. Gilmore).

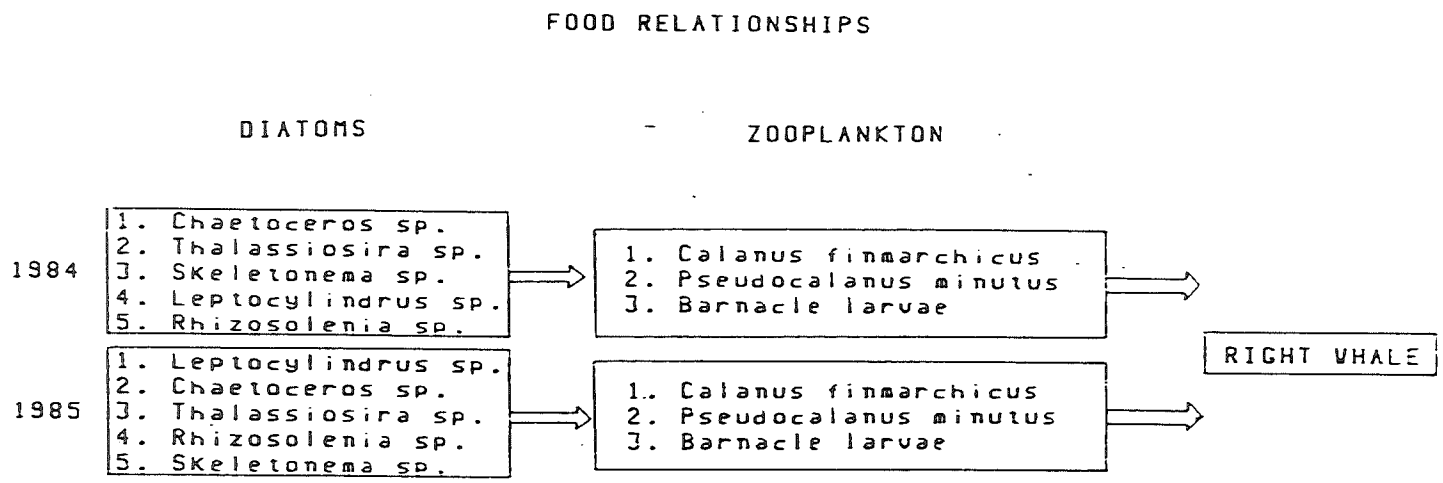


Figure 25. Simplified food web for right whale feeding areas in Cape Cod Bay.

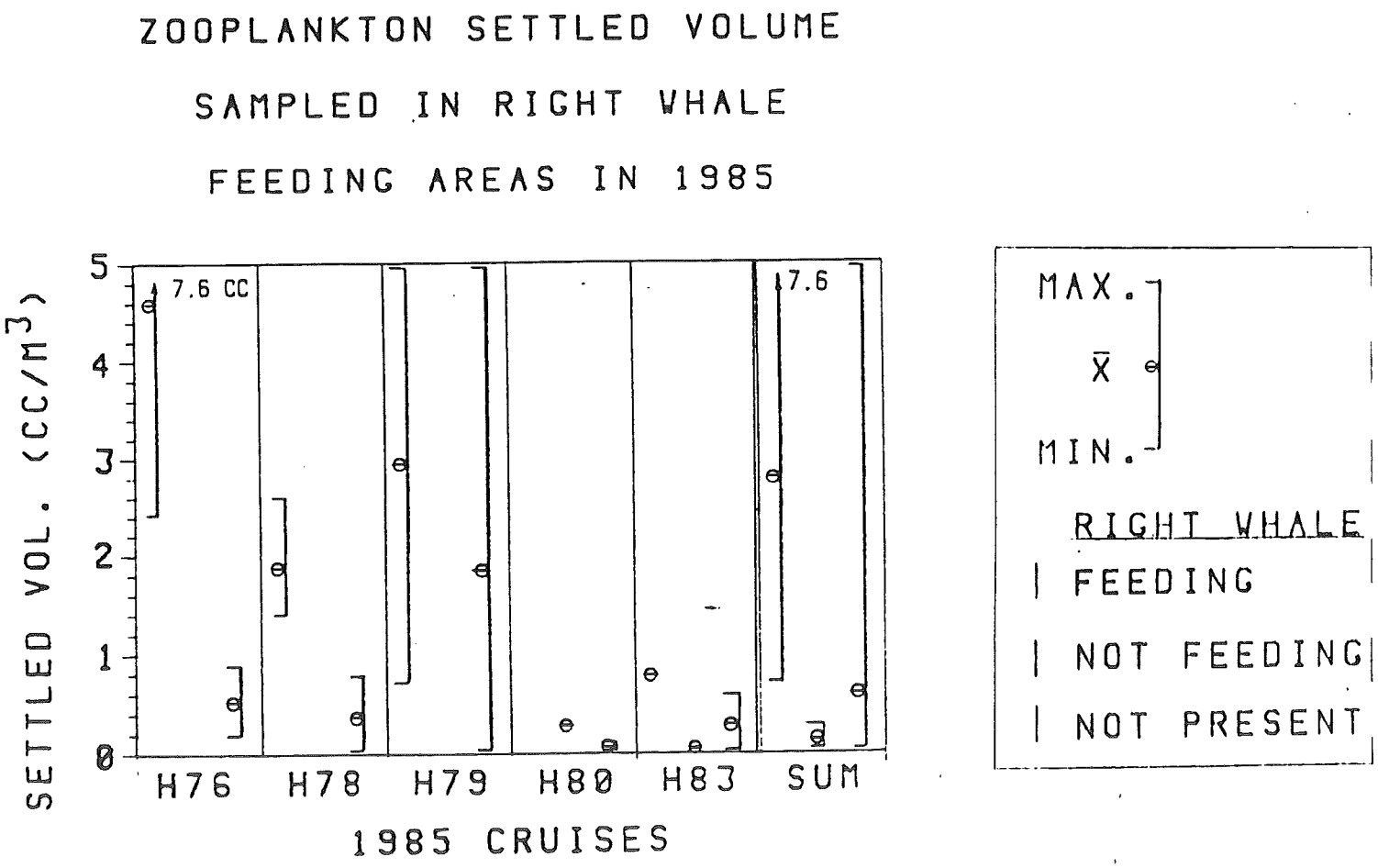


Figure 26. Zooplankton settled volume by cruise.

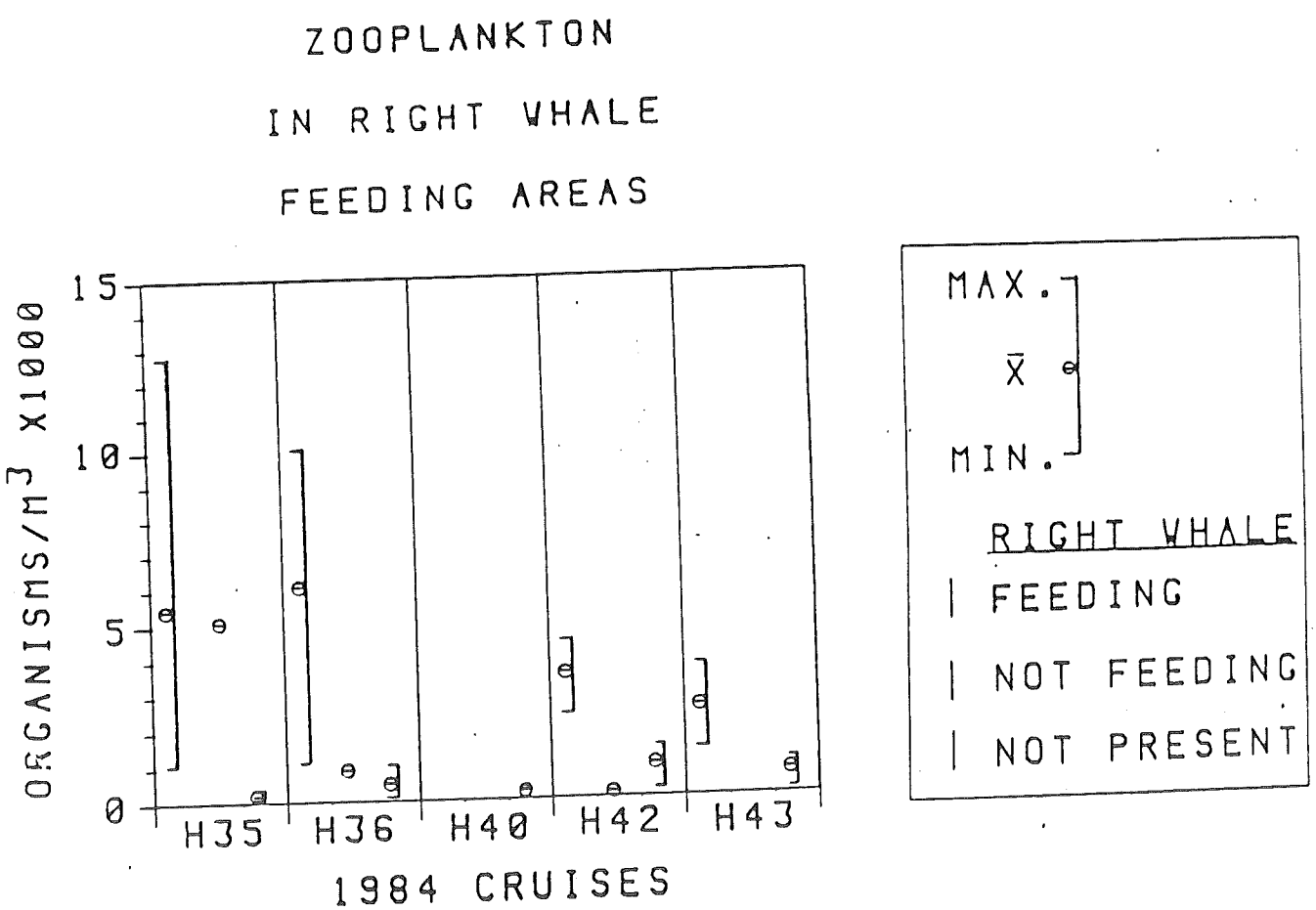


Figure 27. Summary of 1984 zooplankton densities by cruise and right whale feeding behavior.

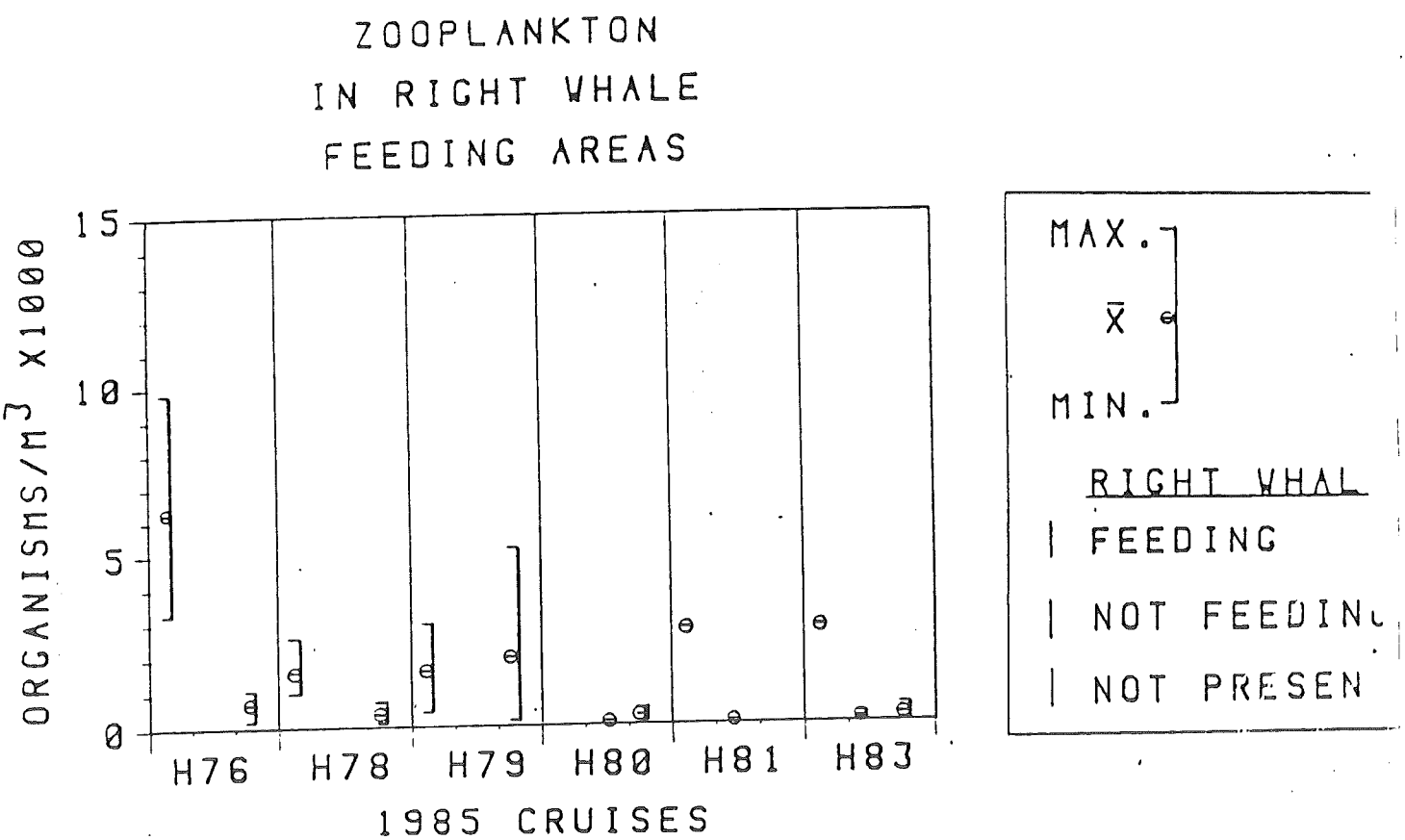


Figure 28. Summary of 1985 zooplankton densities by cruise and right whale feeding behavior.

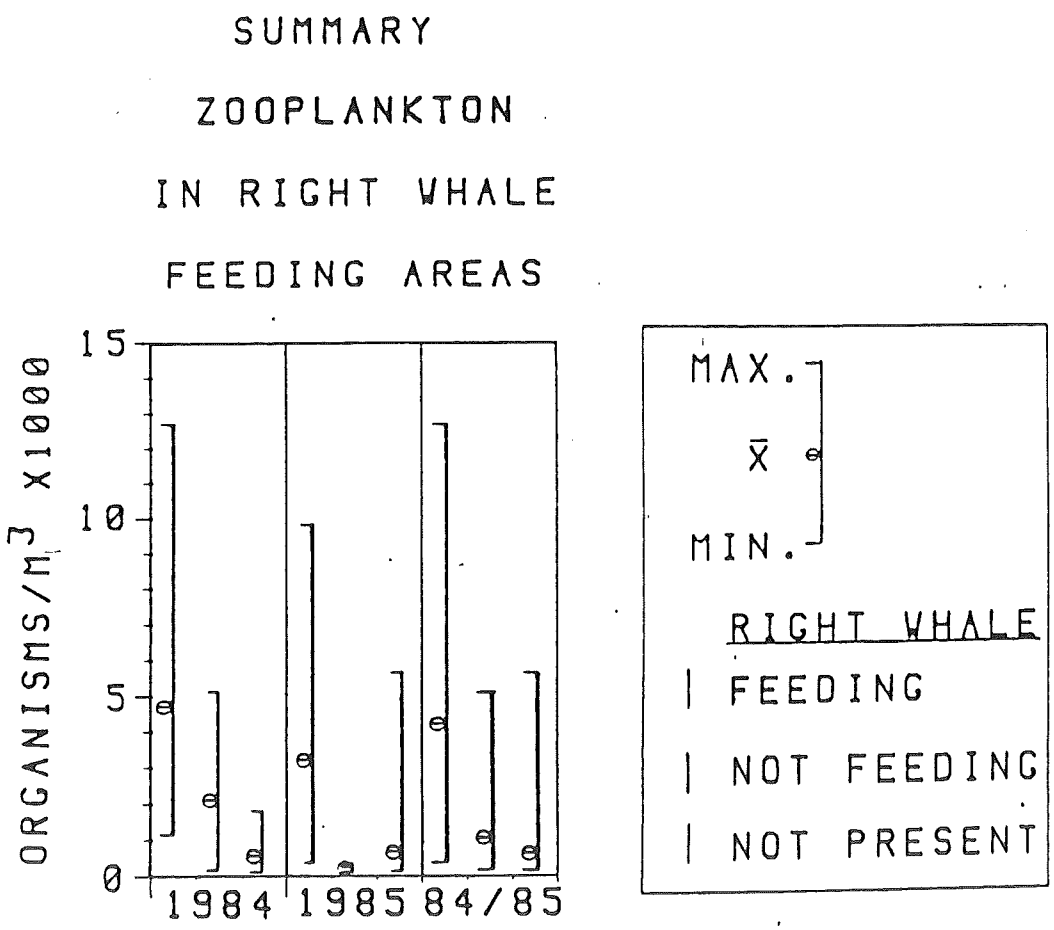


Figure 29. Summary of zooplankton densities by year and as mean of 1984 and 1985 observations.

feeding. This proposed threshold is equal to 0.73 g/M3 wet weight according to our preliminary calculations using in-lab, blotted zooplankton samples.

To accurately characterize the foraging strategies, we analyzed videotapes, LORAN C data and took current velocities into account. Because current velocities in the region may exceed 1 M/sec. and the swimming of right whales relative to the water body did not exceed 2 M/sec., correction for current set was essential for an accurate assessment of feeding distance and velocity. To accomplish such a correction, a surface drogue was deployed on several occasions at the beginning of the observation (Figure 30).

The 13,700 meter foraging path of whale 2584 (Figure 31). shows the typical turning behavior reported by Payne (pers. comm.). This whale fed in a rich patch of calanoid copepods exceeding 3900/M3, skimming at a mean velocity of 1.81 M/sec. On reaching a part of the patch with less than 1500 zooplankters/M3, whale 2584 began to follow a straighter foraging path and eventually ceased to feed.

Other documented patterns of movement similarly show turning behavior within the vicinity of patches. H76J (Figure 32). fed along a path of 1010 meters at 0.54 M/sec. in a patch calculated from an in-path tow of 3086 zooplankters/M3. H79A (Figure 33) displayed a more linear foraging path, perhaps responding to a linear patch shape, at 0.56 M/sec; it then followed a very convoluted track as it ceased to feed and began socializing with a second right whale. H79A stopped feeding in a patch with a sampled density of 3064 organisms/M3, well above the threshold of 1000 organisms. Such a change in directed behavior, from foraging to socializing, suggests that the right whale may be what Schoener (1971) calls a "time minimizer", that is, an animal which uses a patch until it has fulfilled its energy needs and then uses the remaining time for other activities.

The foraging and search path of H83C (Figure 34) suggests, again, the convoluted pattern seen in other feeding observations. In this case, the zooplankton was dominated by barnacle larvae which, while numbering more than 2900/M3, represented a wet weight of only 0.63 gr/M3, one third of that for similar density of copepods. Perhaps this low wet weight explains the velocity of 1.21 M/sec., the second highest recorded, and the termination of foraging and departure from a patch appearing numerically rich numerically. If this interpretation is correct, then the threshold which we have proposed may only apply to the samples which are dominated by calanoid copepods.

The zooplankton resource of the Cape Cod and Massachusetts Bay region is characterized by a disjunct distribution with large interpatch distances. With such a plankton distribution and the feeding threshold we have proposed, the successful exploitation of the resource must depend on well developed search and foraging strategies dependent on a sensitive and selective sensory capacity. We conclude that any decrease in the within-patch prey density or increase in the inter-patch distances may be expected to have a significant, detrimental effect on the fitness of the right whales.

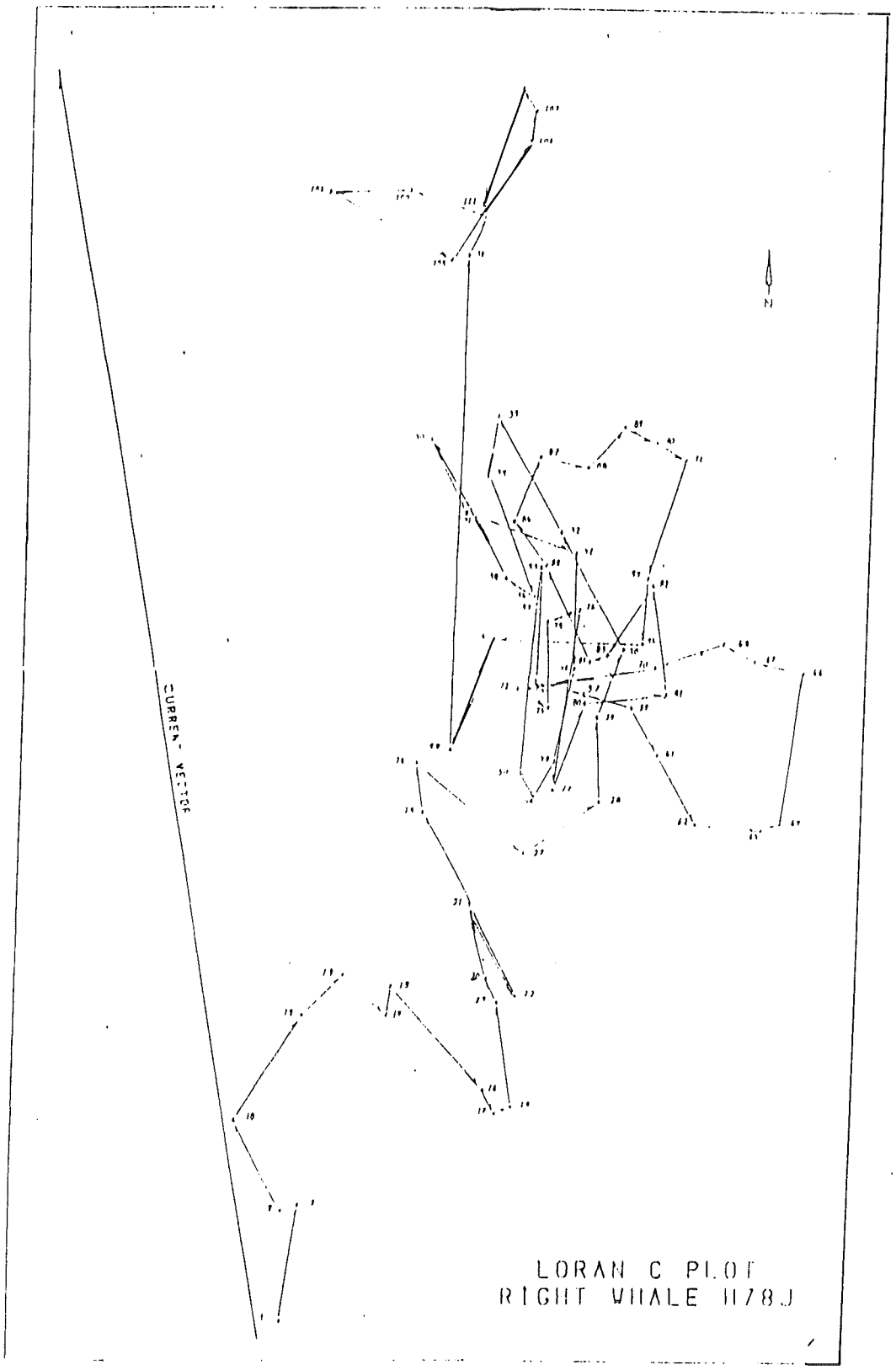


Figure 30. Drogue track and raw loran plot use to derive the relative paths Fig. 31-34

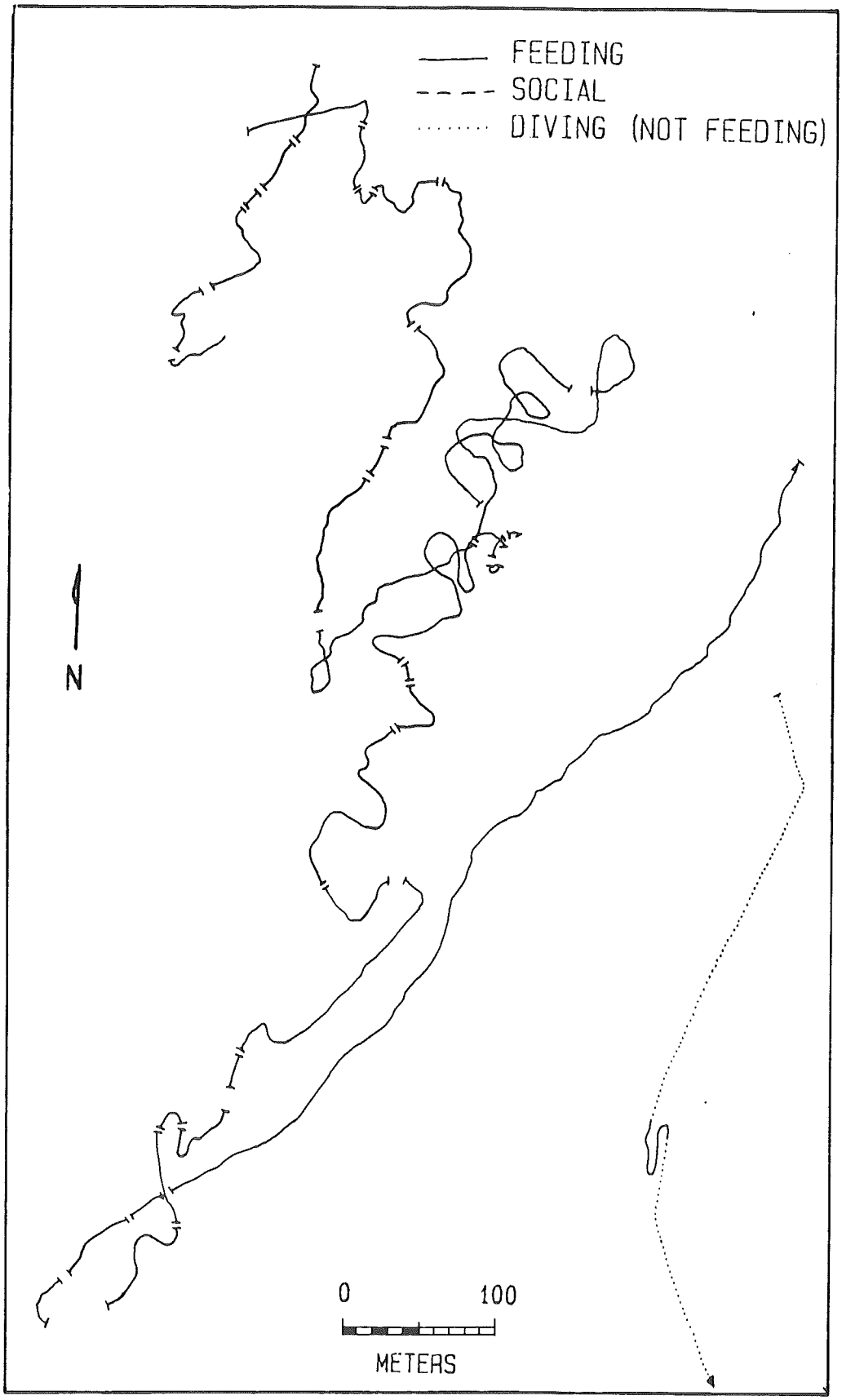


Figure 31. Feeding and diving movements of whale 2584 on 20 April 1984 between 09:59:30 and 11:55:53 Hrs. Corrected for current.

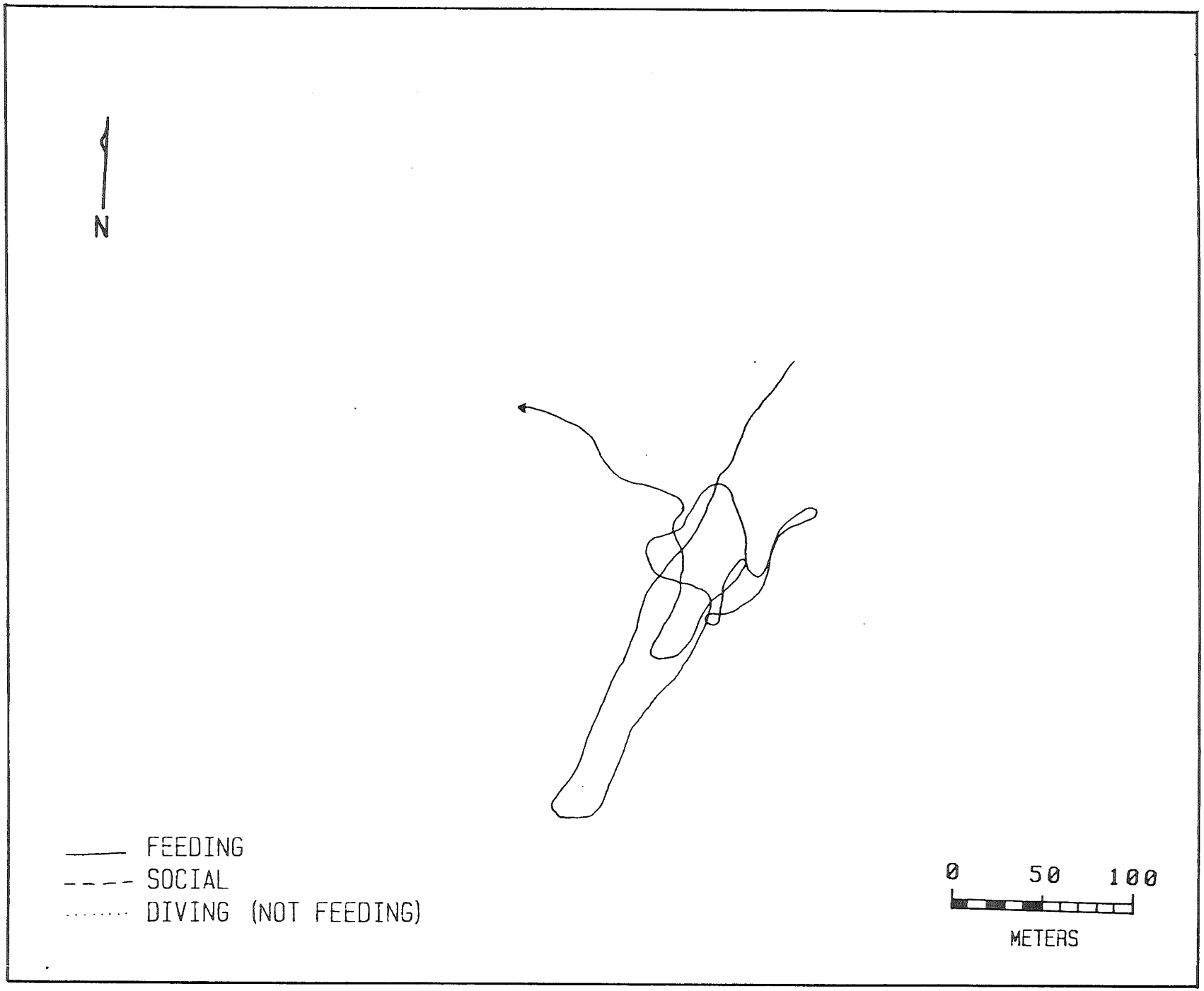


Figure 32. Feeding path of whale H76J as observed between 15:24:30 and 15:55:02 Hrs. on 11 March 1985. Corrected for current.

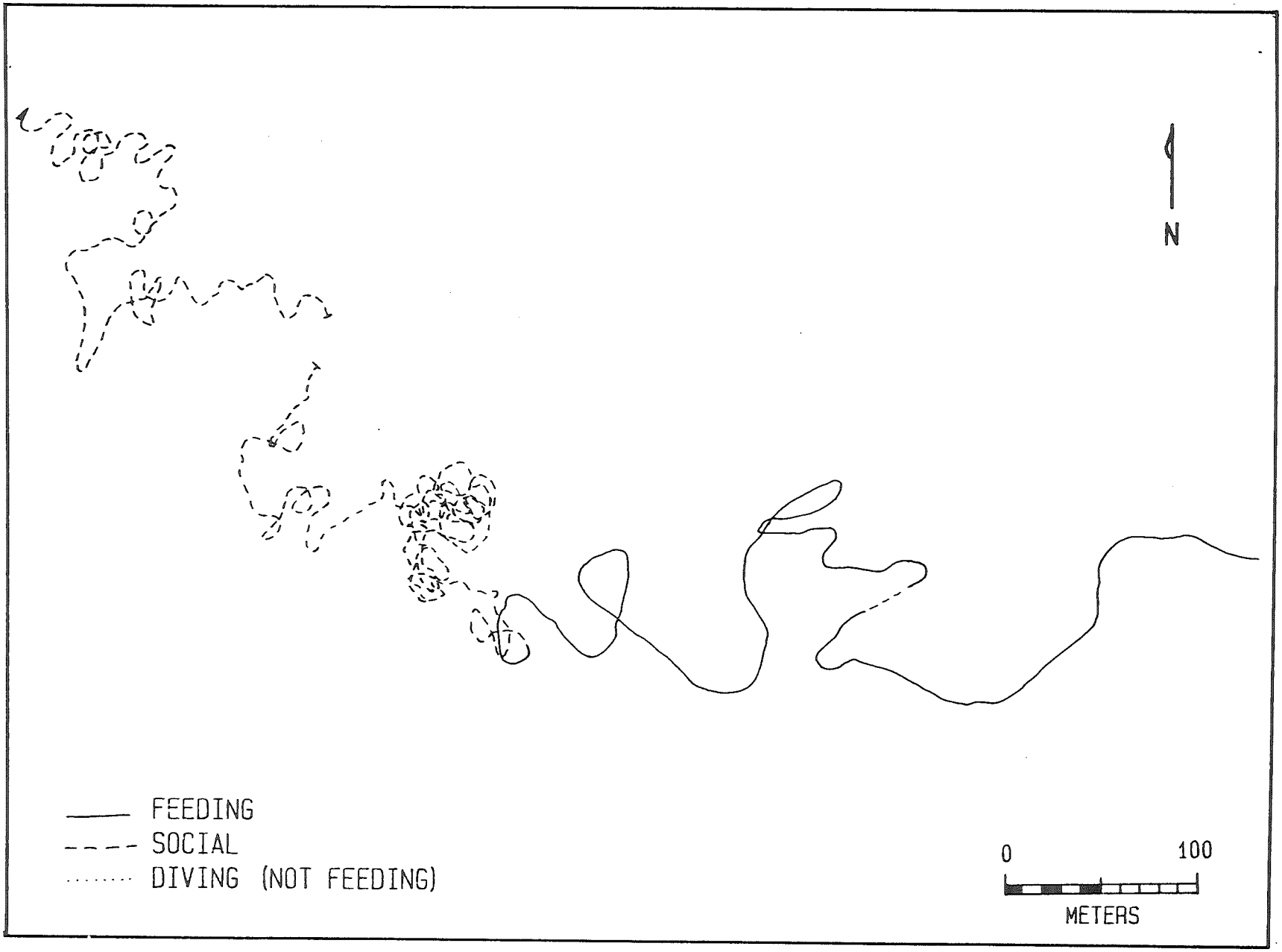


Figure 33. Swimming path of whale H79A as observed on 23 March 1985 between 16:37:25 and 18:03:35 Hrs. Correctd for current.

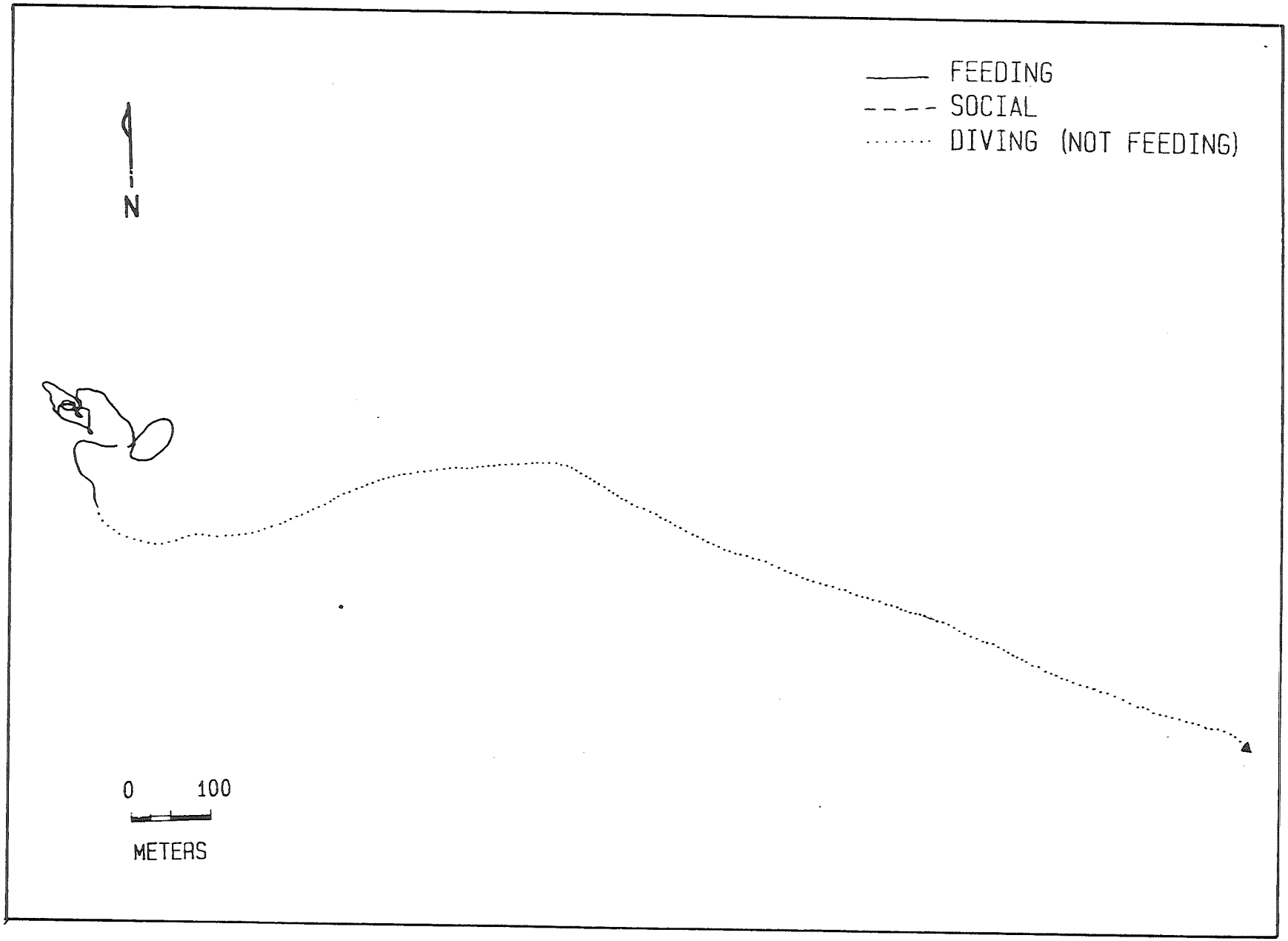


Figure 34. Swimming path of whale H83C on 29 March 1985 between 17:07:45 and 18:14:30 Hrs. Corrected for current.

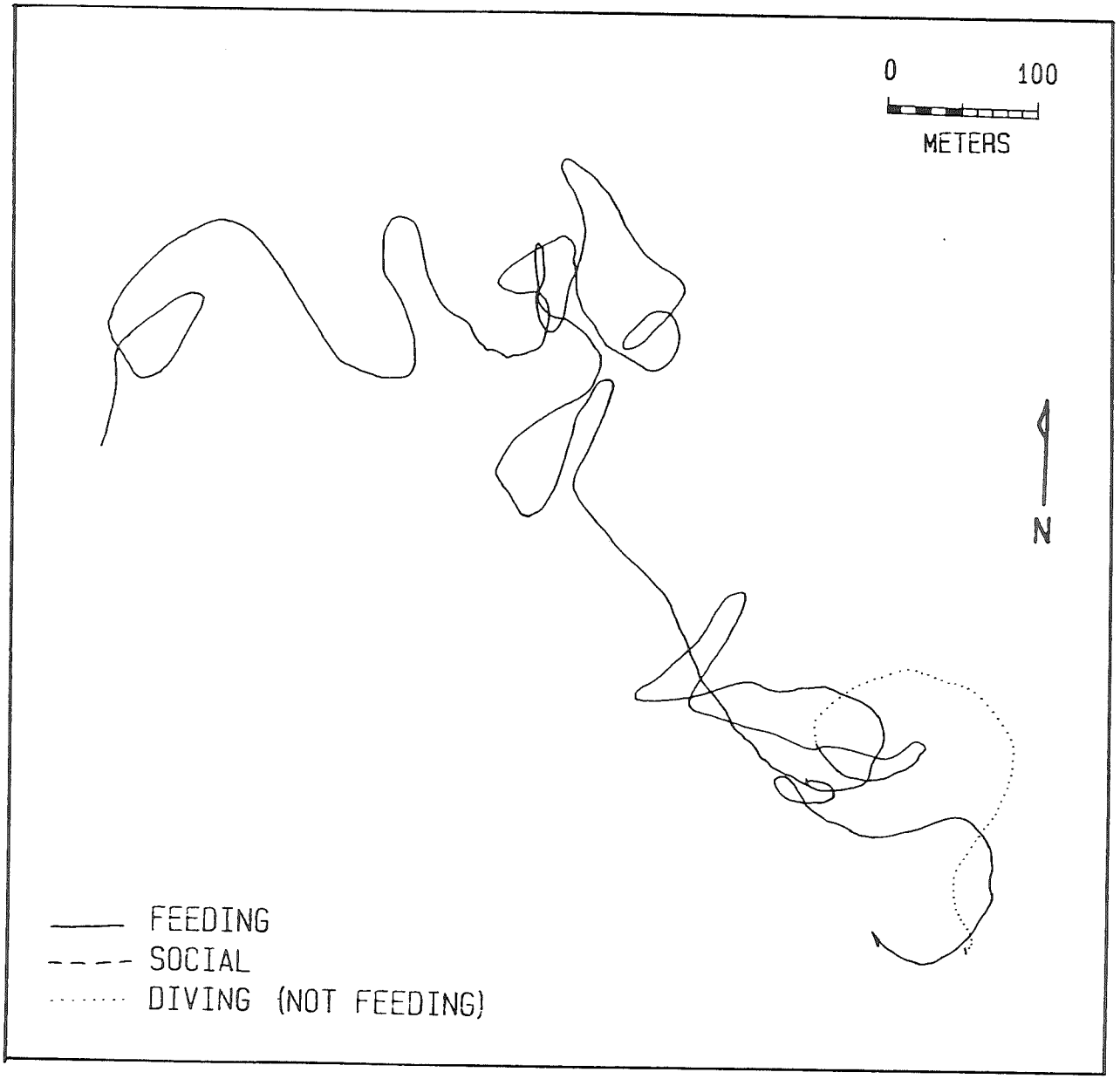


Figure 35. Feeding path of whale H78J on 22 March 1985 between 13:42:29 and 15:04:3, Hrs. Corrected for current.

-Energetics

Using plankton density data and foraging path distances corrected for current, we estimated food intake in an effort to quantify the energy needs of the whales of the region. For such calculations, the unrestricted gape was estimated at 1.1 M2, a value within the range of gape estimates made by Roger Payne (pers. comm.), and the filtration rate of the right whale was approximated by testing the filtration efficiency of baleen samples using a small scale flume.

For the filtration test, whole preserved plankton samples collected near feeding right whales were introduced into the flume at a density of 5000 organisms/M3, within the range of densities observed in the field. Even though the baleen material used in the test appeared of poor quality, the results, comparing injected densities and calculated capture by taxon, indicate that more than 90% by number of the zooplankters collected in our 471 micron nets were captured by the baleen used in the test (Figure 36).

Results from the preliminary flume tests suggest that the capture of zooplankton collected at 333 microns is below 70%. Our zooplankton data therefore likely represents a reasonable, if conservative estimate of zooplankton intake.

We have calculated the zooplankton volume and caloric intake for the foraging paths described above using 3 caloric values for zooplankton samples: (1) those obtained for whole plankton samples collected during the study and which averaged an unexpectedly low 485 KCal/Kg wet weight, (2) 1000 KCal/Kg wet weight, a more reasonable estimate for caloric content, and (3) in the case of whale H83C, foraging on a barnacle swarm, the value of 470 KCal/Kg as determined by lab analysis. The results of these calculations are presented in KCal intake/min. (Figure 37).

For comparison with these caloric estimates, the proposed threshold of 1000 zooplankters/M3 for the copepod rich samples would equal 0.73 g/M3 wet weight.

In summary, our preliminary food and feeding studies indicate that:

(1) right whales prefer feeding on zooplankton patches dominated by calanoid copepods and barnacle larvae;

(2) the lower limit for our observation of feeding was at patch densities of 1000 zooplankters/M3 or approximately 0.73 g/M3 wet weight (copepod - rich samples);

(3) the foraging paths of feeding right whales are convoluted, typical of area restricted searching patterns (krebs, 1974);

(4) the caloric intake calculated from our observation ranged from 10 to 102 KCal/min. at velocity between 0.5 to 1.8 meters/sec.

Our calculations place the <u>maximum possible</u> intake for the observations using the <u>highest</u> observed velocity and patch density and the unlikely <u>maximum</u> feeding time of 24 hours at 146 Kg/day or 146,000 KCal/day. The

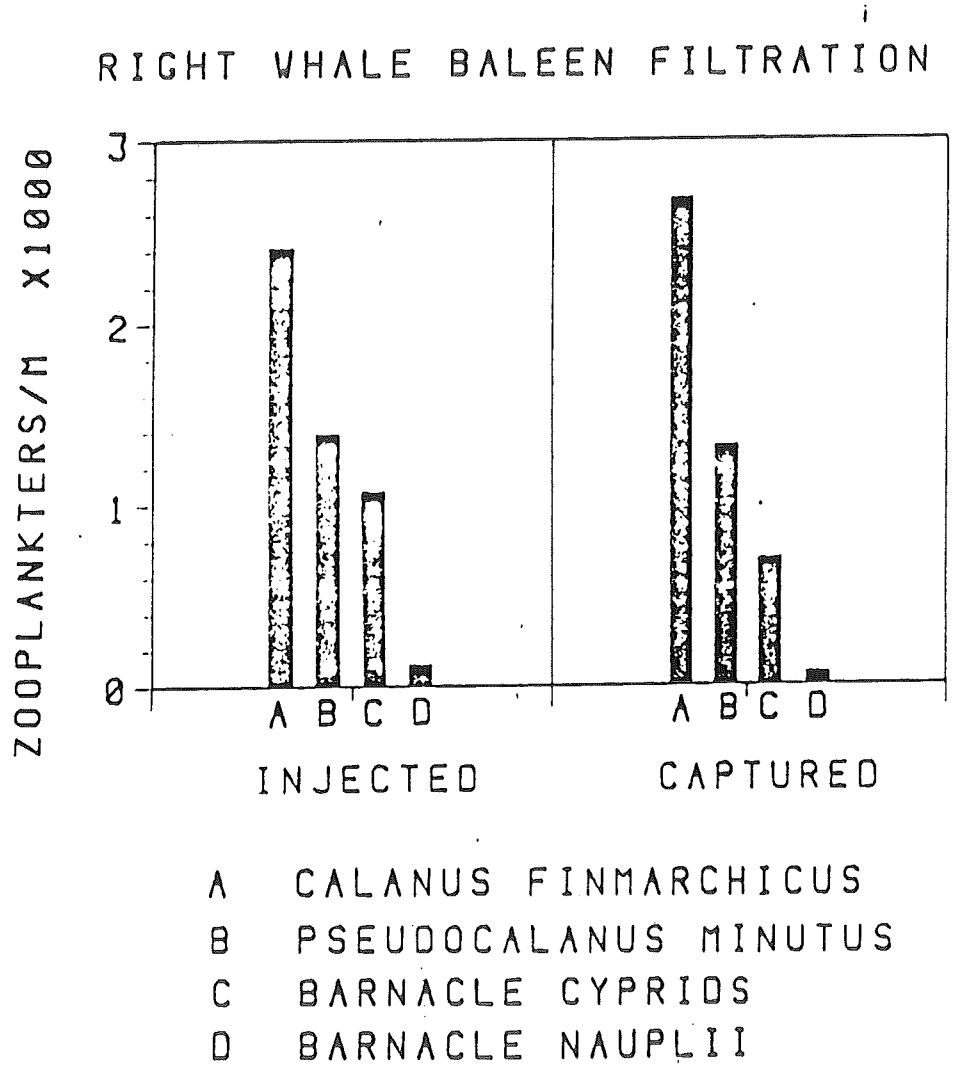


Figure 36. Flume test: capture of mixed zooplankton samples by right whale baleen.

CONSUMPTION OF ZOOPLANKTON

OBS.	VEL. M/SEC.	CONSUMPTION RATES/MIN WET WT. g/MIN.	(1) Kcal/M	(2) Kcal/M
H43	1.87	102.4	49.7	102.4
H76	0.53	72.5	35.0	72.5
H78	0.50	21.9	10.7	21.9
H79	0.56	60.2	29.2	60.2
H83	1.21	45.3	21.3 (3)	——

(1) AT 485 Kcal/Kg WET WEIGHT
(2) AT 1000 Kcal/Kg WET WEIGHT
(3) AT 470 Kcal/Kg WET WEIGHT

Figure 37. Estimated caloric intake by right whale observation based on laboratory estimates of caloric content (notes 1 and 3) and caloric content estimated from literature.

values from this scenario are nonetheless so low as to place such a whale in a radical energy deficit condition by present estimates of energy requirements (Lockyer, 1981).

- Preliminary 1986 Observations

Although the 1986 field season was not completed at the time of the writing of this report, the following information is included as general comments on right whale distribution and behavior during the 1986 season.

(1) Whales were observed in Cape Cod Bay from February through early April. Courting, feeding, resting, and nursery behaviors were observed as in past years, however, feeding whales were less often found than in the previous two years.

(2) Despite increased searching in the region, no whales were seen in the Stellwagen Basin during 1986.

(3) Mother/calf pairs which were common in 1986 in the region of the Basin were seen as transients in the area of Stellwagen Bank and near the north shore of Cape Cod.

(4) Plankton patches in the feeding areas appeared as dense as had been observed in 1984 and 1985, however their extent seemed smaller.

(5) With the exception of one mother/calf pair, the last right whales were observed in the Massachusetts and Cape Cod Bays in mid-April.

(6) The absence of whales in the western region of the Bank was confirmed by once weekly aircraft surveys flown in conjunction with a menhaden spotting program flown by Boston Edison, Inc.

DISCUSSION

-Demographics and Distribution

Although the studies described above are preliminary, some broad inferences may be made about the right whale presence in Cape Cod waters from the data collected during 1984 and 1985.

Although the surveys for right whales were severely restricted by weather conditions and lack of large vessels, the data suggests that whales enter the region of Cape Cod and Massachusetts Bays in numbers sometime between the fifteenth of December and the thirtieth of January. It is not presently clear, because of the preliminary nature of the studies, how many whales enter at that time of the season and whether such whales become resident within the area. These significant remaining questions will be addressed in future investigations of the area.

Distribution patterns observed during our study suggest that the highest concentrations of whales are to be found in two locations within the study area: (1) within the confines of Cape Cod Bay, east of a line from Race Point

through the Fishing Ledge to the Barnstable shore (eastern Cape Cod Bay), and (2) at a location, discovered in 1985 studies, in the deep water basin west of Stellwagen Bank approximately twelve miles north-northwest of the Race Point Lighthouse (Stellwagen Basin). After two years of intensive investigation in the eastern Cape Cod Bay region, with support of data collected during the spring of previous years by whale watching boats and our research vessels, we can predict that a concentration of right whales will be found each year in the eastern locations of the Bay during a great part of the winter and early spring. The distribution data for this location indicates that the whales, in dispersed groups, are found throughout the eastern Bay region. Although more information from this area needs to be collected, our observations suggests that the whales in these aggregations generally cycle from early sightings (February and early March) along the Barnstable shore in the southern and southwestern sections of the Bay to later sightings along shores of Wellfleet and Truro, finally to be found at the end of their residency (mid to late April) along the coast of Provincetown. This broadly counterclockwise movement, if borne out in future studies, is generally similar to the movement of right whale groups observed by Roger Payne (pers. comm.) in Gulfo San Jose, Peninsula Valdez, Argentina. The significance of such a broad distribution pattern to habitat use and our interpretation of it, has yet to be determined. Payne has suggested that such a movement is a reflection of larger migrational patterns within the species. In Cape Cod Bay, the documentation of such a predictable pattern may permit a more reasonable management of the right whale populations and of potential environmental disruption.

The individual identification of right whales and a comparison with mother/calf pairs seen in the region during the period of early to mid - April does not support the contention that right whale calves are born within the Bays, as they are at Peninsula Valdez. No mothers observed in the last two years of study were seen in the area preceding an observation of them with a calf. Nevertheless, Payne (pers. comm.) does believe that calving along the eastern shores of Cape Cod preceding entry into the region is possible. When mothers and calves are observed in Cape Cod Bay, they are often found on the periphery of groups of socially active or feeding whales. The most remarkable characteristic of distribution seen at Valdez, a sharp peak of concentration along the five meter contour, is not observed in Cape Cod Bay, even though the Bay is geologically similar to Valdez and at the same general latitude. Although whales are occasionally observed within one hundred meters of the Cape Cod shoreline and in water depths below ten meters in depth, no distinct peak in concentration within the shallow water regions of the Bay system is apparent in our data.

The composition of the population in Cape Cod Bay and in the Stellwagen Basin area is being analyzed at this time. We do know that a number of the whales observed in 1985 were seen in the area in previous years and that the general composition of the population in either of the two identified locations includes juveniles, adults, males, and females.

The Stellwagen Basin location is of considerable importance in our overall understanding of the habitat use patterns of the right whales of the region as the animals in that location display the distinctive aggregation patterns which are characteristic of socializing right whales in behavior described as courtship or pre-courtship (Payne, pers. comm.; Kraus, pers. comm.). The

whales observed west of Stellwagen Bank in 1985 did not display the distinctive activities of skim feeding seen within the Cape Cod Bay system. We believe that deep feeding may be a characteristic of the Stellwagen Basin area. This aggregation of fifteen to twenty-five individuals was likely the result of the whales' response the two imperatives: feeding and socializing, already suggested for Cape Cod Bay. Stellwagen Basin is geologically, hydrologically, and oceanographically very different from the eastern Cape Cod Bay system where the whales are usually found, and clearly does not represent a habitat similar to that studied by Roger Payne in Argentina. A great deal more information must be collected from the Stellwagen Basin area to permit a detailed analysis of the demographics of the population found there and to confirm that the location is a yearly aggregation location. The general composition of the population does look, on preliminary review, to be similar to that of Cape Cod Bay. Significantly, our initial analysis suggests that the group of fifteen to twenty-five whales seen in each location may not have large numbers of overlapping individuals. Therefore, the two locations may be seen as semi-isolated population units in different environmental settings distinguished by somewhat different behaviors but similar in their response to imperatives including feeding and socializing.

During 1984 when all of our observations were restricted to the Provincetown area, we observed the departure of right whales from Cape Cod Bay during the period of 1 to 7 May. In 1985, departure from the eastern Cape Cod Bay appears to have taken place during the second week of April while the Stellwagen Basin departure probably occurred during the third week of April of 1985. The change in dates of departure from Cape Cod Bay from one year to the next suggests a degree of flexibility of habitat use that might be expected of an animal depending on a patchy and variable resource for feeding (plankton) and socializing (other right whales). The controlling factors in the presence of right whales and their period of residency will be the subject of extensive future investigations.

-Food and Feeding

Direct observation of feeding of North Atlantic right whales, primarily in the Cape Cod Bay area, suggests that the whales depend on the oceanographic and biological characteristics of the system that result in dense swarms of plankton. Our data indicate that right whales prefer concentrations of zooplankton exceeding 1000 organisms per cubic meter. Our overall sampling suggests that such patches are relatively few and far between, that right whale patchiness is directly related to zooplankton patchiness, and that right whales might depend on a very sensitive combination of sensory stimulation and searching behaviors to locate plankton patches. That the interpatch distance is great and the acceptable patch characteristics are relatively ephemeral, further implies a system which is likely very sensitive and easily disturbed. Although we can make some preliminary estimates on feeding threshold, we cannot, at present, characterize either (1) the mechanisms by which the zooplankters swarm or (2) the techniques the right whales use to sense the acceptable food patches.

Estimates of consumption reported here are clearly at variance with caloric inputs estimated from Lockyer's (1981) theoretical models of whale metabolism This variance further suggests that the right whales may be in a state of

delicate energy balance. The following are several explanations of the variation from the theoretical consumption estimates which our data express:

1. Right whales may be feeding on much smaller prey organisms than our filtering data suggests. At present we believe that nets of 333 mircrons mesh size may best approximate the feeding mesh of right whale baleen. If this approximation is correct, it does not in and of itself explain the large variation from the theoretical estimate.

2. Micropatchiness which is not samplable with our equipment may be exploited by right whales. If errors due to micropatchiness are introduced we might imagine that a very thin but extraordinarily dense layer of zooplankton is being consumed by right whales and that our net tows are averages of dense layers and much less dense adjacent layers. Error due to micropatchiness might as easily be seen in the horizontal as in the vertical plane. Although such an error could explain the variation from theoretical estimate no indications that sucn small scale patchiness is indeed occurring have been shown. Our sampling techniques depended on tows taken within several meters of the feeding path suggesting that micropatchiness must, if present, have a very fine structure indeed.

3. Zooplankton samples taken near the feeding path of right whales may be a proportional but fractional reflection of the plankton density being consumed by right whales because of net and vessel avoidance by the prey. Correlated with this potential error is the possibility that highly mobile and therefore unsampled zooplankters may be consumed by right whales; in such a hypothetical situation right whale avoidance must also be considered.

4. The theoretical estimates of right whale consumption may be based on false premise. Gaskin (pers. com.) has suggested that right whales metabolism and general activity may be very different than the Lockyer (1981) model which generally applies to balaenopterid metabolism.

5. Feeding activities of Cape Cod Bay may not be representative of normal feeding behavior of right whales. In such a case, our estimates of intake and consumption would be considered correct, but in Cape Cod Bay the whales are only "cutting their losses", that is, feeding in a suboptimal area at rates which are indeed too low to maintain normal metabolic and energetic requirements. Such an explanation (suggested by Gaskin, pers. com.) is, of course, possible; however, the relatively long residency of feeding whales in the region implies that this cannot be a suboptimal feeding area.

Generally we favor the likelihood that possibilities 2 and 3 explain the potential variation from the theoretical caloric intake estimate.

-Significance to Conservation of the Species

Our preliminary studies suggest that Cape Cod Bay and Stellwagen Basin represent two of what may be many small group aggregating areas for right whales. Until our studies of 1984 the prevailing theory on distribution and

movement of North Atlantic right whales held that virtually all whales moved south along the Atlantic seaboard to the region east of the Hatteras Capes, Georgia, and Florida. Our findings of 1984 and more numerous observations in 1985 imply that a large number of whales remain within the waters east of New England. Observations of active courtship behavior and erect penises, combined with the proper time within the reproductive cycle of the species as presently theorized, indicates that successful copulation may be occurring within the study region. If a significant portion of the North Atlantic right whale population is found within the area studied for the last two years, an area near intensive human activities, then these findings may significantly affect management decisions regarding the species. The following information collected during this study will require consideration by wildlife managers to insure the conservation of the remaining whales of the North Atlantic in Cape Cod waters:

1. Mothers and newborn calves were present, with three to six new calves in the area in 1985,

2. Perhaps more than forty right whales were present (often resident) within the restricted area of our surveys; this may be a seventh of the right whales estimated to remain in the North Atlantic Ocean. These numbers are the result of a relatively small number of limited searches,

3. Courtship and successful mating may occur within the study area during mid-winter,

4. Feeding is an important part of the behavior of resident right whales in the winter,

5. Right whale feeding is dependent on potentially sensitive physical and biological processes which result in the swarming of zooplankters,

6. Acceptable plankton patches are characterized by small "within-patch" area, large interpatch distances, and relatively short term aggregation,

7. Right whales resident in the area do not feed enough to meet basic metabolic needs as determined by theoretical energetic models,

8. Right whales may aggregate in nuclear groups of approximately twenty individuals,

9. Two right whale groups observed in 1985 were found in the vicinity of two locations considered by government agencies for dredge spoil disposal.

Many of the vital questions related to management and protection of North Atlantic right whales will be answered only after more thorough investigation of the winter and early spring residency documented during the 1984 and 1985 studies. The real significance to the future of North Atlantic right whales of such on-going studies remains to be determined, but clearly, the importance of Cape Cod Bay and Massachusetts Bay in the maintenance and increase of right whale stocks in the North Atlantic may be great. The collection of basic information on the species in our study area is crucial. While such studies

are clearly recommended it should be noted that winter research on whales is often hampered by exceedingly difficult weather conditions. Our studies of right whales and other species during the mid-winter are, on the other hand, aided by the fact that we are located in a harbor very easily accessible to the habitats under study using a research vessel outfitted for winter work and carrying all the specialized safety equipment needed to permit such investigations.

- Significance of the Stellwagen Basin to Right Whales

During 1985 and 1986 several cruises were made into the region west of Stellwagen Bank, as described in this report. Although the observations were severly limited by inclement weather and inadequate funding, the residency of right whales in the Basin region in 1985 and the lack of whales in 1986 was confirmed; such a change in occurrence suggests the flexibility in habitat use predicted by our observations of feeding strategies. The information on feeding paths of right whales supports a view that they respond flexibly to the distribution and abundance of prey organisms, searching widely until rich patches are discovered and then remaining in the vicinity of the patch as long as the density is acceptable. In the Basin area, variations in zooplankton density might be reflected in variations in right whale density. The Basin area may, therefore, be a significant and critical habitat for right whales when food resources "bloom" in the winter and spring, while, on subsequent, less productive years it may be a relatively unimportant habitat. Only continued monitoring of the region coupled with intensive studies of prey densities will permit an accurate assessment of the importance of the Stellwagen Basin to right whales.

Occasionally the Stellwagen Basin may be a significant habitat for the feeding of the North Atlantic right whale, therefore an assessment of the potential impacts of human activities on the species is warranted. Generally, activities which affect (1) zooplankton density, swarming, and general patch character, (2) the suitability of the zooplankton as a food (through toxic pollution or reduction of the nutritional content by affecting the phytoplankton community), and (3) the general marine ecosystem resulting in modification of the environment (by noise production, changes in water quality, or increased vessel traffic) may have an impact on the whales. Although these alterations in the habitat of the right whales might be expected to have an impact, it is impossible at present to predict the degree of impact or its significance to the species.

V. DISTRIBUTION OF CETACEANS IN WATERS WITHIN AND IMMEDIATELY ADJACENT TO THE FOUL-AREA DISPOSAL SITE (FADS) BASED ON AERIAL SURVEYS, JANUARY - JUNE 1986

P. M. Payne and L. A. Selzer

Historically, assessments of whale abundance or stock size were based on catch statistics and life-history data derived from commercial harvesting. Only recently have methodologies and analytical procedures focused on direct survey methods. Line-transect and strip-census survey methods have been applied successfully to terrestrial populations (Burnham et al. 1980), however, the application of these procedures to marine mammals is recent and requires modification owing to the unique problems involved in surveying marine mammals. Eberhardt et al. (1980) outlined these difficulties using several different survey procedures. Scott and Winn (1980) reported on the development of whale survey methodology (particularly surveys conducted from ships). The Cetacean and Turtle Assessment Program (CETAP) of the University of Rhode Island, sponsored by the Bureau of Land Management, developed aerial survey methods and analytical procedures to assess the spatial and temporal distribution of cetaceans and turtles in the shelf waters of the northeastern United States (Kenney and Scott 1981; Scott et al. 1981; CETAP 1982). Hay (1982) used these methods to survey populations of large whales in the coastal and offshore waters of eastern Newfoundland and southeastern Labrador. A summary and discussion of the methodologies and analytical procedures employed by CETAP was provided by Scott and Gilbert (1982) and CETAP (1982). During the aerial surveys of cetaceans in the FADS between January and June 1986, these methods were applied wherever applicable.

The study area was defined to include the three 10' latitudinal block sampling areas in Massachusetts Bay surrounding the FADS (see Fig. 2). The inner 10' block (Subarea A) is bounded by the coast of Massachusetts Bay. The middle 10' latitudinal block (Subarea B) contains the Foul Area Disposal site. The outer 10' block (Subarea C) is bounded on the east by the northwest corner of Stellwagen Bank.

In this study, emphasis was placed on three endangered species of whales, the humpback whale *Megaptera novaeangliae*, the fin whale *Balaenoptera physalus*, and the right whale *Eubalaena glacialis*, all of which use Stellwagen Bank and the surrounding waters extensively for feeding.

Aerial Survey Methods

Six surveys were flown (one per month) between January - June 1986. The transect line flown is shown in Fig. 38. A total of 221.5 nautical track miles was flown during each of the surveys. The survey effort was divided approximately equally between each of the three 10' survey blocks (Table 11). The transect line forms a Z-pattern which is flown in one direction, then again in the reverse direction during each one of the surveys. The northernmost transect line runs through the immediate area of the FADS disposal site (see Fig. 38). The surveys were flown at an altitude of 750 feet and an air speed of 120 knots/hr. The surveys were conducted only during sea conditions with a Beaufort Sea Scale equivalent of less than 3 (windspeed less than 16 nm/hr) and during times of unlimited visibility. The survey track was independent of any previous discussion concerning whale distributions and abundance in these waters, (i.e. these transects were not designed along expected clines in whale density (following Scott and Gilbert 1980) nor were areas of increased whale density, based on results of previous surveys, surveyed with greater frequency).

The sampling platform employed in the aerial survey was a single engine Cessna 182 equipped with a Loran Navigation System. The survey team consisted of a pilot/navigator, and two observers. Each observer was responsible for

Table 11. The number of linear km flown in each of three 10'-survey blocks within the FADS study area by month.

Survey Period	Subarea A (western boundary)	Subarea B	Subarea C (eastern boundary)	TOTAL
January	70.2	74.2	77.1	221.5
February	70.2	74.2	77.1	221.5
March	70.2	74.2	77.1	221.5
April	70.2	74.2	77.1	221.5
May	70.2	74.2	77.1	221.5
June	70.2	74.2	77.1	221.5
Total	421.2	445.2	462.6	1329.0

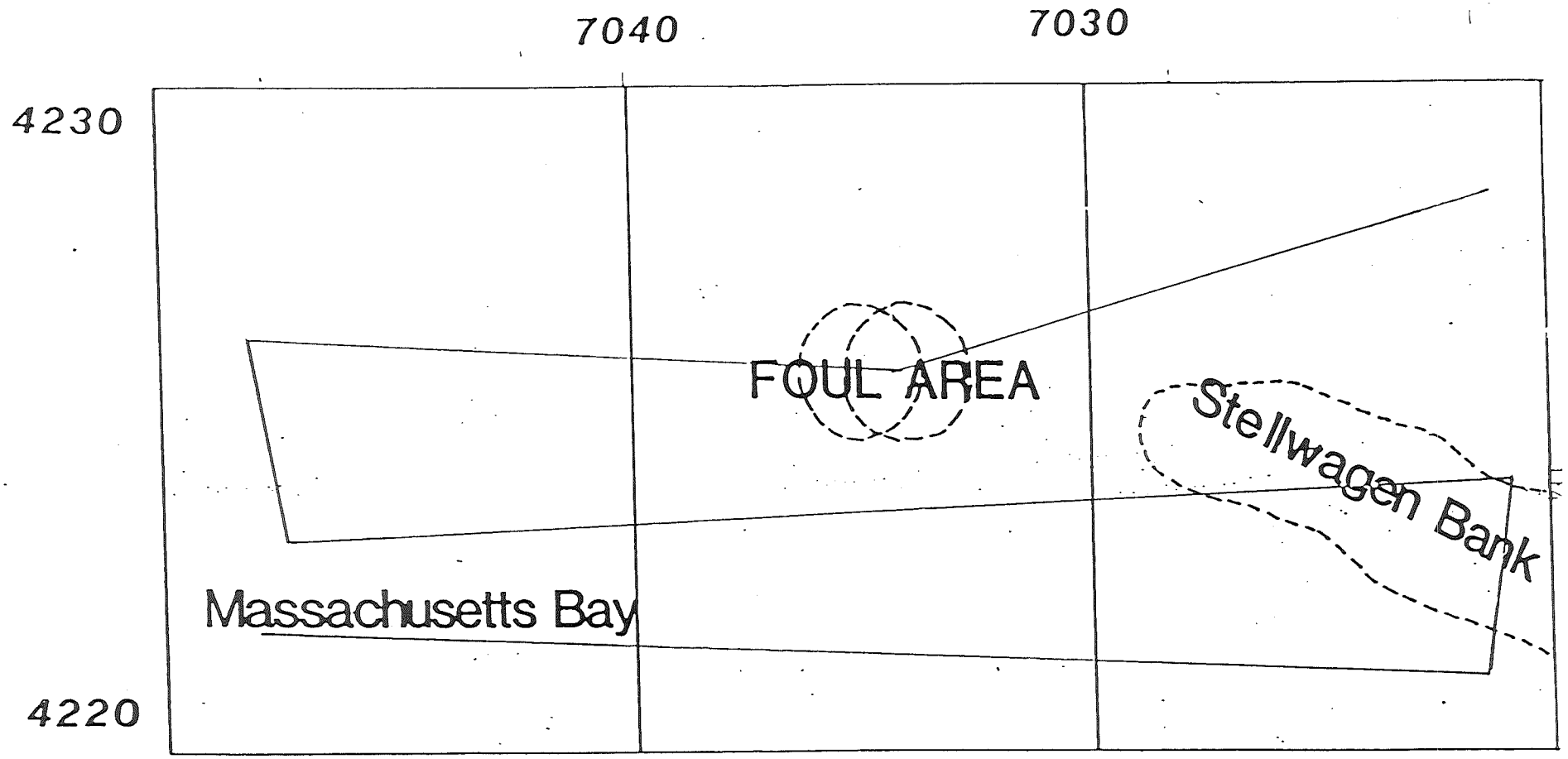


Figure 38. An outline of the study area showing the location of the Foul-Area Disposal Site and the northwest corner of Stellwagen Bank relative to the flight path of the aerial survey.

reporting sightings of cetaceans in his respective field of view (from the trackline to approximately 90° port or starboard). Sightings were classified to a right-angle distance interval away from the transect line using two techniques. CETAP (1982) and Hay (1982) used a reference scale based on degrees of declination below the horizon. The reference scale was calibrated for a survey altitude of 750 feet below the visual horizon as reported in Kenny and Scott (1981). The right-angle distance intervals based on this reference scale were as follows: 0 - 0.25, 0.25 - 0.50, 0.50 - 0.75, 0.75 - 1.00, and > 1.00 nautical mile. Sightings were classified as to a right-angle distance interval when the sighting was directly abeam of the aircraft. In addition, when the sighting was abeam of the aircraft, the aircraft could break away from the track-line in order to identify and count the animals in each group. When the airplane was directly over a sighting, a position was taken in order to plot the exact location of each sighting. The perpendicular distance between the transect line and position of sighting also was used as a second measurement of right-angle distance. If another sighting was noted while circling the first sighting, then the second sighting was approached for identification purposes. If the subsequent sighting was of the same species as the original sighting, then the count for the second sighting was included with that for the original sighting and the total was called the primary sighting (following CETAP 1982). Only primary sightings (sightings from the track line) were included in the abundance estimates. Subsequent sightings of different species were called secondary sightings and not considered in density estimation. This ensures that sightings are independent, an important assumption of line-transect theory (Burnham et al. 1980). After a sighting was investigated, the pilot/navigator took the aircraft back to the break-off point and the survey was continued along the transect line.

Several differences exist between the CETAP survey methods and those employed in the present study. The most obvious and potentially most important difference is between survey platforms. CETAP surveys were conducted in a twin-engine BEECHCRAFT AT-11. The specifications of this aircraft are described in Scott and Gilbert (1982). The BEECHCRAFT AT-11 has a forward observation blister which allows for unrestricted visual observations along the trackline directly below the aircraft. The CESSNA 182 employed in the present study did not have a similar blister, resulting in an "exclusion area" (an area of obstructed downward visibility) along the transect centerline. Potentially, this violates one of the fundamental assumptions of line-transect theory, that all animals along the transect line can be seen (Burnham, et al. 1980). The obvious complication is that estimates of density may be biased downward, however, this problem was addressed by Leatherwood et al. (1982). The extent of this complication is in large part due to the effective width of the "exclusion area." The CESSNA 182 we used is equipped with bubble windows along each side of the aircraft which facilitate downward viewing, therefore the effective width of the "exclusion area" was the width of the aircraft only, or approximately 5 feet on either side of the transect line. Given the conspicuousness of the target species in this study (i.e. large whales) and the width of the "exclusion area" relative to the right-angle distance intervals employed in this study, we suggest that any possible negative effects of the "exclusion area" on the estimates of density are not significant.

Environmental variables were not recorded in this study. Emphasis was placed on the location and observed behaviors of cetaceans relative to the FADS.

Abundance Estimation

Estimates of relative densities and abundances in FADS were made using line-transect sampling theory. Density estimates (D) are as follows:

$$D_t = \frac{n_t f(o)}{2 L_t}$$

where L_t is the transect length sampled at time t, n_t is either the number of individuals observed per transect or the number of primary groups observed per transect, f(o) is the species-specific or species-group specific (i.e. large whales, dolphins) estimate of the sighting probability density function evaluated at a perpendicular distance from the transect of zero. Pooled primary sighting data for each species or species-group were used to estimate f(o) as follows:

$$f(o) = \frac{3\ n_1 - n_2}{2\ L_t N} \qquad \text{(following Scott } \underline{\text{et}}\ \underline{\text{al.}}\text{ 1981)}$$

where right angle distance intervals away from the track line are of equal length. Here n_1 is the number of individuals sighted in the right angle interval nearest the trackline, n_2 is the number sighted in the next, and N is the total number of individuals sighted.

The number of animals in each 10' latitudinal survey block was estimated as

$$N_t = D_t A$$

where A is the area of each of the three 10' blocks within the FADS (Subareas A, B, and C).

Estimation of f(o)

The f(o) for humpback and fin whales was derived using all large whale sightings. Hay (1982) found the sighting cues for these two species to be the same (a conspicuous blow). Therefore, the sighting curves should not differ significantly. Pooled data should increase the accuracy and precision of the estimate of f(o). This has been the standard method of treating sighting data in previous studies (Scott et al. 1981; CETAP 1982; Payne et al. 1984).

Forty primary dolphin sightings and forty primary whale sightings were used to determine the f(o) for each respective group. The f(o) for large whales was 1.3498. The f(o) for dolphins was 2.5108. The effective half-width of the survey strip is equal to the inverse of each f(o) respectively. Therefore the effective half-searching width from the center transect line was 0.400 km for dolphins and 0.831 km for large whales.

RESULTS

A total of 68 large whales (42 finback and 26 humpback whales) on 40 different sightings (32 finback and 8 humpback) were observed during the January to June period (see Table 12). Finback whales were observed within all subareas of FADS and on each of the surveys. Sixty-six percent (n = 22) of the sightings and sixty-six percent of the individuals observed (n = 28) occurred in Subarea C (the easternmost subarea which includes the northwest corner of Stellwagen Bank). Ninety percent (n = 9) of the finback sightings in Subareas A and B occurred during mid-winter (January to March).

The number and total density of finbacks observed (from Table 13) were greatest during March and April. Estimated numbers within the study area ranged from two (February and June) to 51 (March), from Table 13.

Humpback whales were not observed until the April survey (Table 12). However, humpbacks were seen in the study area in late March by shipboard observers (Mayo, pers. comm.). Humpbacks were only seen in Subarea C during April and May (Table 12). The estimated number of whales in the study area during these two months was between 26 and 31 (range) (Table 13).

Humpbacks were observed bubble-feeding during the April and May surveys. Multispecies assemblages (i.e. humpbacks, finbacks and white-sided dolphins) also were observed at four different locations during these two survey periods. In addition, four humpbacks with calves were observed. All humpback feeding activity occurred along the perimeter of Stellwagen Bank.

Finback and humpback whales were the only two endangered species observed during the surveys. Northern right whales were not observed during this study.

White-sided dolphins were most abundant during March. Peak numbers (672 individuals, 27 sightings, Table 12) and densities (Table 13) occurred in the outermost quadrat nearest Stellwagen Bank.

DISCUSSION

Within the survey area, the total number of sightings and individuals observed generally increased from west to east, or in the direction of Stellwagen Bank (Table 12). Sixty percent (n = 22) of the finback sightings, 100 percent (n = 8) of the humpback sightings, and 75 percent (n = 29) of the white-sided dolphin sightings occurred in the outermost quadrat (Subarea C). The importance of northern Stellwagen Bank to cetaceans is discussed in other sections of this report.

Based on previous literature and observations, the general decrease in total sightings during May and June (Table 12) that we observed was not expected. However, during 1986, a decrease in the total number of cetaceans observed on Stellwagen Bank after mid-May, also has been reported by other sources operating in these waters. This trend was particularly evident during the June survey when only one finback whale was seen. This is the first time since 1976 that whales have left the Stellwagen area during late-spring to mid-summer. At present, no explanation for the decrease in cetacean activity can be verified, although an overall decrease in sand eel (prey) abundance has occurred (based on stomach content analyses of commercial fishes, NMFS/NEFC, pers. comm.) and may have resulted in a recent shift of feeding locations for cetaceans.

Table 12. The number of individuals and the number of sightings (in parentheses) of fin whales (upper numbers), humpback whales (middle numbers) and white-sided dolphins (lower numbers) by subarea and survey period.

Survey Period	Subarea A	Subarea B	Subarea C	Total
January	2(1)	1(1)	---	3(2)
	---	---	---	---
	---	---	---	---
February	1(1)	---	---	1(1)
	---	---	---	---
	---	---	---	---
March	5(3)	4(3)	14(13)	23(19)
	---	---	---	---
	3(1)	34(7)	672(27)	709(35)
April	---	1(1)	11(6)	12(7)
	---	---	12(3)	12(3)
	---	29(3)	19(2)	48(5)
May	---	---	2(2)	2(2)
	---	---	14(5)	14(5)
	---	---	---	---
June	---	---	1(1)	1(1)
	---	---	---	---
	---	---	---	---
TOTAL	8(5)	6(5)	28(22)	42(32)
	---	---	26(8)	26(8)
	3(1)	63(10)	691(29)	757(40)

Table 13. Density (animals/km^2) (upper number) and total estimated number (in parentheses) for fin whales, humpback whales and white-sided dolphins by subarea and survey period.

Species	Survey Period	Subarea A	Subarea B	Subarea C	TOTAL
Fin Whale	January	0.0192 (5)	0.0091 (2)	--- ---	0.0091 (7)
	February	0.0096 (2)	--- ---	--- ---	0.0030 (2)
	March	0.0480 (12)	0.0364 (9)	0.1225 (30)	0.0701 (51)
	April	--- ---	0.0091 (2)	0.0963 (23)	0.0366 (26)
	May	--- ---	--- ---	0.0175 (4)	0.0061 (4)
	June	--- ---	--- ---	0.0087 (2)	0.0030 (2)
Humpback Whale	January	---	---	---	---
	February	---	---	---	---
	March	---	---	---	---
	April	---	---	0.1050 (25)	0.0365 (26)
	May	---	---	0.1225 (30)	0.0426 (31)
	June	---	---	---	---
White-sided Dolphin	January	--- ---	--- ---	--- ---	--- ---
	February	--- ---	--- ---	--- ---	--- ---
	March	0.0536 (13)	0.5752 (139)	10.9420 (2,649)	4.0184 (2,919)
	April	---	0.4906 (119)	0.1970 (48)	0.0680 (49)
	May	---	---	---	---
	June	---	---	---	---

VI. AREAL AND TEMPORAL DISTRIBUTION AND BEHAVIOR OF RARE AND ENDANGERED MARINE MAMMALS AND TURTLES IN WATERS WITHIN AND IMMEDIATELY ADJACENT TO THE CAPE ARUNDEL DISPOSAL SITE (CADS)

P. M. Payne and L. A. Selzer

SPECIES ACCOUNT

Balaenopteridae

Fifteen sightings (33-36 individuals) of large whales (those whales with characteristic and visible spout) were recorded by the Gulf of Maine Sighting Network in the waters immediately surrounding CADS between the period 1975-1981 (Fig. 39). The presence of a visible spout indicates that sightings were of endangered Balaenopteridae, either fin whales or humpback whales; not the smaller minke whale which usually does not have a visible blow. Between these years, four positive identifications of fin whales occurred in summer (Table 14). Three sightings of humpback whales also occurred during summer and fall (Table 14). The remaining sightings were unidentified to species.

The low number of sightings in the Cape Arundel Area likely is a result of the reduced number of large whales in the immediate area of CADS, as well as the lack of survey effort in that area. Based on the available information, and the seasonal movements of the baleen whales in the Gulf of Maine, endangered species of large whales would occur near the CADS most frequently from spring through fall. There are no known concentrations of humpback whales in the waters adjacent to the CADS. The Bigelow Bight - Jeffreys Basin area is the nearest known location of large concentrations of feeding humpbacks and is located southeast of the immediate waters of CADS. The humpback sightings in the CADS area were all northeast of the CADS disposal site (Table 14). There were no obvious behaviors noted. It is likely that humpbacks move through this area in spring and fall as they travel between feeding locations in the Stellwagen-Jeffreys Ledge area and those in more northerly portions of the Gulf of Maine.

The most abundant endangered species in the area is the fin whale. A feeding concentration of six to eight fins (Table 14) was recorded on 4 June 1978 at 43°23'N, 70°15'W. Fin whales have been reported immediately adjacent to, and inshore of, the CADS dumpsite location and likely are most abundant spring through fall, but in low numbers. Schools of herring move into this region in late-summer and fall and fin whales, possibly following the movements of this prey species, appear more abundant during this period.

No other endangered cetaceans have been recorded in these waters.

Marine Turtles

Although Leatherback turtles may be found in waters of the Cape Arundel Disposal Site, no endangered or threatened marine turtles of this species have been reported in the immediate waters of CADS.

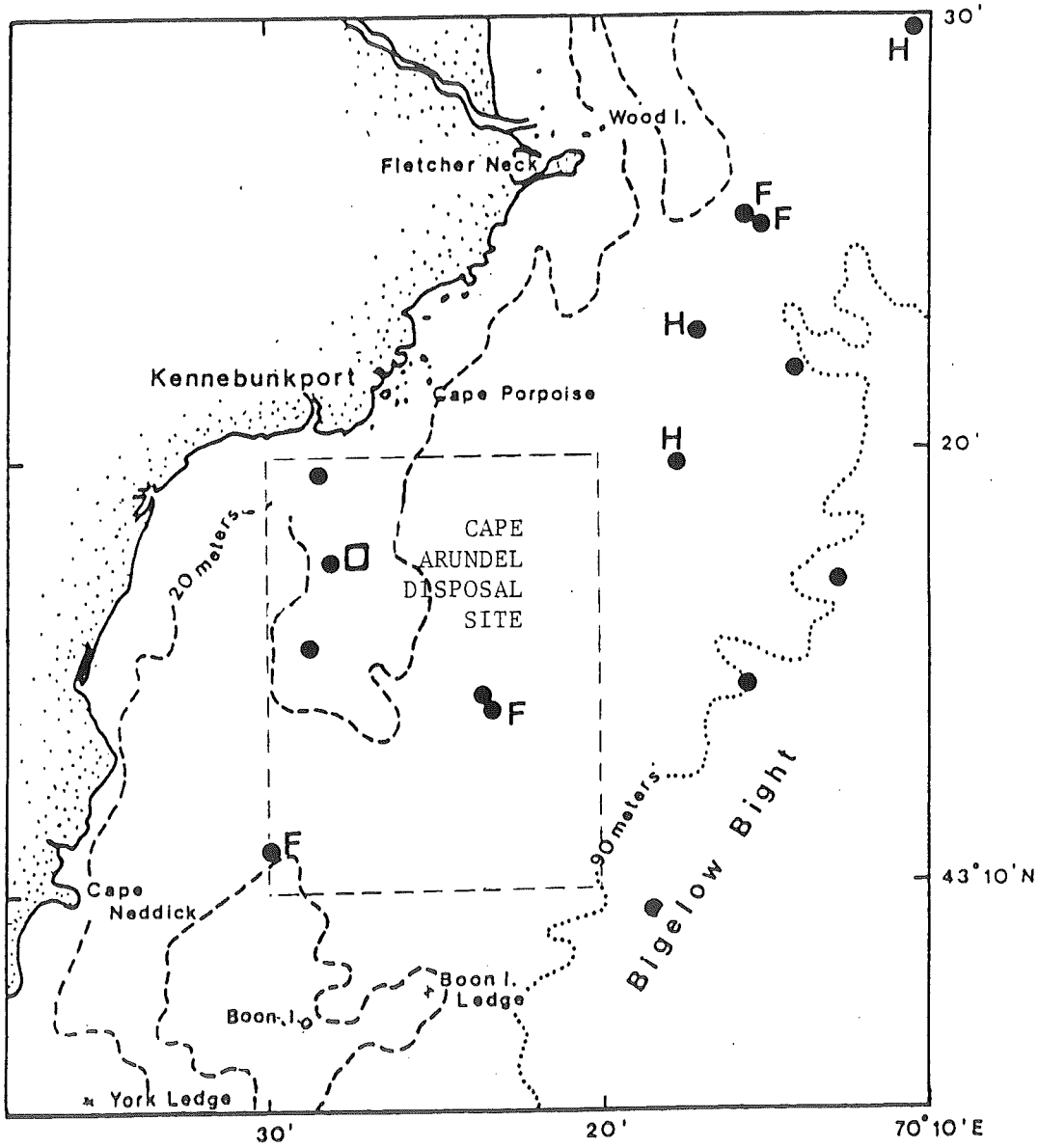


Figure 39. Sightings of endangered cetaceans within the waters of the Cape Arundel Disposal Site study area for all seasons.

Table 14. Observations of endangered species of cetaceans and marine turtles[1] in waters immediately surrounding the Cape Arundel Dumpsite.

SPECIES	DATE	LOCATION	NUMBERS
Unidentified Balaenopteridae	07 Aug 1974	43°17'N, 70°13'W	1
	10 Sep 1975	43°15'N, 70°15'W	3
	24 May 1976	43°10'N, 70°18'W	1
	27 Jul 1977	43°15'N, 70°30'W	2
	08 Aug 1977	43°19'N, 70°28'W	1
	18 Aug 1977	43°25'N, 70°17'W	2
	04 Jun 1978	43°23'N, 70°15'W	6-8
	31 Jul 1980	43°20'N, 70°29'W	2
Finback Whale	16 Jun 1976	43°11'N, 70°30'W	1
	28 Jul 1977	43°24'N, 70°16'W	1
	18 Aug 1977	43°25'N, 70°17'W	2
	26 Jun 1979	43°14'N, 70°24	2
Humpback Whale	07 Sep 1977	43°24'N, 70°17'W	3
	22 Sep 1977	43°30'N, 70°10'W	3-4
	11 Jun 1980	43°20'N, 70°18'W	1

Sources: Payne *et al*. 1984; Hain *et al*. 1981; Gulf of Maine Sighting Network, Allied Whale, College of the Atlantic 1975-1981; MBO unpubl. data 1984-1985.

[1] No marine turtles were reported.

VII. AN OVERVIEW OF THE DISTRIBUTION AND ABUNDANCE OF NON-ENDANGERED CETACEANS, PINNIPEDS AND SEABIRDS IN THE GULF OF MAINE AND ADJACENT WATERS (NORTH OF 40°00'N LATITUDE) WITH SPECIAL EMPHASIS ON THE FOUL-AREA DISPOSAL SITE AND THE CAPE ARUNDEL DISPOSAL SITE

L. A. Selzer, P. M. Payne, J. A. Brown, and A. A. Whitman

CETACEAN SPECIES ACCOUNTS

Minke Whale Balaenoptera acutorostrata

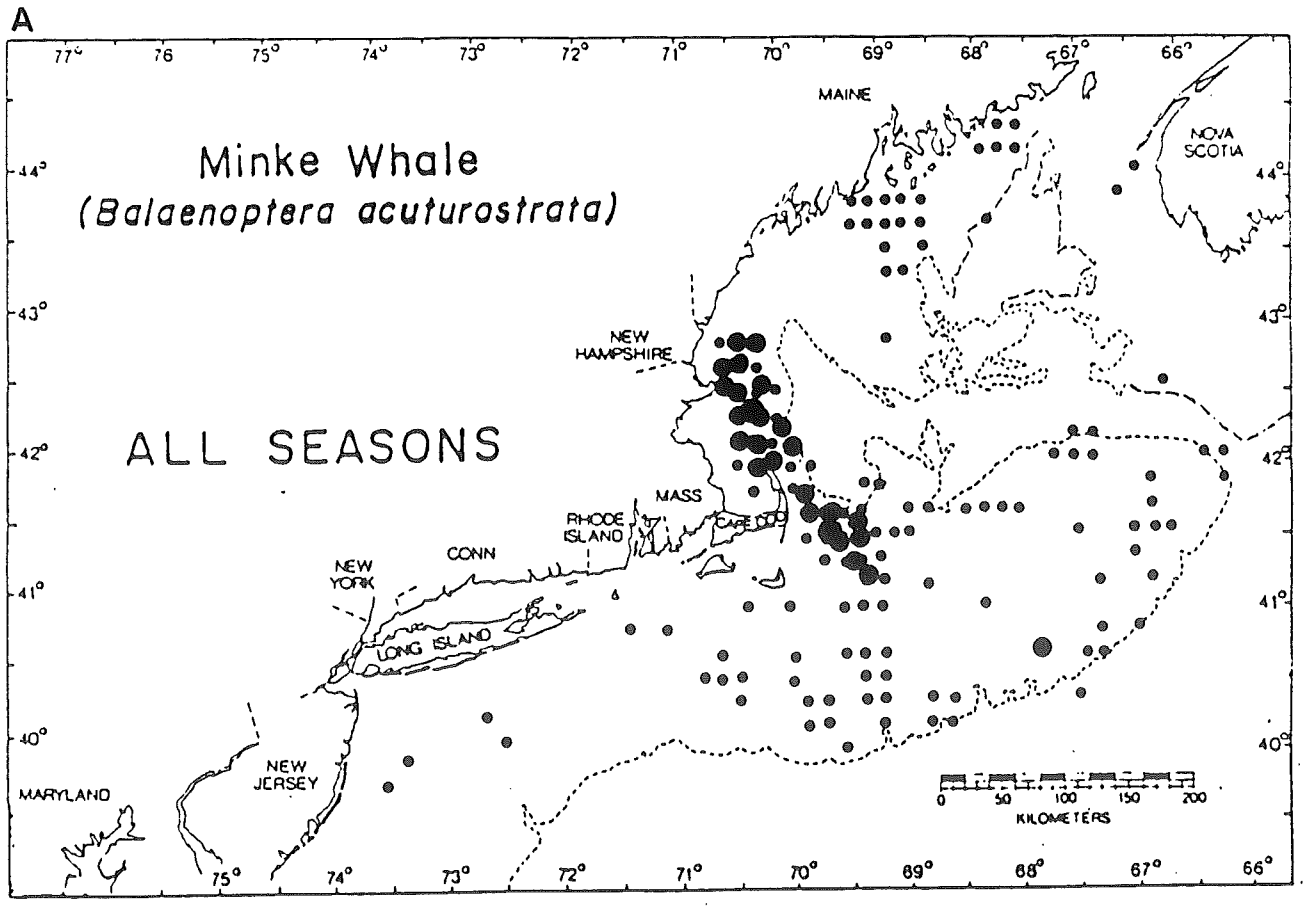
The minke whale is the smallest member of the family Balaenopteridae. The range of the minke whale in the northwest Atlantic extends across shelf waters from Baffin Island, Ungava Island and Hudson Strait south to the Gulf of Mexico and the Caribbean Sea (Sergeant 1963; Mitchell 1974c; Leatherwood et al. 1976; Winn and Perkins 1976). Seasonal north-south, onshore and offshore movements (similar to that of the finback whale) are likely. Minke whale sightings in all but excellent conditions are limited due to the inconspicuousness of the species; therefore seasonal trends are more difficult to determine. However, during spring and summer, the range of the minke whale in the northwest Atlantic extends north from Cape Hatteras.

Minke whales occupy wide regions of the shelf, especially in spring and summer. The area of greatest abundance as described by CETAP (1982) is a U-shaped area extending east from Montauk Point, Long Island, southeast of Nantucket Shoals to the Great South Channel, then northward along the 100 m contour outside Cape Cod to Stellwagen Bank and Jeffreys Ledge (Figs. 40a-e). All sightings south of Nova Scotia from mid-April to October generally are concentrated in this region (Hain et al. 1981). In late summer, their range extends into the northern Gulf of Maine - lower Bay of Fundy (Fig. 40c). Their range is contracted in fall and winter (Figs. 40d-e). Although winter sightings are reported from the Gulf of Mexico (Gunter 1954), northeast Florida and the Bahamas (Katona et al. 1977), winter sightings in shelf waters southeast of Nantucket (south of 40°00' N) are rare.

Minke whales are secondary and tertiary carnivores that feed primarily on schooling fish and euphausids (Sergeant 1963, Mitchell 1973, 1974b, 1974c, 1975c; Leatherwood et al. 1976; Jonsgard 1982). In the Gulf of Maine, minke whales eat fish, especially herring and sand eel (Katona et al. 1977).

Due to the limited detectability of this species at sea, abundance estimates based on sighting data likely are biased downward. In the Gulf of Maine, abundance estimates from shipboard surveys (MBO 1980-85) range from 30 (winter) to 520 (summer). Estimates resulting from CETAP (1982) surveys range from 0 (winter) to 113 (summer).

Figure 40. Relative distribution and abundance of minke whales in the Gulf of Maine, including Georges Bank (north of 40°00'N latitude) by season.



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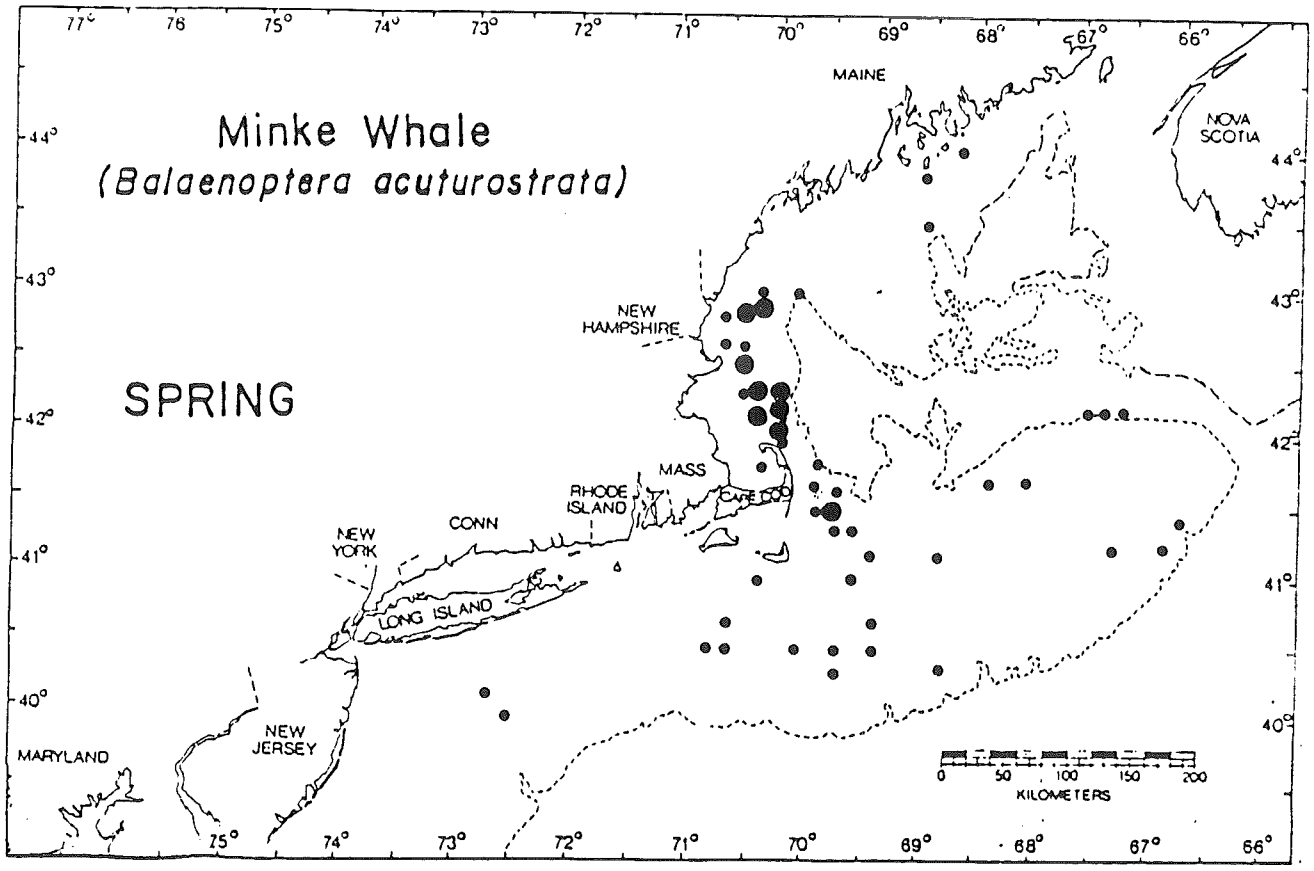
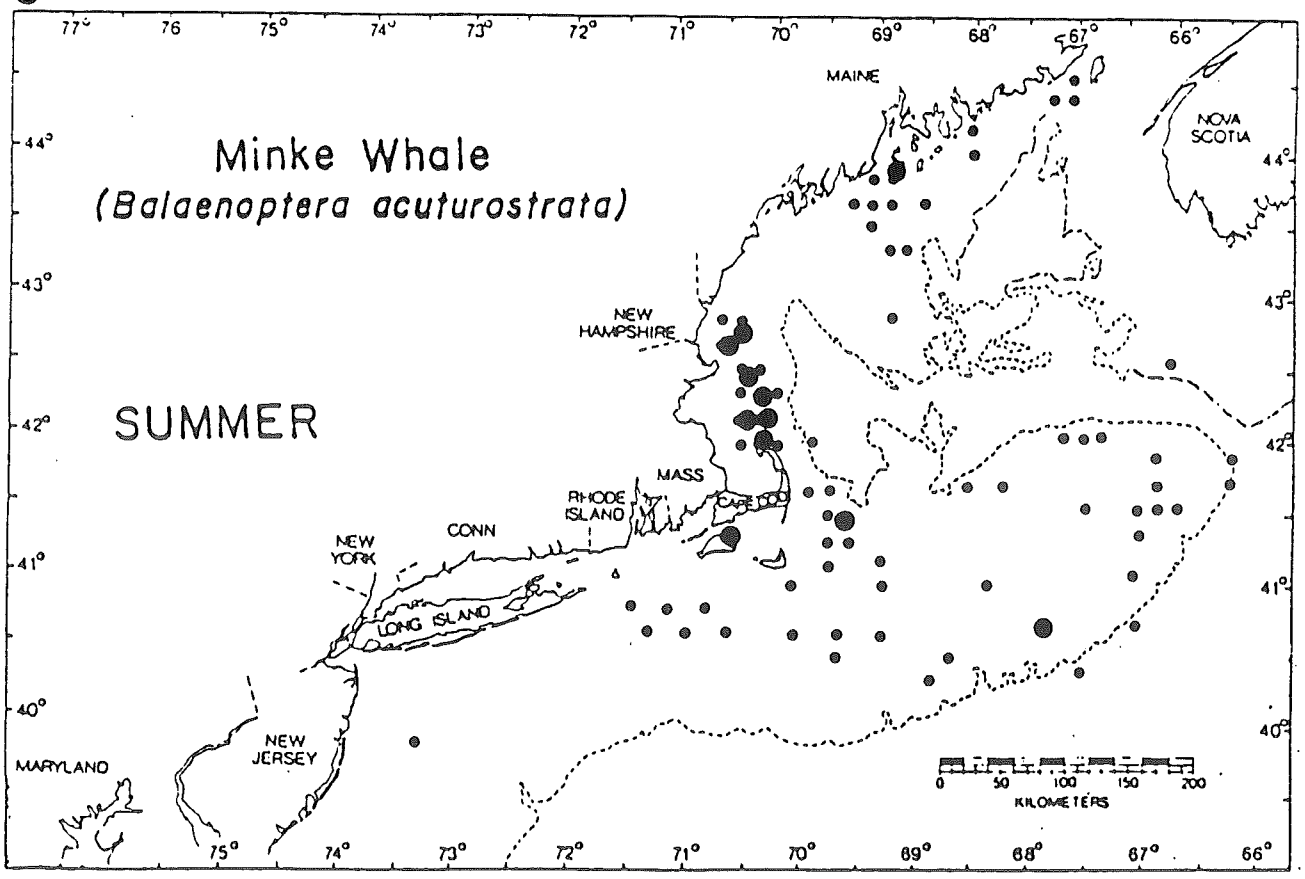

Minke Whale
(Balaenoptera acuturostrata)
SPRING
MAINE
NOVA SCOTIA
NEW HAMPSHIRE
MASS
RHODE ISLAND
CONN
NEW YORK
LONG ISLAND
NEW JERSEY
MARYLAND
KILOMETERS
0 50 100 150 200
77° 76 75° 74° 73° 72° 71° 70° 69° 68° 67° 66°
44° 43° 42° 41° 40°

C


Minke Whale
(Balaenoptera acuturostrata)
SUMMER
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LONG ISLAND
NEW JERSEY
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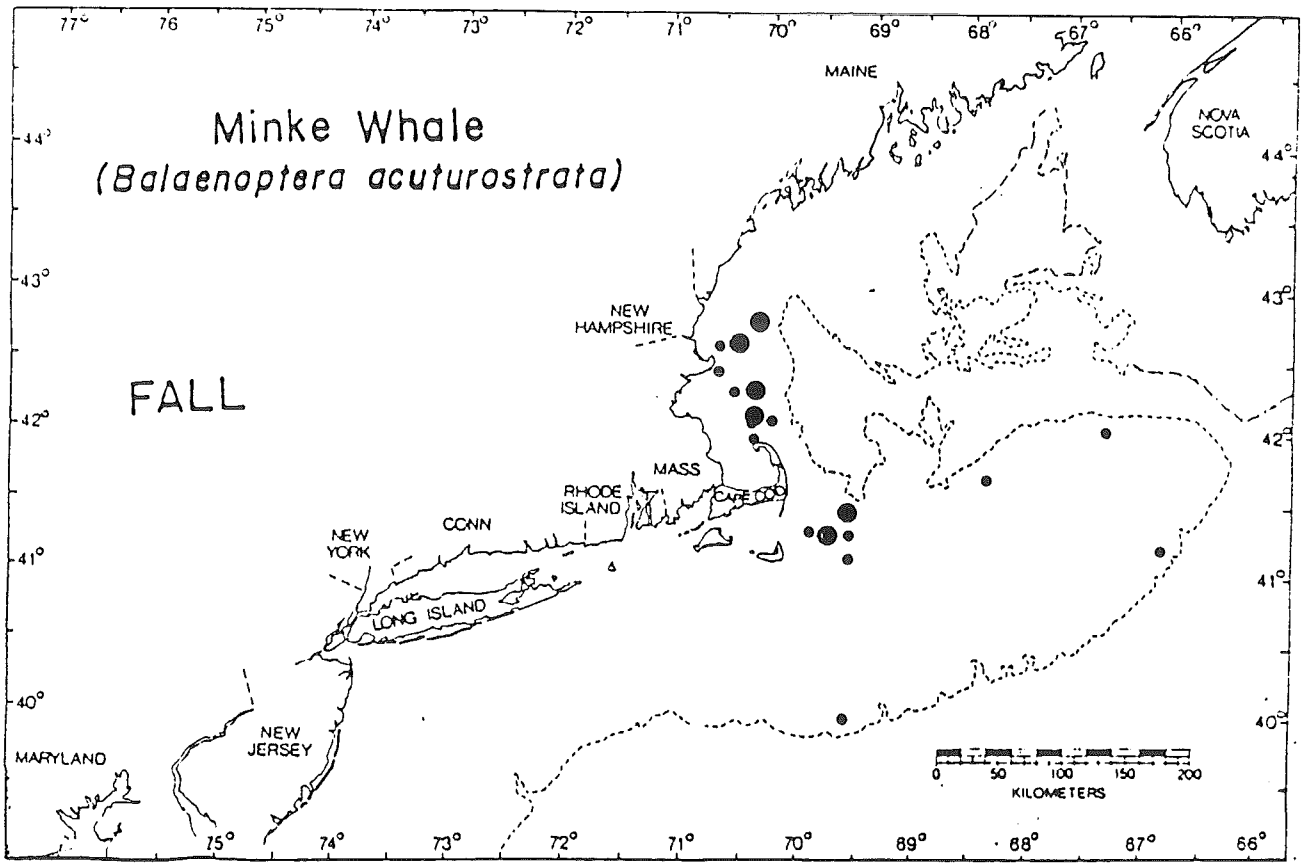
D


Minke Whale
(Balaenoptera acuturostrata)
FALL
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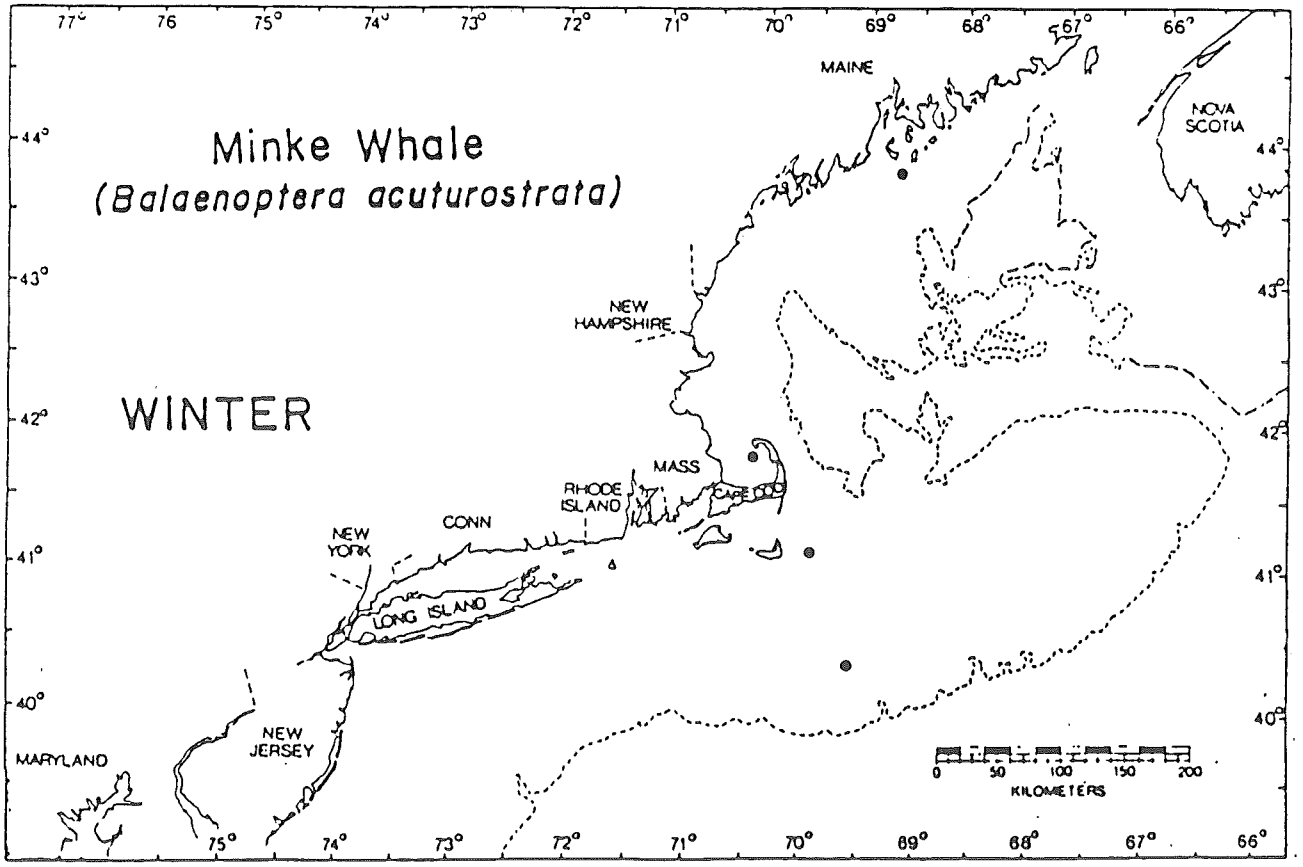
KILOMETERS

E


Minke Whale
(Balaenoptera acuturostrata)
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NEW YORK
LONG ISLAND
NEW JERSEY
MARYLAND
0 50 100 150 200
KILOMETERS

Bottlenosed Dolphin (Tursiops truncatus)

Bottlenosed dolphins are distributed worldwide in warm and temperate waters (Katona et al. 1977). The bottlenosed dolphin is common along the east coast of the United States from Nova Scotia to Florida, westward into the Gulf of Mexico and south to Venezuela (Hain et al. 1981; Katona et al. 1977; Leatherwood et al. 1976; Fritts and Reynold 1981, Marcuzzi and Pilleri 1971; Payne et al. 1984; Powers and Payne 1983; Sergeant et al. 1970).

Between Cape Hatteras and Nova Scotia, bottlenosed dolphins have a distinct J-shaped distribution consisting of an elongated offshore portion along the shelf-edge and an abbreviated inshore portion between Cape Hatteras and approximately Delaware Bay (Hain et al. 1981; CeTAP 1982). Two forms of this species are recognized. A smaller, inshore form is found in coastal waters of the mid-Atlantic south of Delaware Bay (Hain et al. 1981). The larger form occurs offshore along the shelf edge from Cape Hatteras to at least northeastern Georges Bank (35°00'n to 42°00'N Fig. 40), (Rowlett 1980; Hain et al. 1981; CETAP 1982; Payne et al. 1984; Powers and Payne 1983). Bottlenosed dolphins occur in the outer shelf waters of Georges Bank year around (CETAP 1982; Powers and Payne 1983). The offshore population of bottlenosed dolphins remains similar in distribution and abundance levels from May to October (Hain et al. 1981; Powers et al. 1981; CETAP 1982; Powers and Payne 1983). The nearshore component of the population, generally limited to the mid-Atlantic, also has a relatively constant distribution and level of abundance during spring and summer, but is displaced southward in the fall, and in winter is absent north of Cape Hatteras (CETAP 1982).

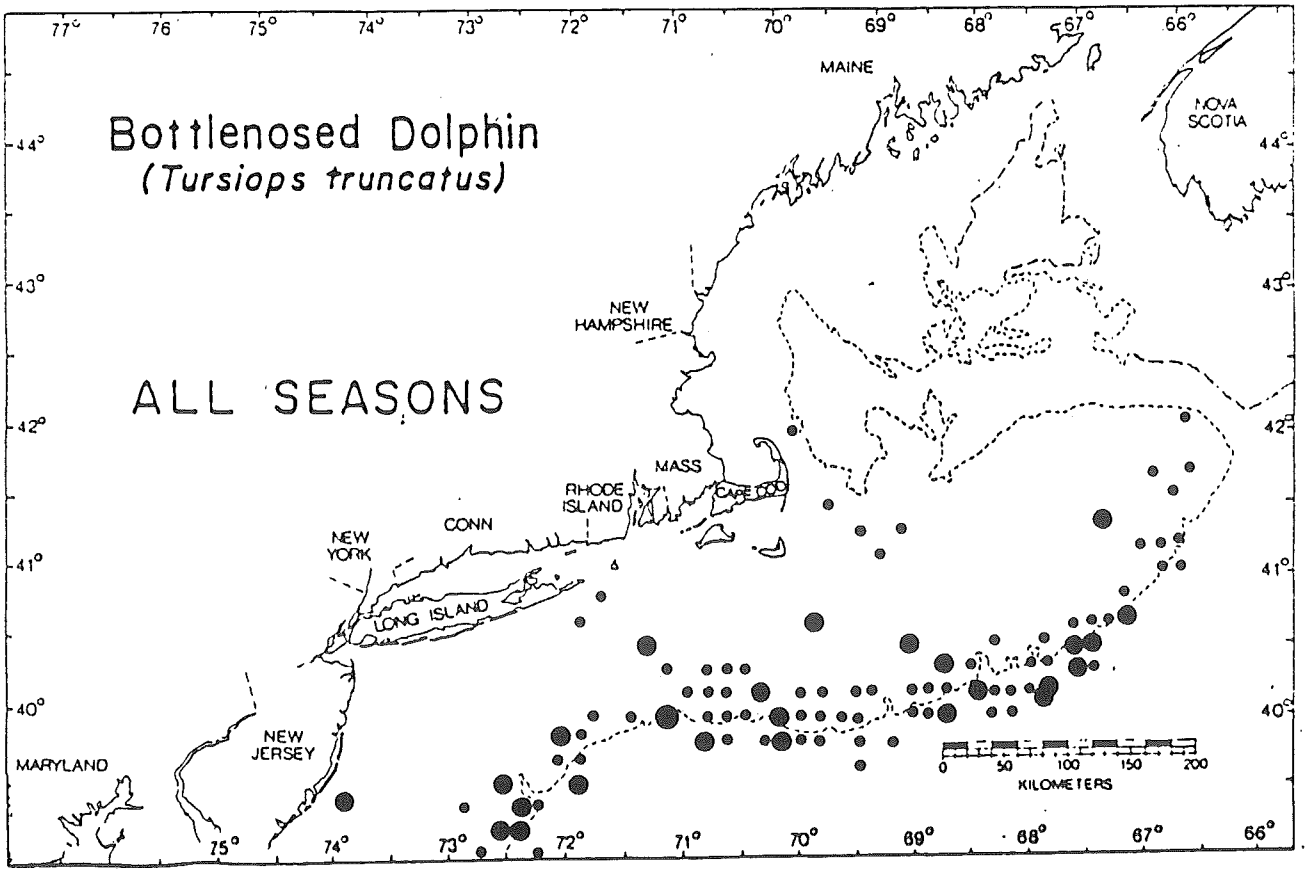
Bottlenosed dolphins are secondary or tertiary carnivores which opportunistically feed on a wide variety of species including fish, squid and invertebrates (Godin 1977; Leatherwood 1975; Leatherwood et al. 1976). They may feed on squid and crustaceans (Katona et al. 1977) or scavenge behind shrimp boats, feeding off fish stirred up by the trawls or on offal (Leatherwood 1975; Leatherwood et al. 1976). They also have been seen to feed cooperatively on schools of fish (Hoese 1971).

Sightings of bottlenosed dolphins within the Gulf of Maine occur in late summer to fall, but these appear extralimital (Fig. 41). This species generally is considered absent from the Gulf of Maine.

Figure 41. Relative distribution and abundance of bottlenosed dolphins in the Gulf of Maine, including Georges Bank (north of 40°00'N latitude) for all seasons.

Relative Abundance
cetaceans per 10'x10' block

- 1 - 9
- 10 - 99
- >100



Spotted Dolphin (Stenella spp.)

Spotted dolphin (Stenella spp.) taxonomy is not clear but S. attenuata/frontinalis and S. plagiodon occur in the western North Atlantic (Katona et al. 1977; Hain et al. 1981; Schmidly 1981; CETAP 1982). S. plagiodon is found in warm and temperate waters throughout the western Atlantic, Gulf of Mexico, and Caribbean and considered to be the more northern of the species (Gunter 1954; Fritts and Reynolds 1981). The distribution of S. plagiodon overlaps with, and then is replaced by S. attenuata/frontinalis in the Caribbean (Katona et al. 1977; CETAP 1982); thus we refer to all spotted dolphins as Stenella spp.

Spotted dolphins are distributed broadly on the shelf, along the shelf edge, and offshore (> 1000 m) south of 40°00'N, with evidence of a seasonal shift in the distribution pattern in winter. No spotted dolphins have been sighted north of Cape Hatteras in winter (CETAP 1982; Payne et al. 1984). Spotted dolphins regularly occur in the inshore waters of the mid-Atlantic Bight south of Chesapeake Bay; however, their distribution generally is near the shelf edge and in slope waters (Hain et al. 1981; CETAP 1982; Powers and Payne 1983). Sightings occur as far north as the slope waters of Georges Bank (41°00'N) during mid-summer and fall, and these represent the northernmost extension of their range within our study area (Fig. 42). Spotted dolphins have not been recorded in the Gulf of Maine.

Spotted dolphins are tertiary carnivores that feed primarily on fishes. In the Atlantic, spotted dolphins feed on herring, anchovies, carangids, and squid (Caldwell and Caldwell 1966). In the Pacific they feed on epipelagic and mesopelagic fishes (Fitch and Brownell 1968; Perrin et al. 1973).

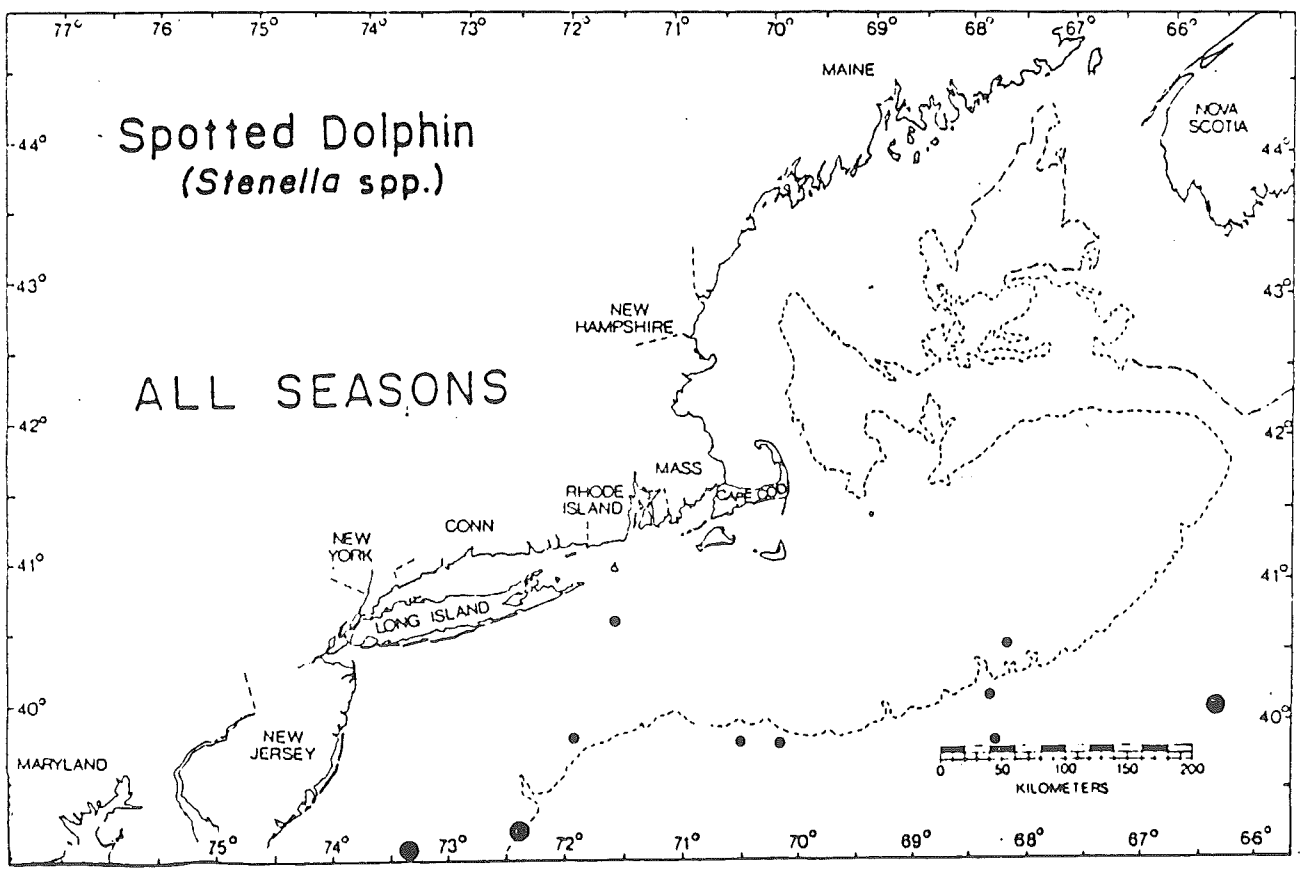
Striped Dolphin (Stenella coeruleoalba)

Striped dolphins are known mainly from tropical and temperate waters of the Atlantic and Pacific, preferring offshore waters (rather than coastal or shelf waters), with seasonal movements poleward in spring-summer, and toward the equator in autumn-winter (Watson 1981). In our study area, striped dolphins are distributed along the shelf-edge from Cape Hatteras to the southern margin of Georges Bank, and offshore, generally seaward of 1000 m isobath (Fig. 43) (Hain et al. 1981; CETAP 1982; Powers and Payne 1983). CETAP (1982) showed that in spring there is a concentration of striped dolphins along the shelf-edge in the mid-Atlantic, and another southeast of Nantucket along the southwest edge of Georges Bank. The latter area is occupied throughout the year (CETAP 1982).

Striped dolphins feed mainly on small pelagic fishes, squid and shrimp (Nishiwaki 1975; Watson 1981; Kenney et al. 1985).

Striped dolphins are recorded infrequently within the Gulf of Maine.

Figure 42. Relative distribution and abundance of spotted dolphins in the Gulf of Maine, including Georges Bank (north of 40°00'N latitude) for all seasons.



Common Dolphin (Delphinus delphis)

Common dolphins have been reported throughout the temperate and tropical waters of the Atlantic (Leatherwood et al. 1976) and Pacific oceans (Evans 1974). In the western North Atlantic, they have been reported off Nova Scotia (Sergeant and Fisher 1957, Leatherwood et al. 1976), throughout the shelf waters off the eastern United States into the Gulf of Mexico (Fritts and Reynolds 1981), and south to Venezuela (Leatherwood et al. 1976).

Common dolphins are widespread from Cape Hatteras northeastward to the eastern tip of Georges Bank (35°00'N to 42°00'N) in mid-to-outer shelf waters (Hain et al. 1981; CETAP 1982; Powers et al. 1982; Powers and Payne 1983), on a year-around basis (Figs. 44a-e). Sightings in the Gulf of Maine are limited to fall and winter (Figs. 44d-e), and generally occur on the northeastern edge of Georges Bank. Their mid-to-outer shelf distribution is evident especially from Georges Bank southward. Greatest sighting frequencies occurred on central Georges Bank in fall; however, common dolphins are abundant on Georges Bank May to June and again from October to December (Hain et al. 1981; Powers et al. 1982). There is a decrease in sightings during mid-to late summer when common dolphins apparently move north onto the Scotian Shelf (Fig. 44c). Hain et al. (1981) suggested that summer and fall sightings are greatest north of 37°30'N and winter and spring sightings south of this latitude; however common dolphins occur regularly on Georges Bank throughout the winter. Powers et al. (1982) reported a summer sighting in the mid-Atlantic Bight, south of the 37° 30'N latitude indicated by Hain et al. (1981) as a possible seasonal limit.

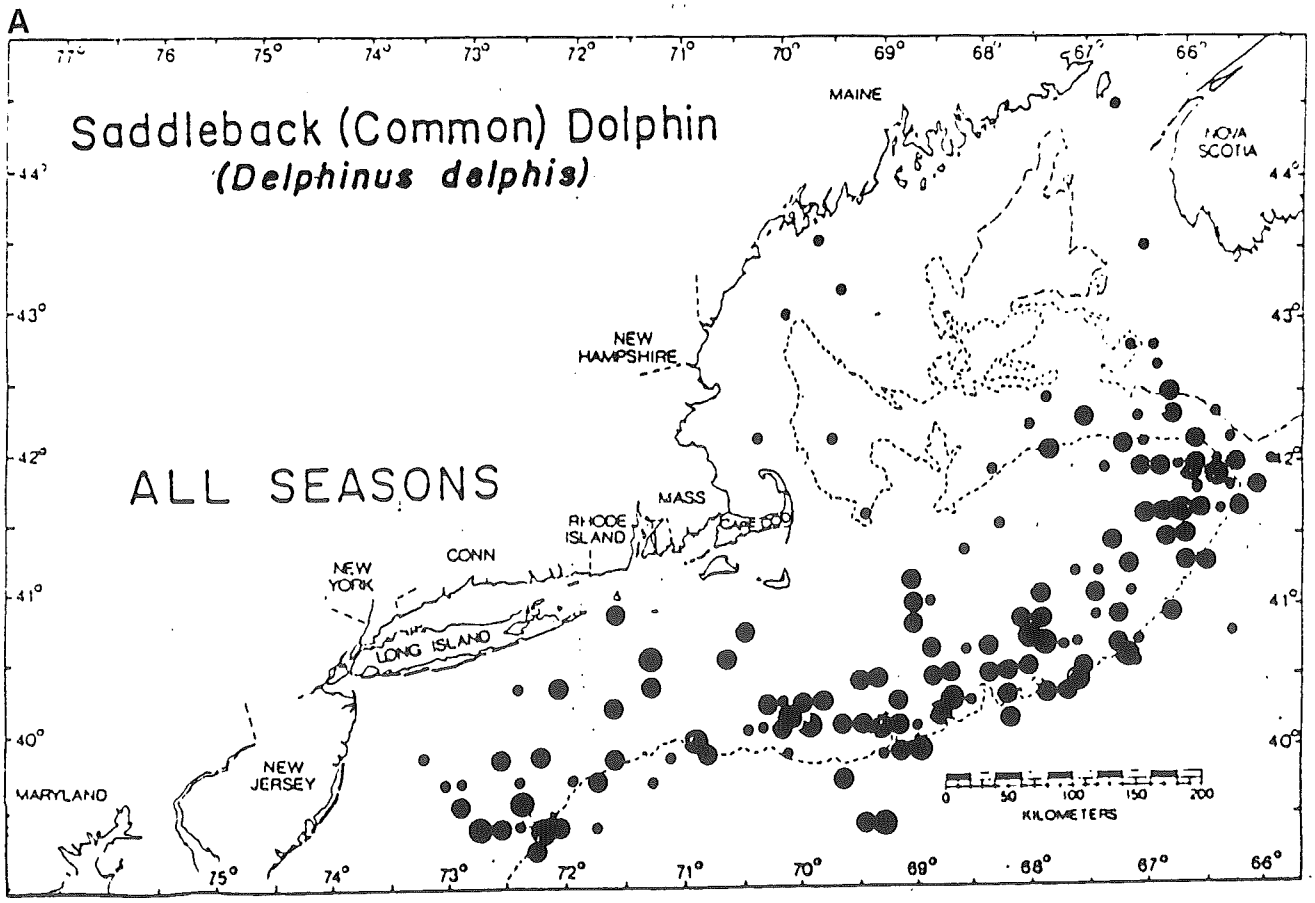
Common dolphins are tertiary carnivores that feed on a wide variety of schooling fishes, which include anchovies, lanternfish (myctophids) and hake (Leatherwood et al. 1976), and squid (Sergeant 1958; Katona et al. 1977). They also have been observed feeding on saury Scomberesox sp. (MBO, unpubl. data). Most sightings of feeding Delphinus are on Georges Bank and in the Mid-Atlantic Bight, between mid-shelf and slope waters (Hain et al. 1981; CETAP 1982; MBO, unpubl. data).

Common dolphins are year-round residents south of the Gulf of Maine, and occur as stragglers into the Gulf of Maine, especially in fall and winter.

Figure 44. Relative distribution and abundance of common dolphins in the Gulf of Maine, including Georges Bank (north of 40000'N latitude) by season.

Relative Abundance
cetaceans per 10'x10' block

- 1-9
- 10-99
- >100



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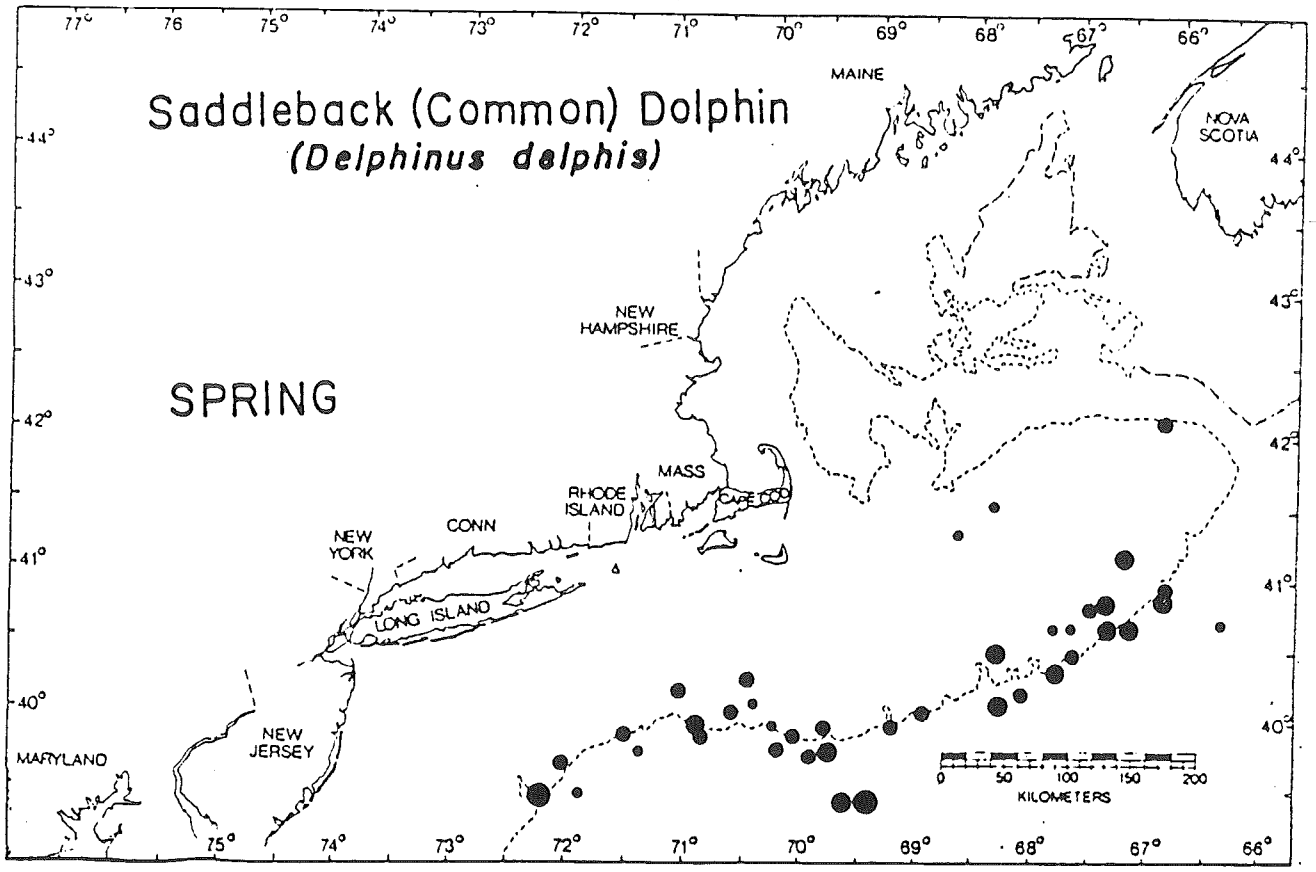
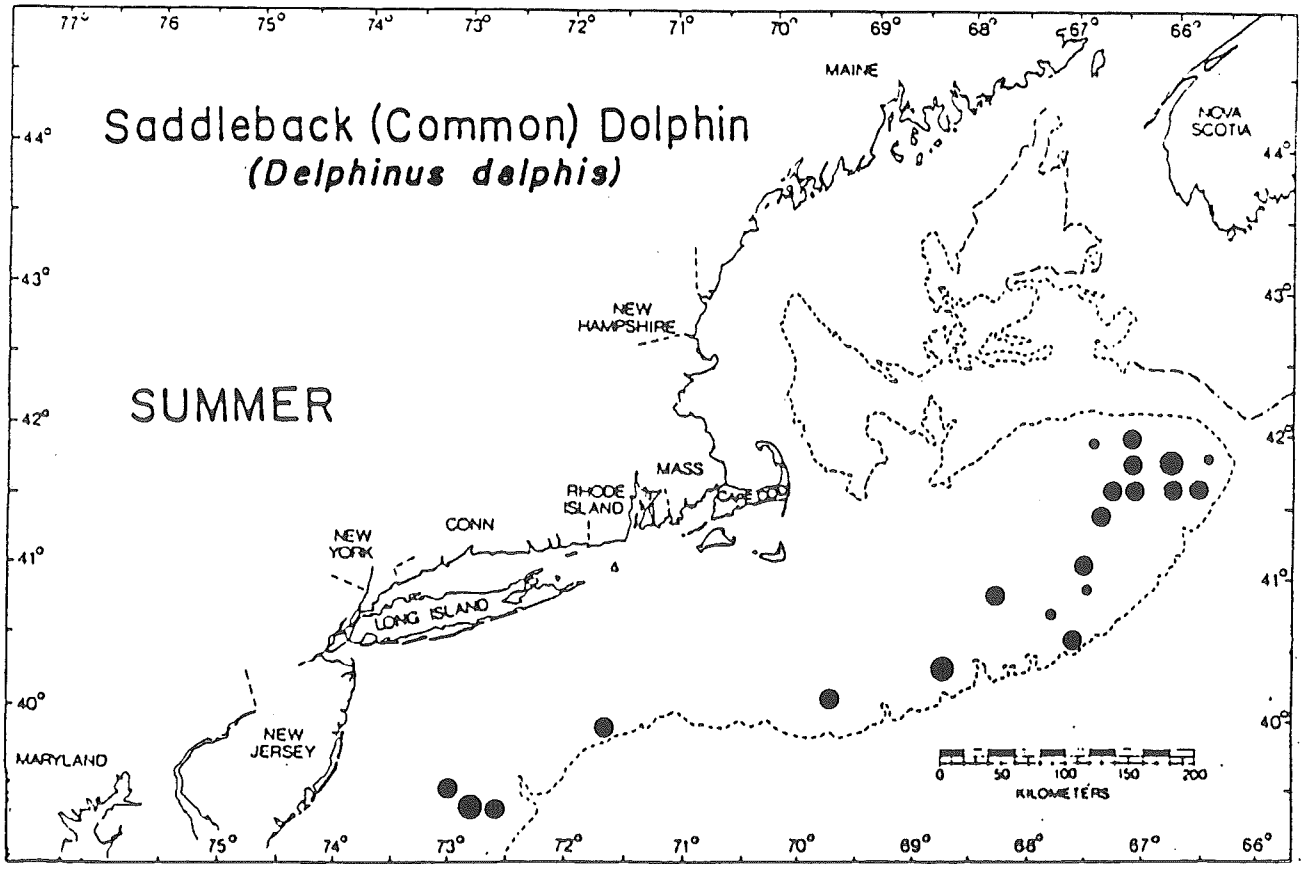

Saddleback (Common) Dolphin
(Delphinus delphis)
SPRING
MAINE
NOVA SCOTIA
NEW HAMPSHIRE
MASS
RHODE ISLAND
CONN
NEW YORK
LONG ISLAND
NEW JERSEY
MARYLAND
0 50 100 150 200
KILOMETERS

C


Saddleback (Common) Dolphin
(Delphinus delphis)
SUMMER
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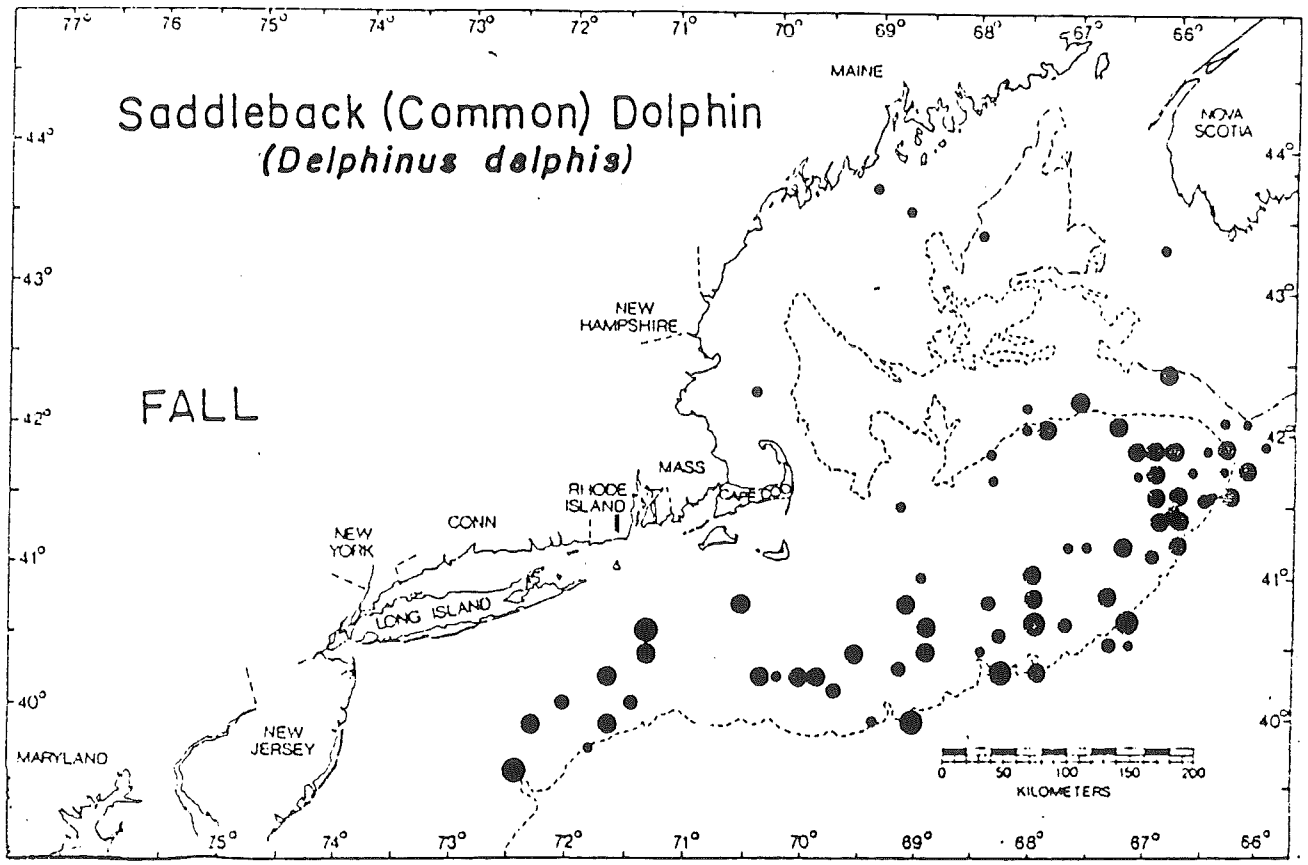
KILOMETERS

D


Saddleback (Common) Dolphin
(Delphinus delphis)
FALL
MAINE
NOVA SCOTIA
NEW HAMPSHIRE
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MARYLAND
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KILOMETERS

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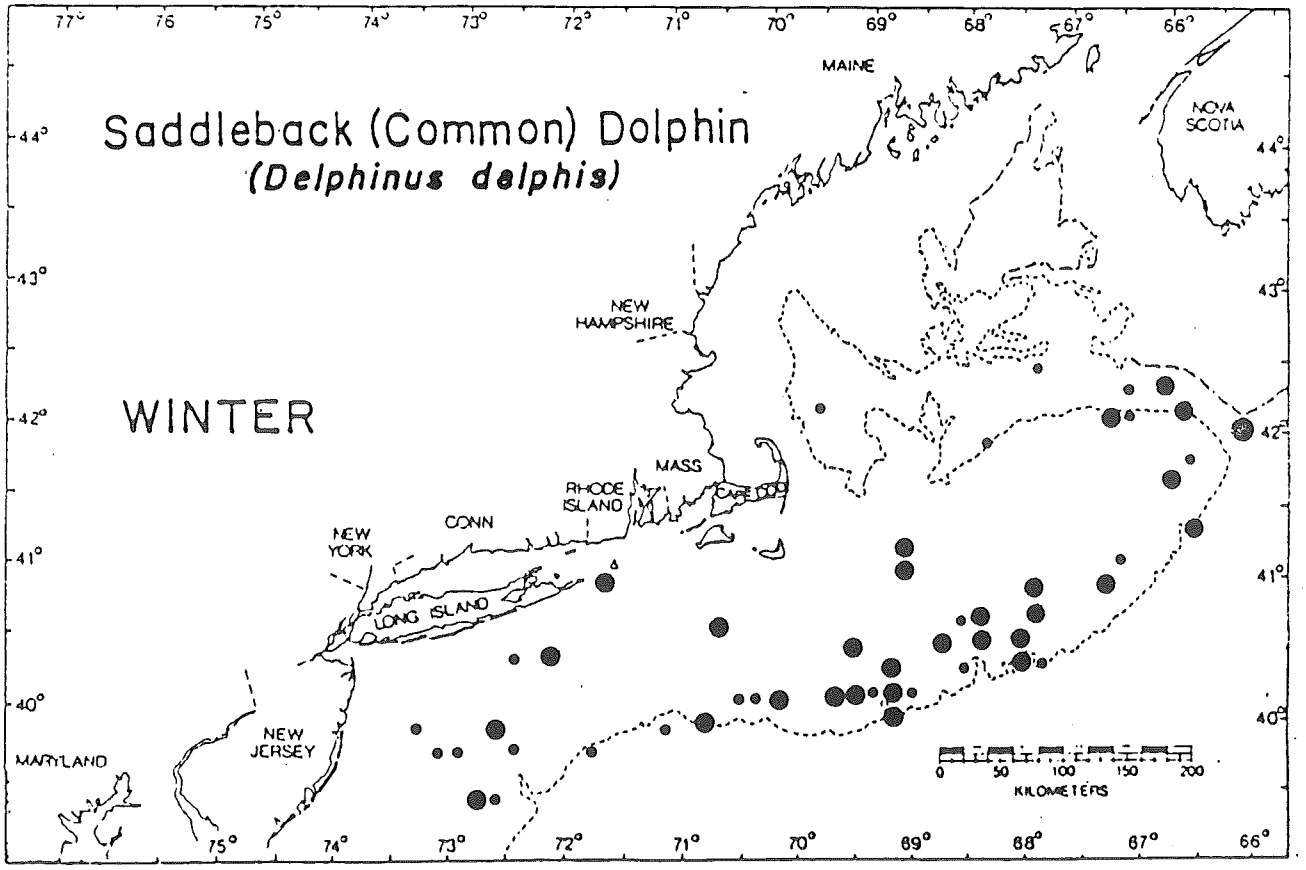
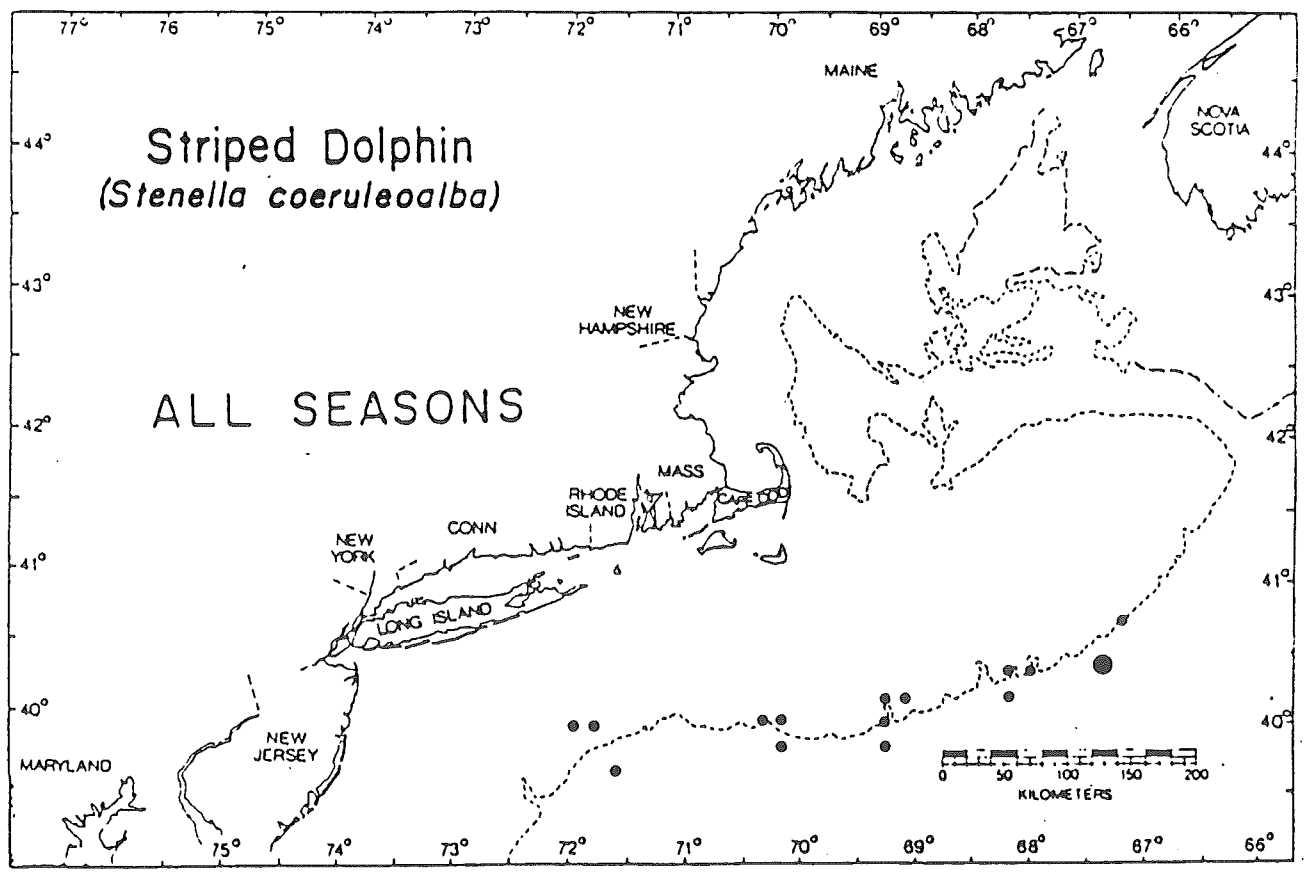

Saddleback (Common) Dolphin
(Delphinus delphis)
WINTER
MAINE
NOVA SCOTIA
NEW HAMPSHIRE
MASS
RHODE ISLAND
CONN
NEW YORK
LONG ISLAND
NEW JERSEY
MARYLAND
0 50 100 150 200
KILOMETERS

Figure 43. Relative distribution and abundance of striped dolphins in the Gulf of Maine, including Georges Bank (north of 40°00'N latitude) for all seasons.



White-sided Dolphin (Lagenorhynchus acutus)

In the western North Atlantic, Leatherwood et al. (1976) reported white-sided dolphins from Davis Strait south to Hudson Canyon. The first confirmed report of white-sided dolphins from Cape Cod occurred in 1956 (Schevill 1956). The southernmost extent of their range was redefined to the mid-Atlantic Bight near Chesapeake Bay by Testaverde and Mead (1980). This southern range limit was supported by Hain et al. (1981), CETAP (1982), and Powers and Payne (1983). White-sided dolphins are widespread throughout the Gulf of Maine and Georges Bank throughout the year south to approximately 40°00'N (Figs. 45a-e) (Hain et al. 1981; CETAP 1982). Within these regions they are most abundant in the southwestern Gulf of Maine. Hain et al. (1981) suggested that their distribution is most widespread from October to November. In the spring and fall, sightings occurred along the shelf edge from south of Nantucket to Virginia. White-sided dolphins were the most abundant (total numbers) cetacean observed by Scott et al. (1981) and CETAP (1982).

White-sided dolphins are tertiary carnivores reported to feed on a variety of fishes, including Atlantic herring Clupea harengus, Silver Hake Merluccius bilinearis and smelt Osmerus mordax, and squid Illex illecebrosus (Schevill 1956; Sergeant et al. 1980; Katona et al. 1977; 1978; Kenney et al. 1985). In the Gulf of Maine and on Georges Bank white-sided dolphins have been seen in close association with feeding humpback and fin whales (Katona et al. 1977; Hain et al. 1981; Mayo 1982) which are believed to be feeding on sand eel Ammodytes americanus (Overholtz and Nicolas 1979; Hain et al. 1982; Mayo 1982; Payne et al. 1986). Thus, it seems likely that white-sided dolphins also feed on sand eel. Most sightings of feeding in this study occurred over shelf edges, or along shelf bottoms with rugged relief, often in the presence of whales. Sightings of feeding were common in the southwest Gulf of Maine, between the 70-100m depth contours. The apparent prey during surface-feeding activity were sand eel (Mayo 1982).

White-sided dolphins were most widespread winter and spring, and most abundant in summer. This species is found year-round only in the Gulf of Maine where it is the dominant delphinid. The areas of greatest concentrations were in the south and southwest regions of the Gulf of Maine.

White-beaked Dolphin Lagenorhynchus albirostris

The range of the white-beaked dolphin extends from approximately Cape Cod north to Greenland (Leatherwood et al. 1976; Katona et al 1983). They are found only in the North Atlantic and are the more northerly distributed of the two Lagenorhynchus species, being far more numerous in waters off Canada and Greenland (Sergeant and Fisher 1957; Katona et al. 1977; Whitehead and Glass 1985).

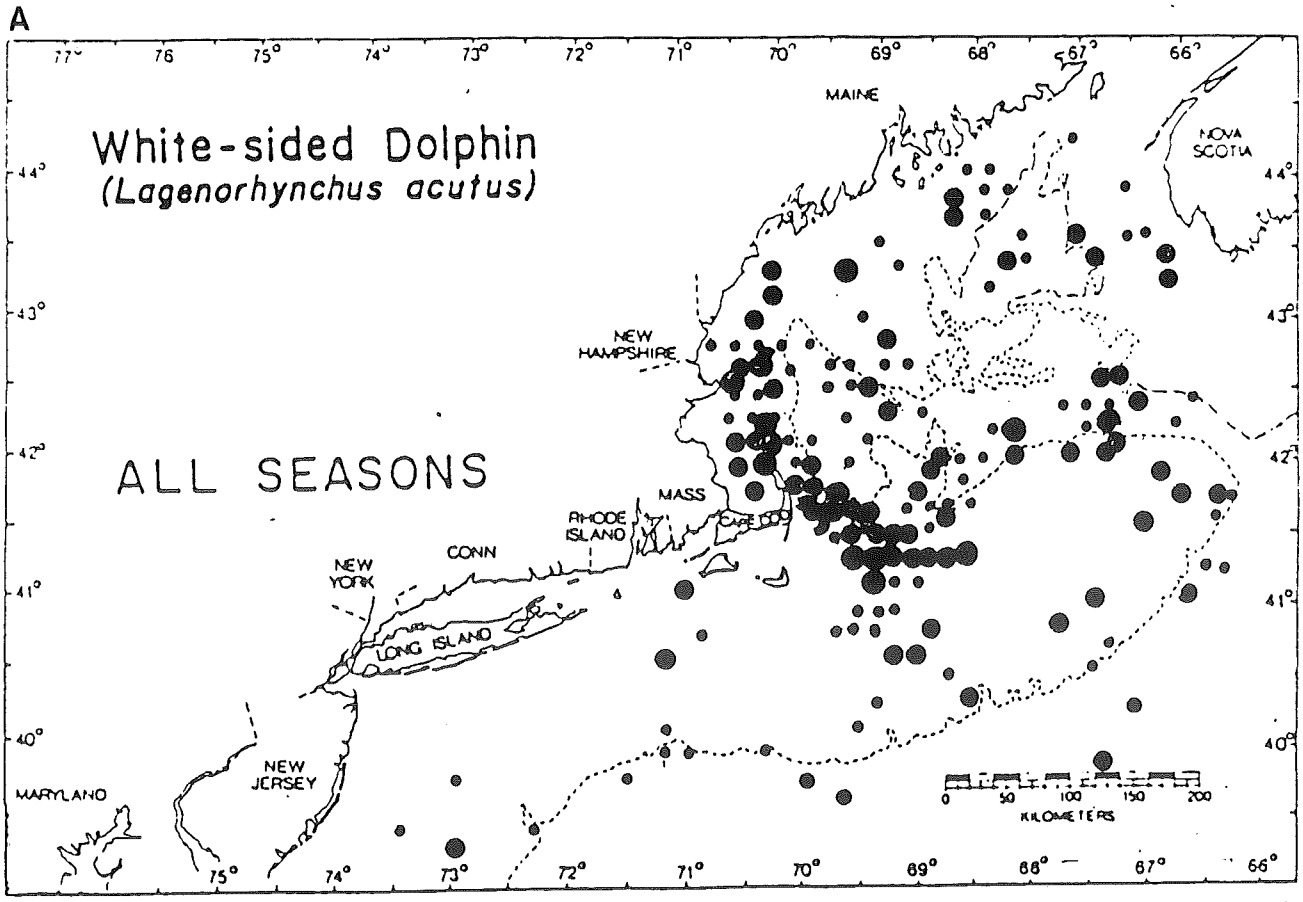
Within the Gulf of Maine sightings occur most frequently between April and November from Cape Cod - Great South Channel north to include Jeffreys Basin (CETAP 1982). This species is thought to have been more common around Cape Cod in the 1950s than at present, and the apparent decline has been accompanied by an increase in sightings of white-sided dolphins (Katona et al 1983).

In Canadian waters white-beaked dolphins feed on schooling fishes (herring and capelin), and squid sp. (Van Bree and Nigssen 1964). CETAP (1982) suggested that white-beaked dolphins in the Gulf of Maine likely feed on sand eel.

Figure 45. Relative distribution and abundance of white-sided dolphins in the Gulf of Maine, including Georges Bank (north of 40°00'N latitude) by season.

Relative Abundance
cetaceans per 10'x10' block

- 1 - 9
- 10-99
- >100



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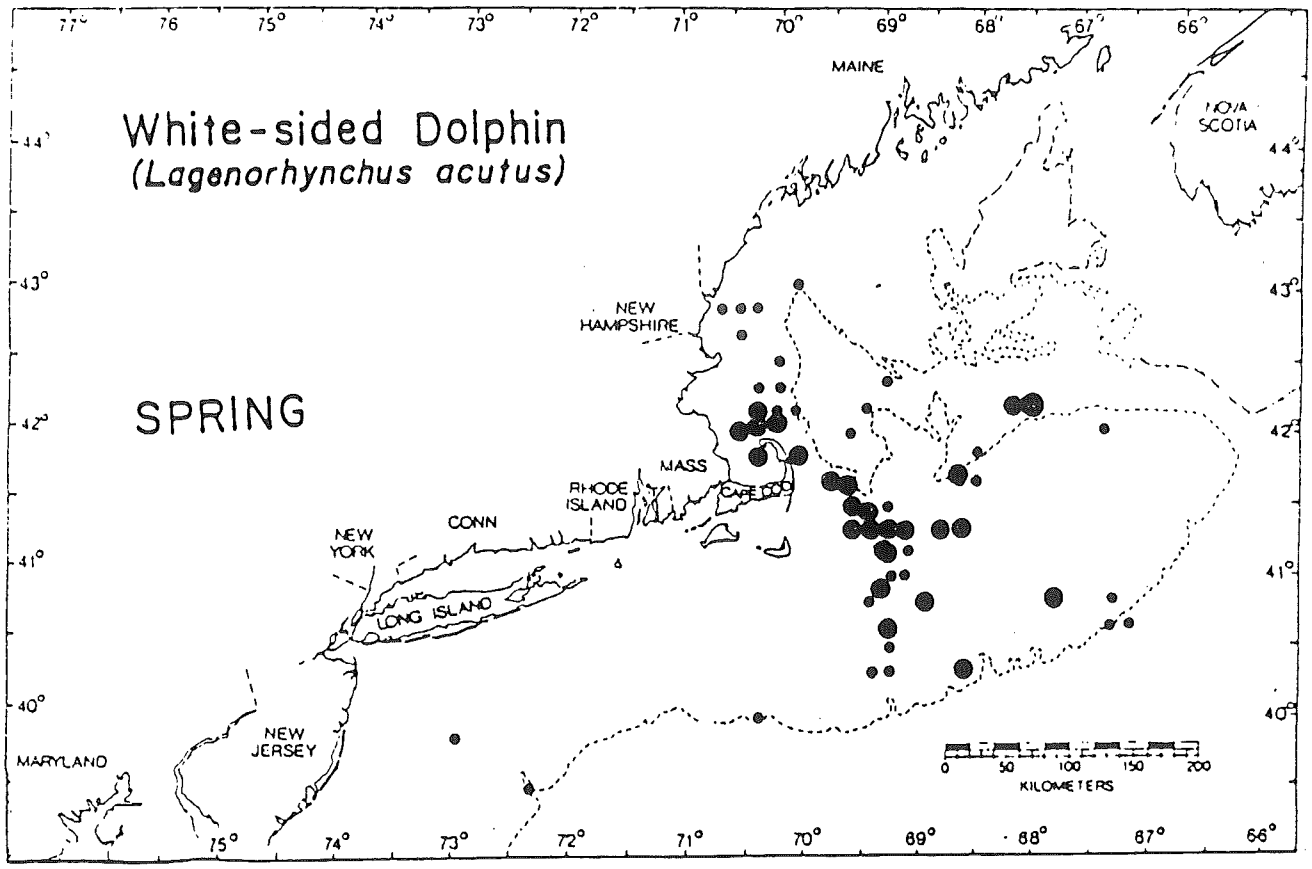
White-sided Dolphin
(Lagenorhynchus acutus)
SPRING
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NOVA SCOTIA
NEW HAMPSHIRE
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NEW JERSEY
MARYLAND
0 50 100 150 200
KILOMETERS

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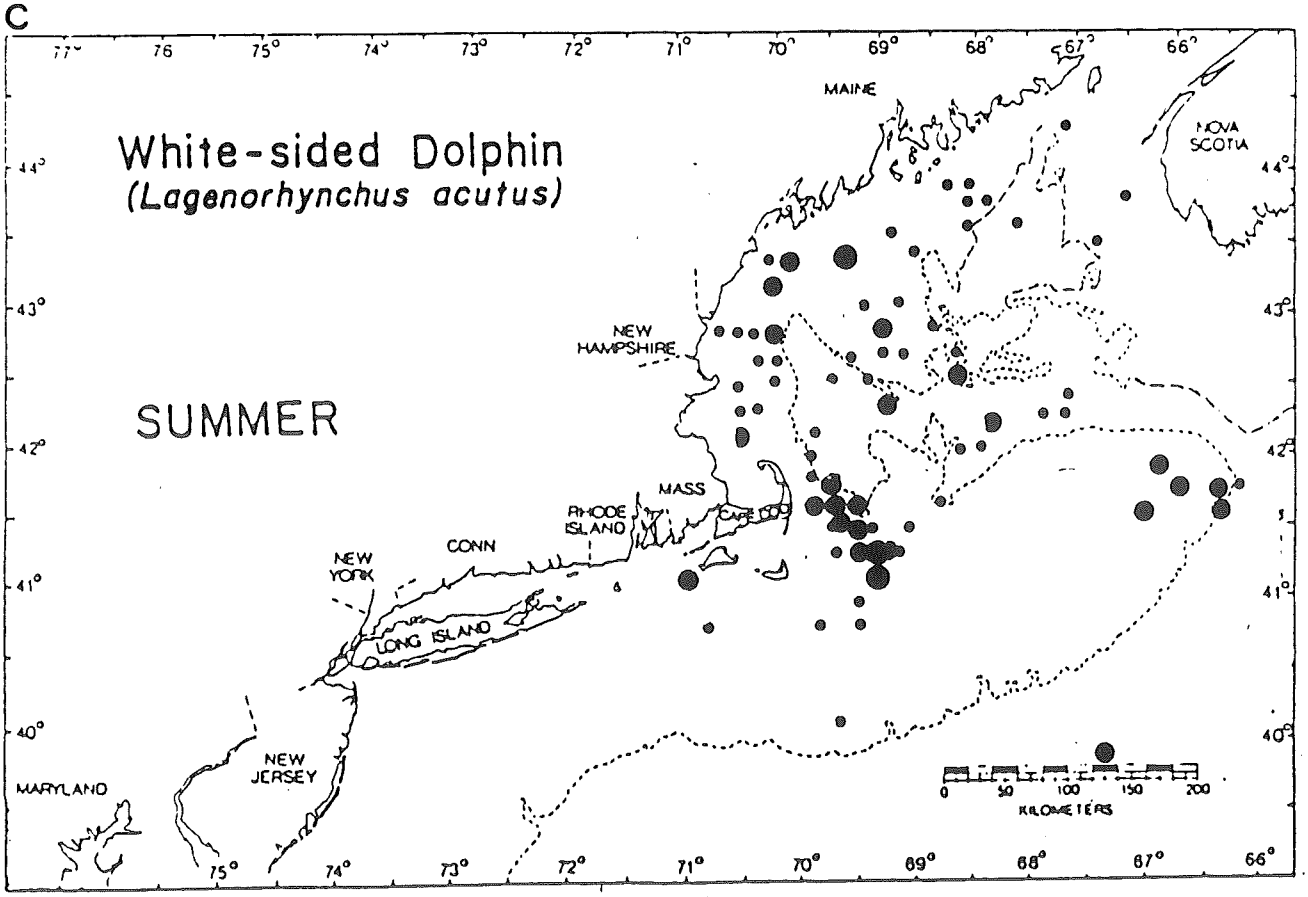
White-sided Dolphin
(Lagenorhynchus acutus)
SUMMER
MAINE
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NEW HAMPSHIRE
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LONG ISLAND
NEW JERSEY
MARYLAND
0 50 100 150 200
KILOMETERS

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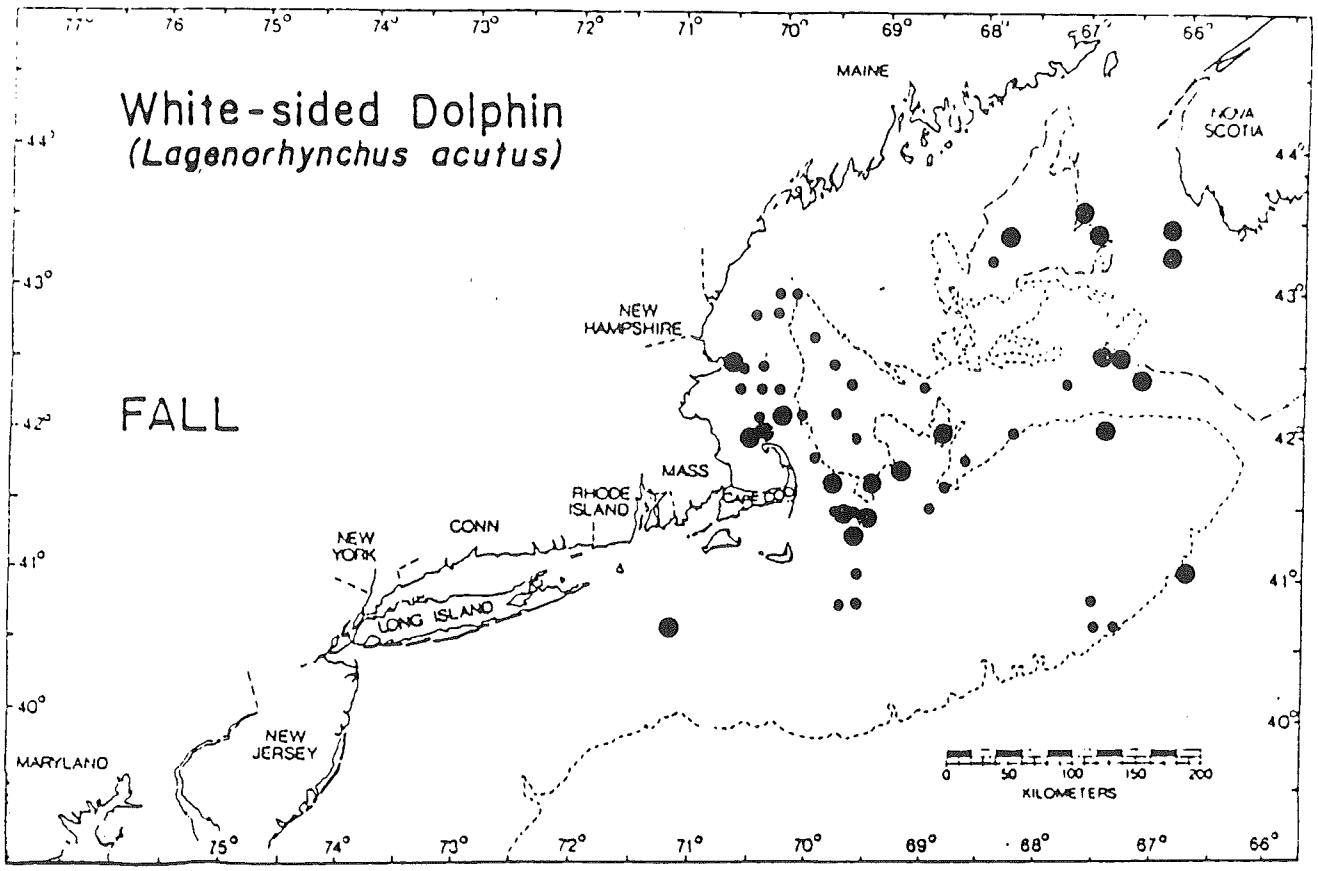
White-sided Dolphin
(Lagenorhynchus acutus)
FALL
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NOVA SCOTIA
NEW HAMPSHIRE
MASS
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NEW JERSEY
MARYLAND
KILOMETERS

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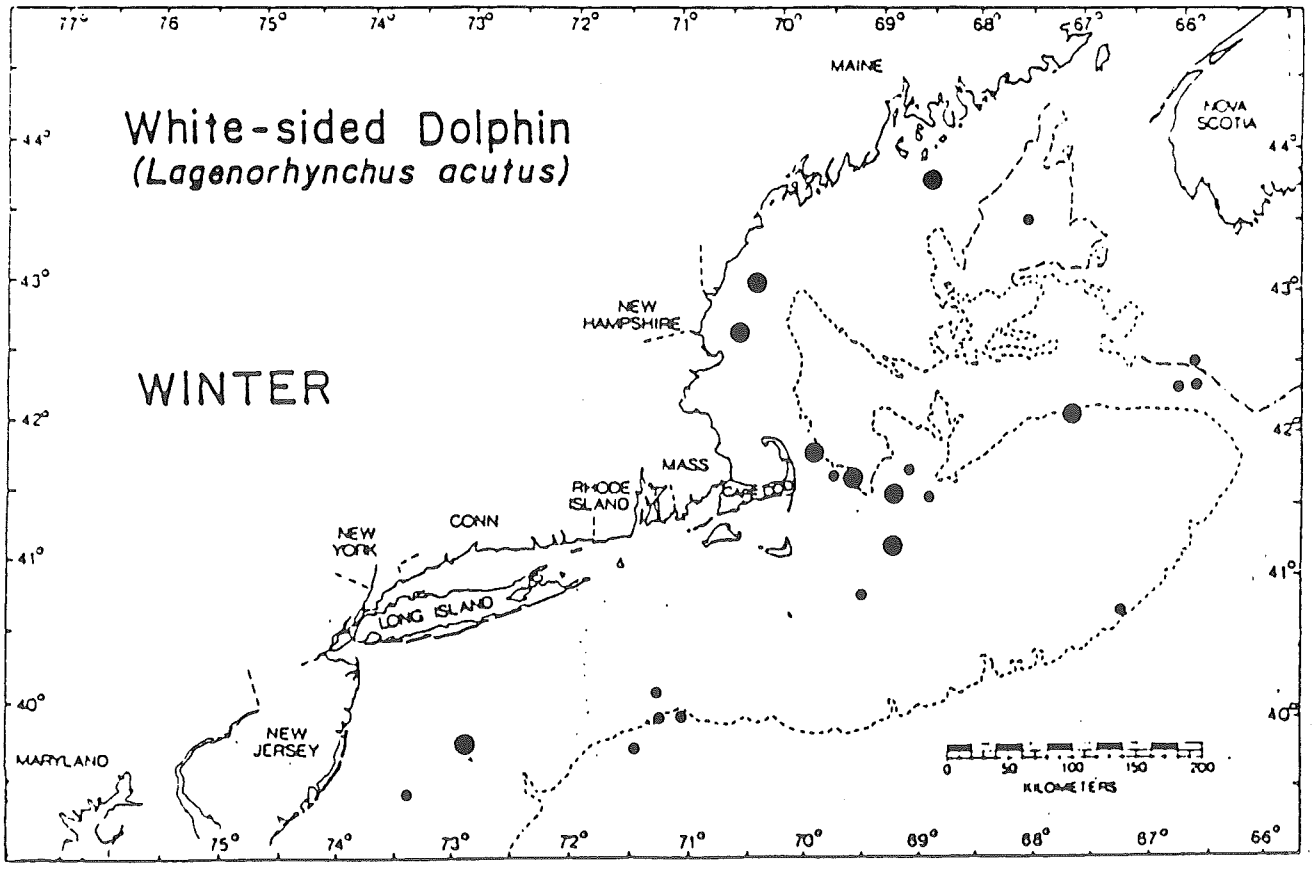

White-sided Dolphin
(Lagenorhynchus acutus)
WINTER
MAINE
NOVA SCOTIA
NEW HAMPSHIRE
MASS
RHODE ISLAND
CONN
NEW YORK
LONG ISLAND
NEW JERSEY
MARYLAND
KILOMETERS

Grampus (Grampus griseus)

Grampus are widely distributed in tropical and temperate waters around the world (Leatherwood et al. 1980). In the western North Atlantic, grampus occur from eastern Newfoundland to the Lesser Antilles (Leatherwood et al. 1976) into the Gulf of Mexico (Gunter 1954; Paul 1968; Fritts and Reynolds 1981).

The center of grampus sightings along the eastern United States occurs along the shelf-edge-slope waters from Cape Hatteras north to Georges Bank (36°00'N to 41°00'N) during spring, summer and fall (Figs. 46a-e) (Hain et al. 1981; CETAP 1982; Powers et al. 1982; Powers and Payne 1983). They occur infrequently inshore of the 100 m contour (Powers and Payne 1983). CETAP (1982) reported that their range contracts to the mid-Atlantic Bight during winter when they move offshore (> 100 m).

Grampus are tertiary carnivores that feed almost exclusively on squid (Nishiwaki 1972; Leatherwood et al. 1976, 1980). CETAP (1982) considered grampus as sub-surface feeders, feeding throughout their range.

Grampus generally are considered absent from the Gulf of Maine, although individuals have been recorded.

Killer Whale Orcinus orca

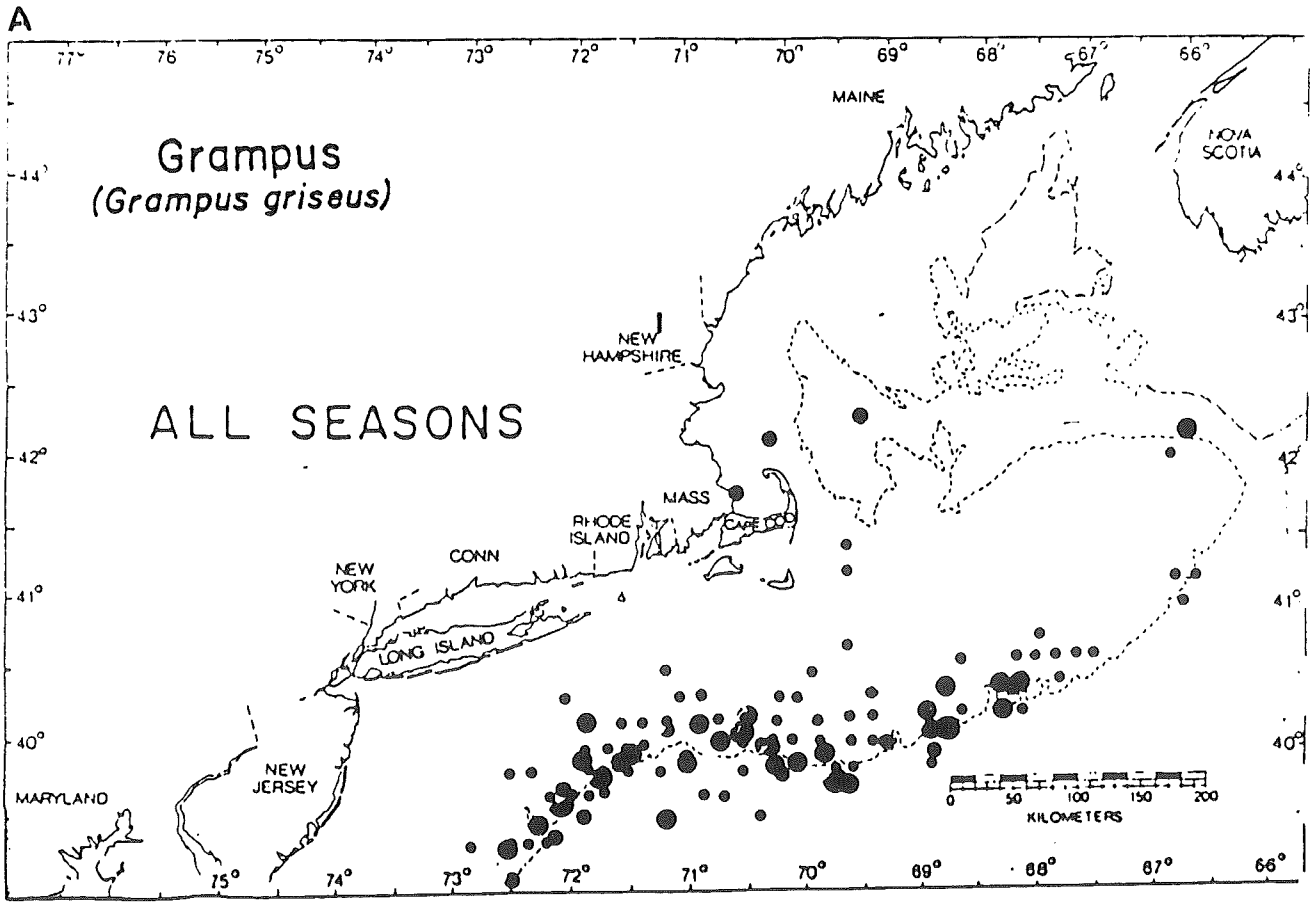
In the western north Atlantic, killer whale sightings are widespread, but sporadic. They occur from near pack-ice south into the Gulf of Mexico (Leatherwood et al 1976; Schmidly 1981), although generally they are more common in cooler waters and in productive coastal regions (Katona et al. 1983). Within the Gulf of Maine, killer whale sightings are most common from mid-July to September in the southwest Gulf of Maine (Katona et al 1976; CETAP 1982). Killer whales are thought to follow the schools of bluefin tuna Thunnus thynnus which move into these waters during late-summer as part of their annual migration. All sightings by CETAP (1982) occurred in shelf waters outside the Gulf of Maine.

Killer whales are opportunistic feeders, feeding on a wide variety of fishes, pinnipeds and cetaceans (Leatherwood et al. 1976; Whitehead and Glass 1985). In the Gulf of Maine, Katona et al. (1983) thought tuna, mackerel, and herring to be likely prey items.

Figure 46. Relative distribution and abundance of grampus in the Gulf of Maine, including Georges Bank (north of 40°00'N latitude) by season.

Relative Abundance
cetaceans per 10'x10' block

- 1 - 9
- 10 - 99
- >100



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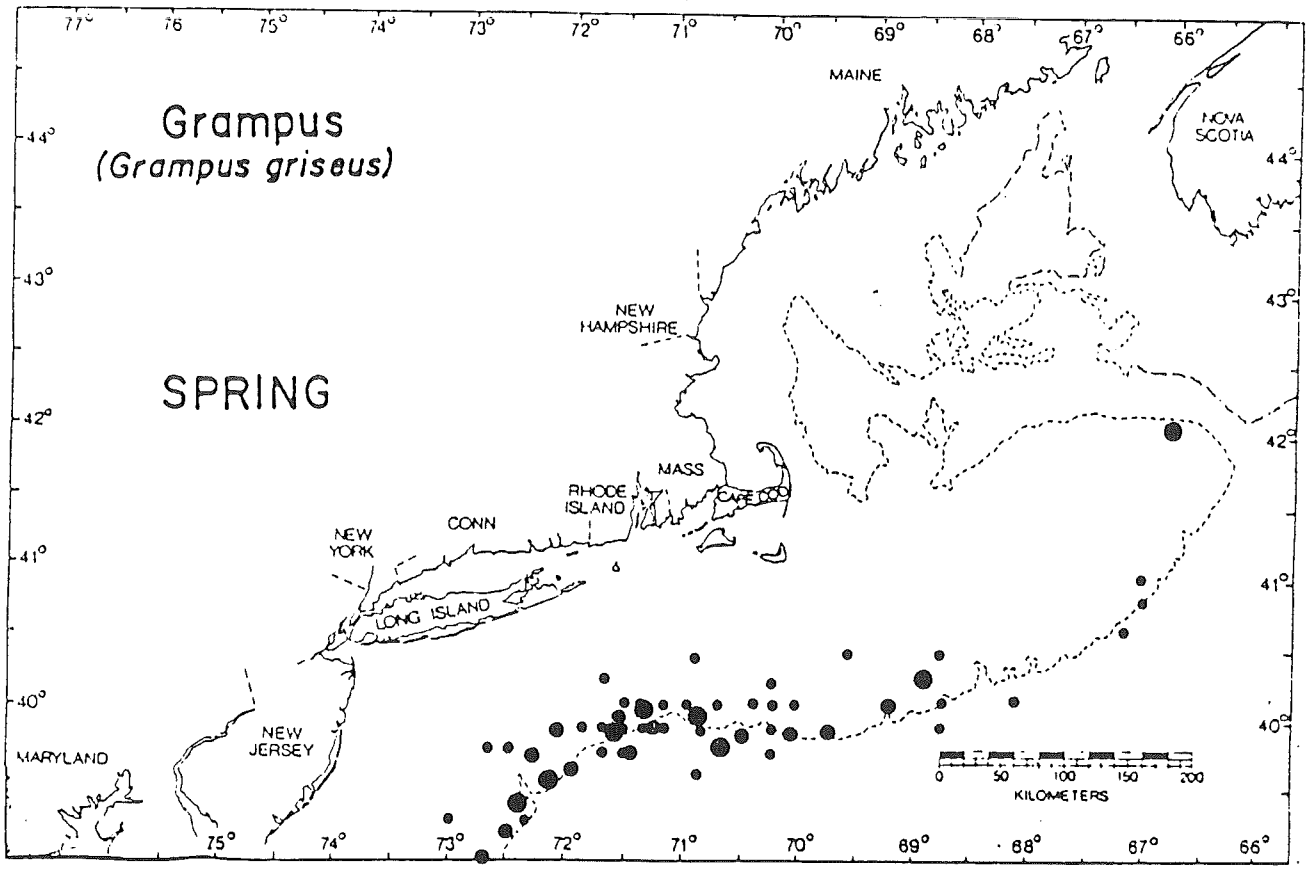
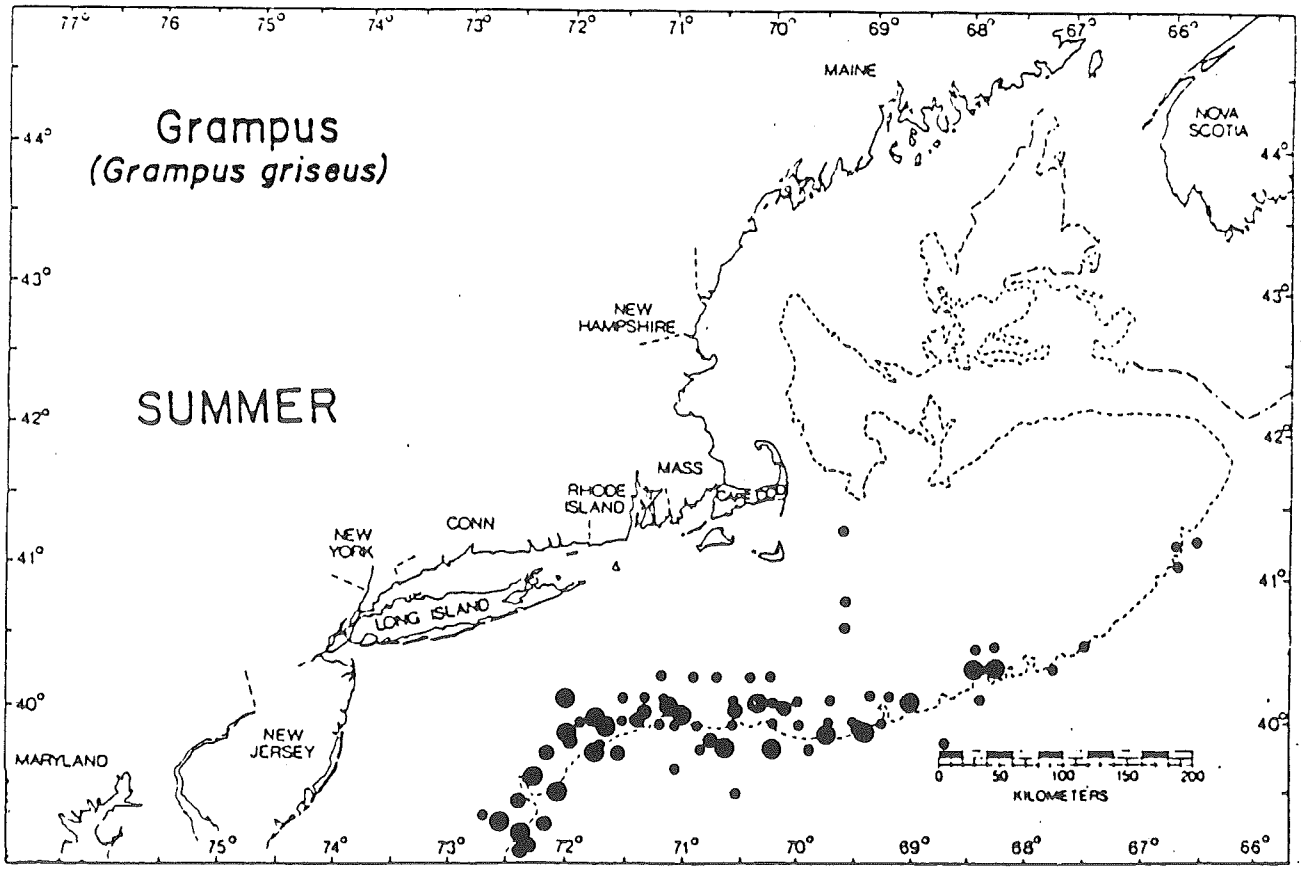

Grampus
(Grampus griseus)
SPRING
MAINE
NOVA SCOTIA
NEW HAMPSHIRE
MASS
RHODE ISLAND
CONN
NEW YORK
LONG ISLAND
NEW JERSEY
MARYLAND
0 50 100 150 200
KILOMETERS

C


Grampus
(Grampus griseus)
SUMMER
MAINE
NOVA SCOTIA
NEW HAMPSHIRE
MASS
RHODE ISLAND
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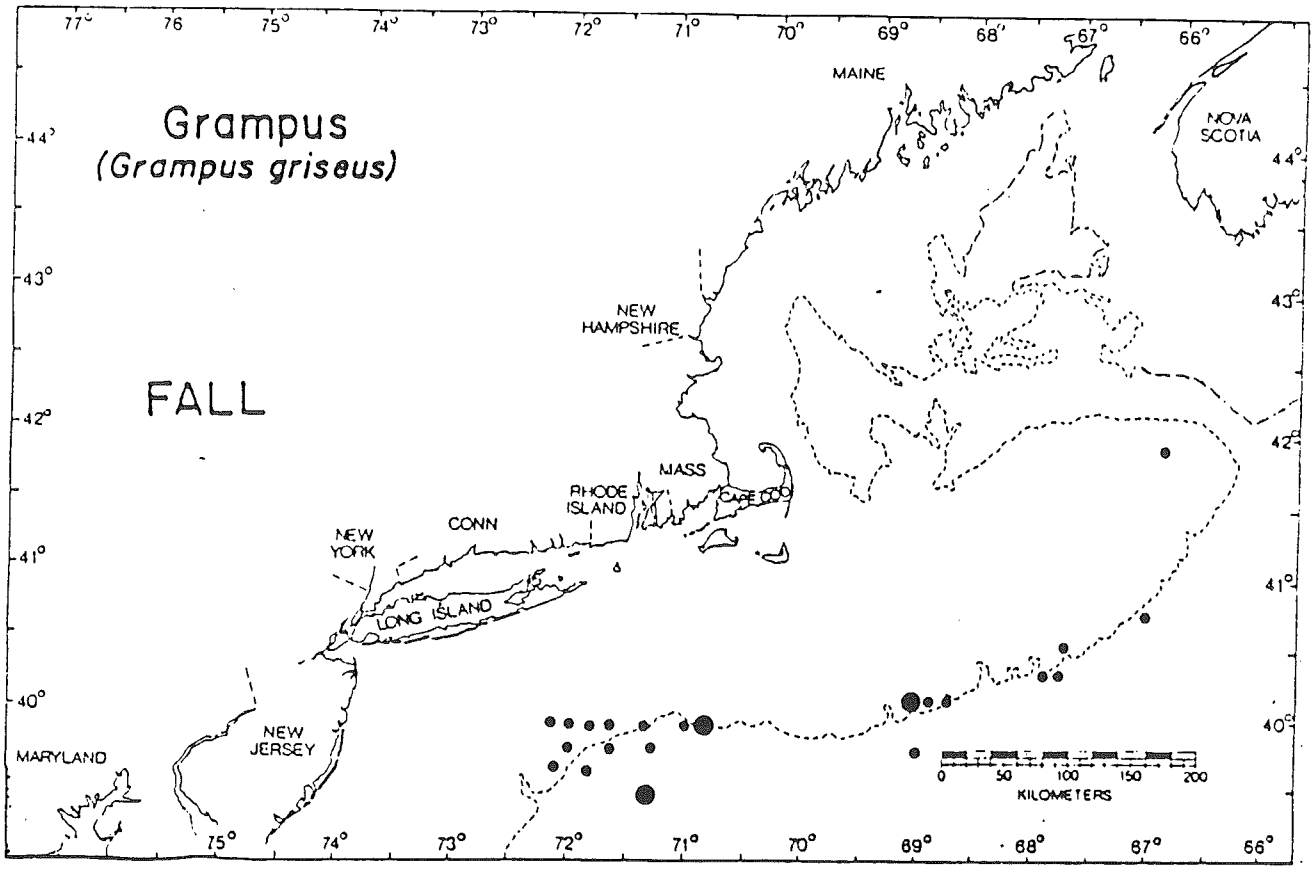
NEW YORK
LONG ISLAND
NEW JERSEY
MARYLAND
0 50 100 150 200
KILOMETERS

D


Grampus
(Grampus griseus)
FALL
MAINE
NOVA SCOTIA
NEW HAMPSHIRE
MASS
RHODE ISLAND
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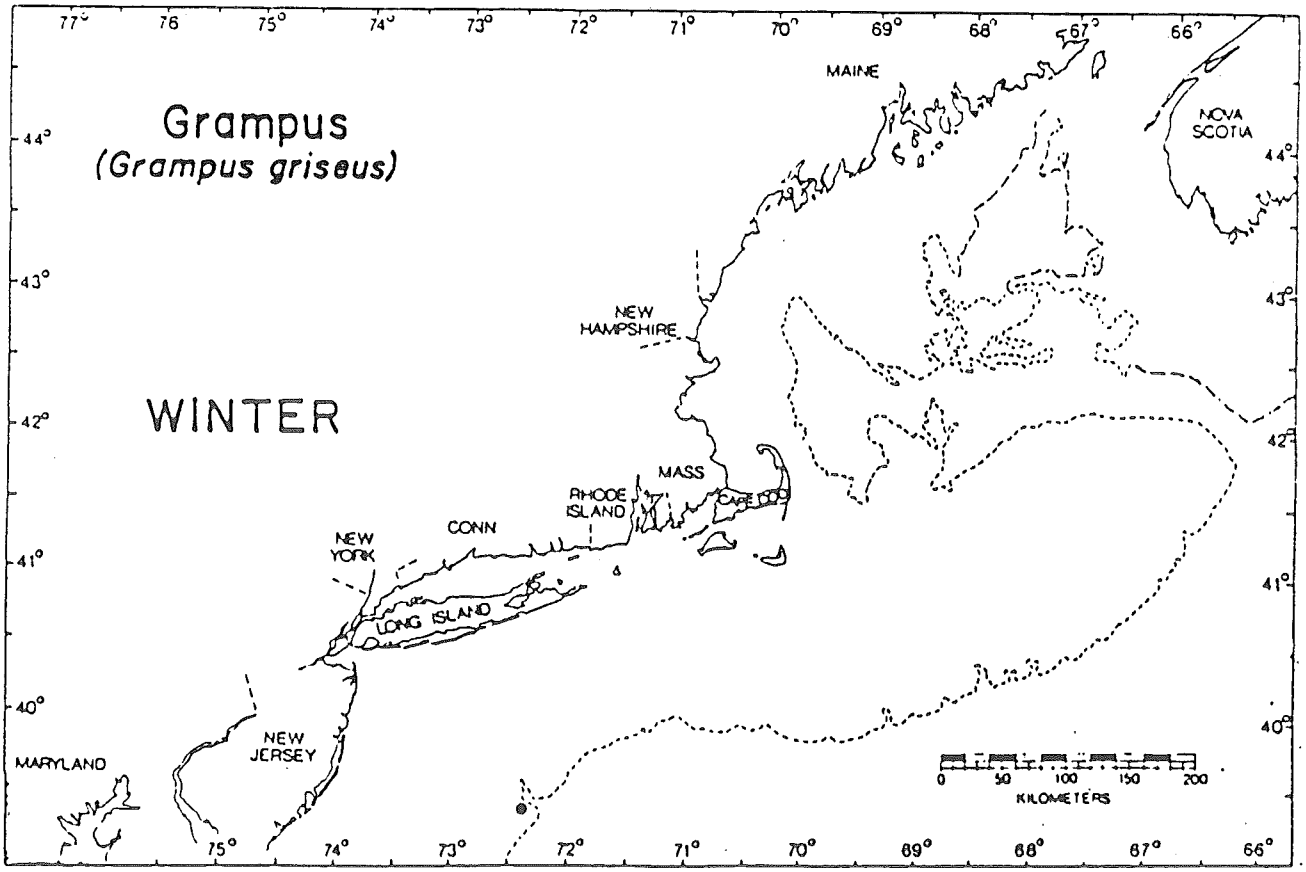
NEW YORK
LONG ISLAND
NEW JERSEY
MARYLAND
0 50 100 150 200
KILOMETERS

E


Grampus
(Grampus griseus)
WINTER
MAINE
NOVA SCOTIA
NEW HAMPSHIRE
MASS
RHODE ISLAND
CONN
NEW YORK
LONG ISLAND
NEW JERSEY
MARYLAND
0 50 100 150 200
KILOMETERS

Pilot Whale (Globicephala spp.)

The Atlantic pilot whale G. melaena is common from Greenland, Iceland, and the Faeroe Islands (Saemundsson 1939; Sergeant 1968; Kapel 1975; Mercer 1975; Mitchell 1975) south to at least Cape Hatteras (Leatherwood et al. 1976; Katona et al. 1977; Hain et al. 1981; CETAP 1982) and east across the north Atlantic to European waters (Brown 1961). In the southern portion of its western North Atlantic range, G. melaena is sympatric with the short-finned pilot whale G. macrorhyncha. G. macrorhyncha is a more tropical species, common off Florida, in Caribbean waters (Mead 1975, in Katona et al. 1977; Caldwell et al. 1971; Caldwell and Caldwell 1975; Leatherwood et al. 1976) and into the Gulf of Mexico (Fritts and Reynolds 1981). It has stranded as far north as New Jersey (Katona et al. 1977).

From Cape Hatteras to northeast Georges Bank, including the Gulf of Maine, the distribution of pilot whales (although G. melaena is the most common species in our study area, both species are considered together due to difficulties in field identification) generally follows the shelf edge between the 100 m and 1000 m contour (Figs. 47a-e). During mid-winter to spring (December to May), sightings are reported along the shelf edge of the mid-Atlantic and southern New England regions. Throughout spring (Figs. 47a-b), sightings increase along the shelf edge and north to, and including, Georges Bank. They are most abundant on Georges Bank from May to October (Hain et al. 1981; Powers et al. 1982). This is consistent with the findings reported by Katona et al. (1977) and CETAP (1982). During summer and fall, sightings occur on central Georges Bank north along the northern edge of the Bank, and into the central Gulf of Maine. This trend continues as pilot whales move north to the inshore Newfoundland waters by June (Sergeant and Fisher 1957; Sergeant et al. 1970).

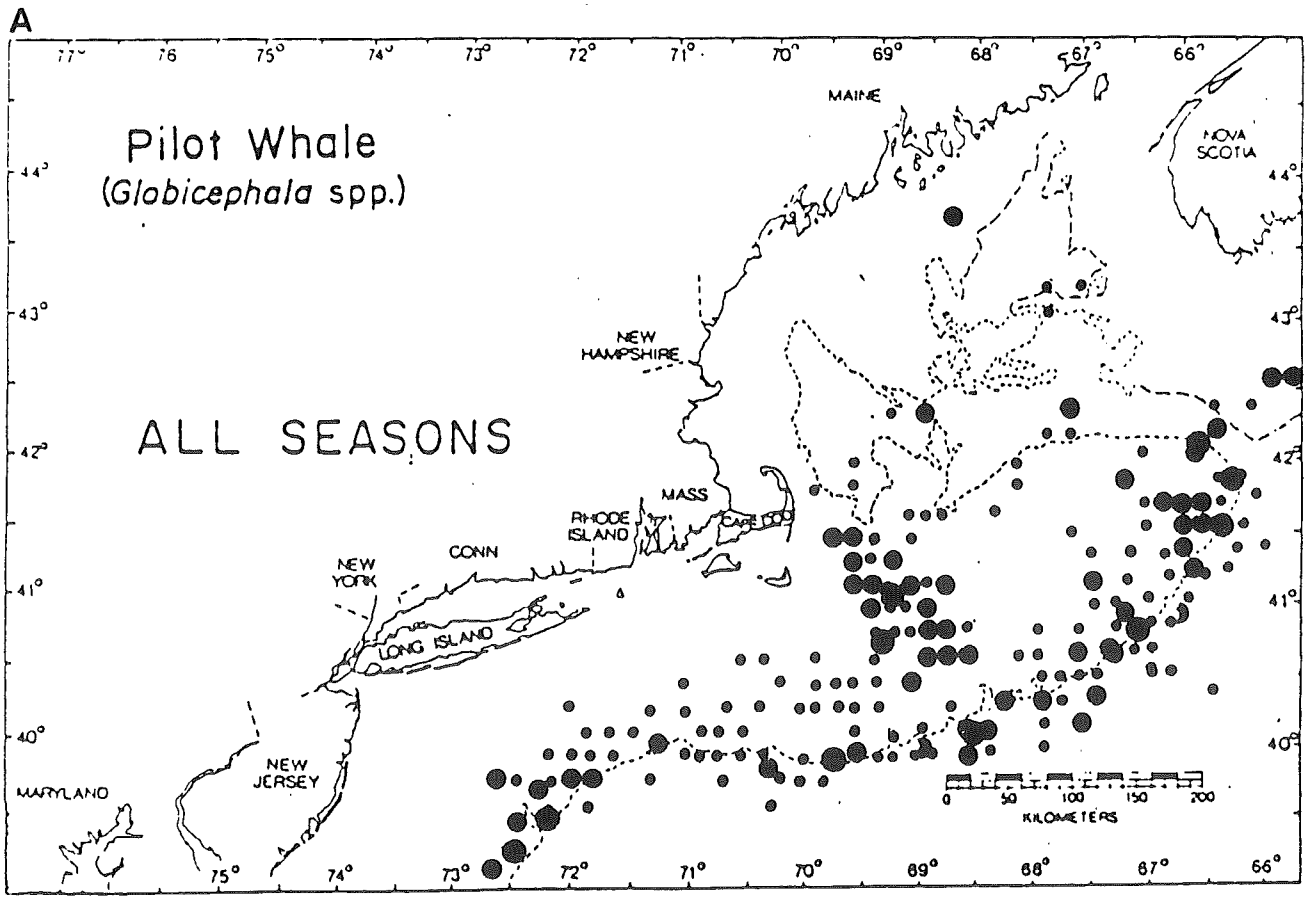
Pilot whales are present on Georges Bank summer through winter (Figs. 47b-e) with scattered sightings along the shelf edge of Georges Bank throughout the year. Sightings are clustered along the northern edge of the Bank and in the Great South Channel in fall. Thus, during the fall migration south, sightings occur over a broader area of the shelf than during the spring northward movement which occurs principally along the shelf edge.

Globicephala are tertiary consumers that are considered teuthophagous (Scott et al. 1983), feeding primarily on squid (Mercer 1975; Caldwell et al. 1971), with fish and invertebrates as alternative prey items (Sergeant 1962; Mercer 1967; Katona et al. 1977). The preferred food of Globicephala meleana, off Newfoundland, is the short-finned squid Illex illecebrosus (Sergeant 1962). Food eaten when squid were not present were Atlantic cod Gadus morhua (Sergeant 1962) and Greenland turbot Reinhardtius hippoglossoides (Mercer 1967). The squid taken most commonly by G. meleana in north European waters is probably Ommastrephes sagittatus; fish observed in pilot whale stomachs from north Britain include horse mackeral Caranx trachurus and flatfish Pleuronectiidae (Mitchell 1975a). In our study area, the long-finned squid Loligo pealei and Atlantic mackerel Scomber scombrus have been suggested as probable prey items in the mid-Atlantic Bight during winter and spring (G. Waring, NMFS/NEFC, pers. comm.).

Figure 47. Relative distribution and abundance of pilot whales in the Gulf of Maine, including Georges Bank (north of 40°00'N latitude) by season.

Relative Abundance
cetaceans per 10'x10' block

- 1 - 9
- 10-99
- >100



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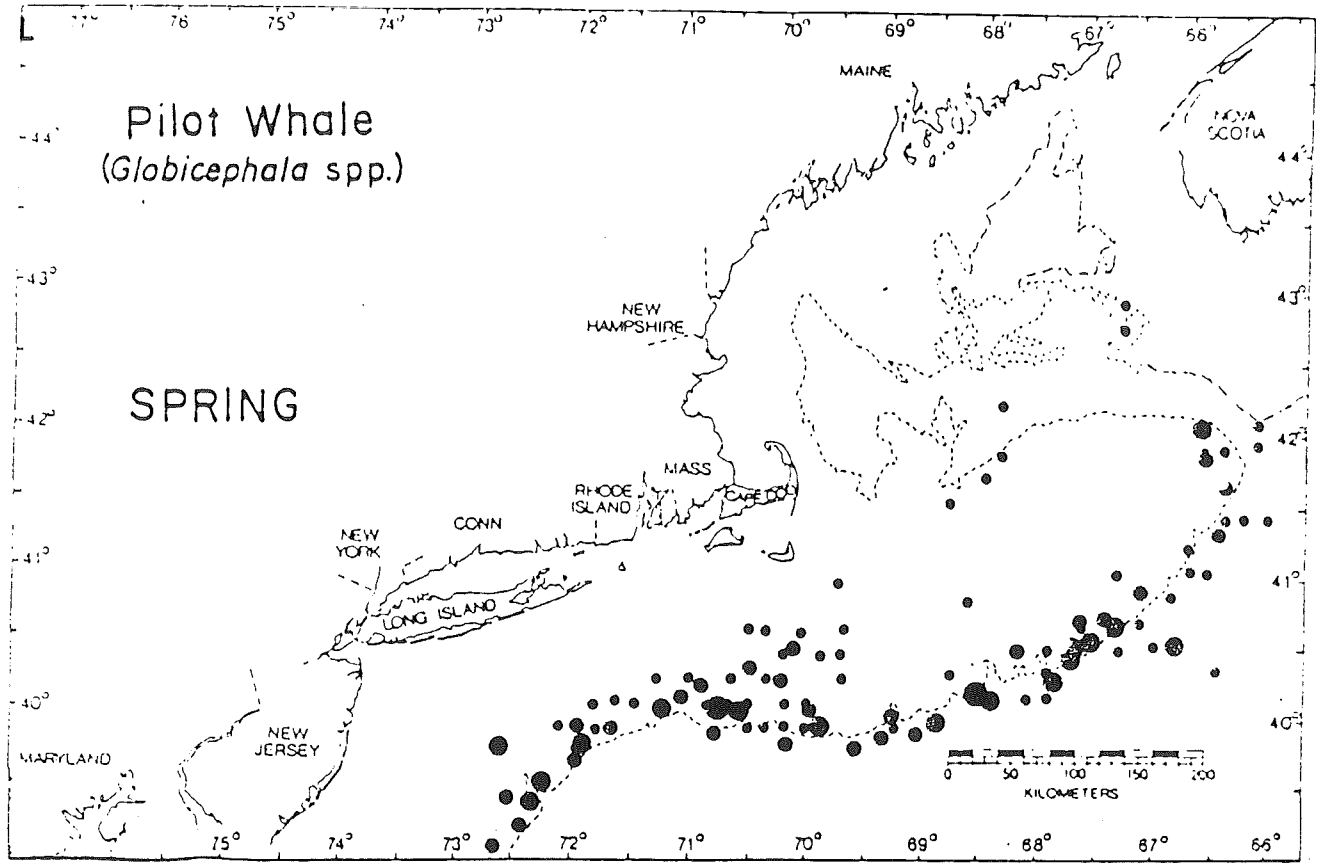
Pilot Whale
(Globicephala spp.)
SPRING
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NOVA SCOTIA
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NEW JERSEY
MARYLAND
KILOMETERS

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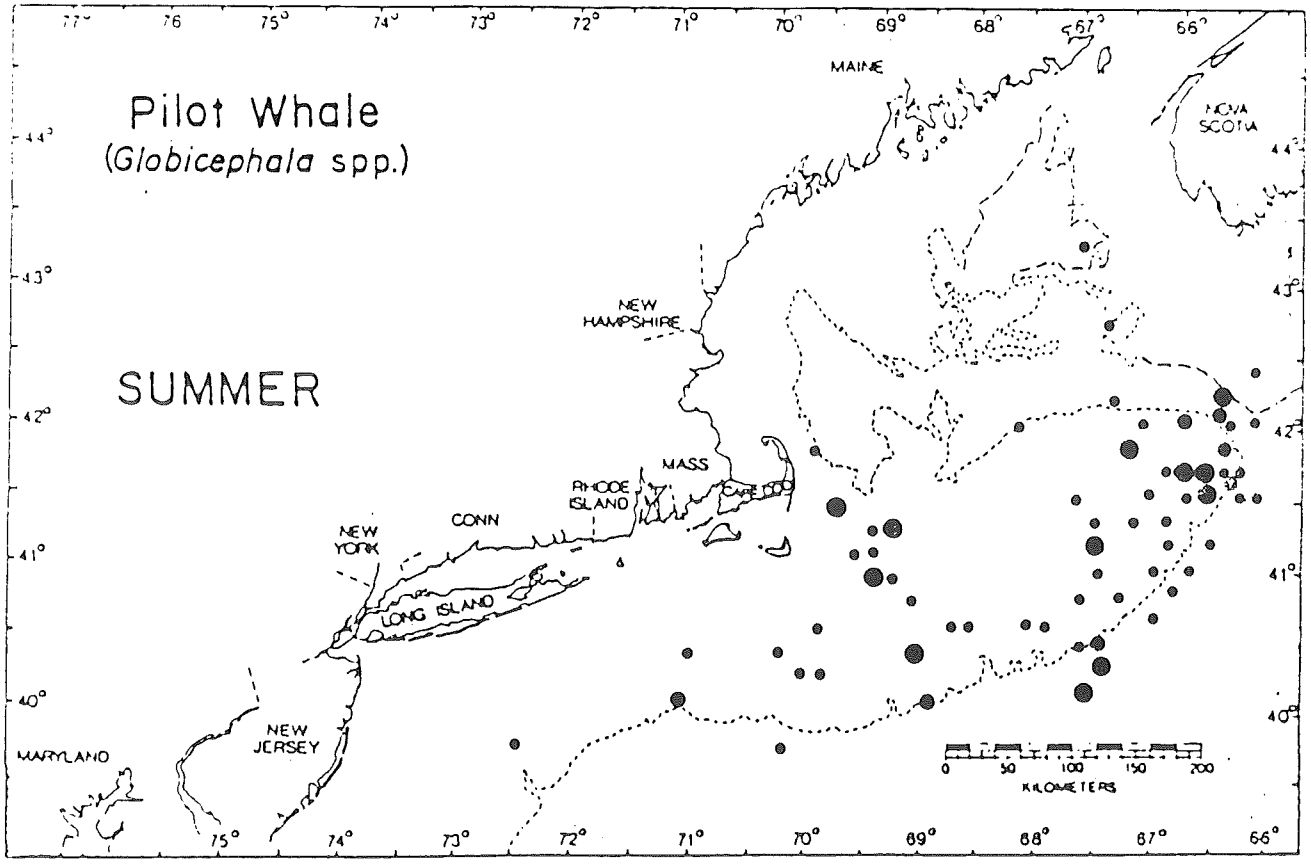
Pilot Whale
(Globicephala spp.)
SUMMER
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MARYLAND
KILOMETERS

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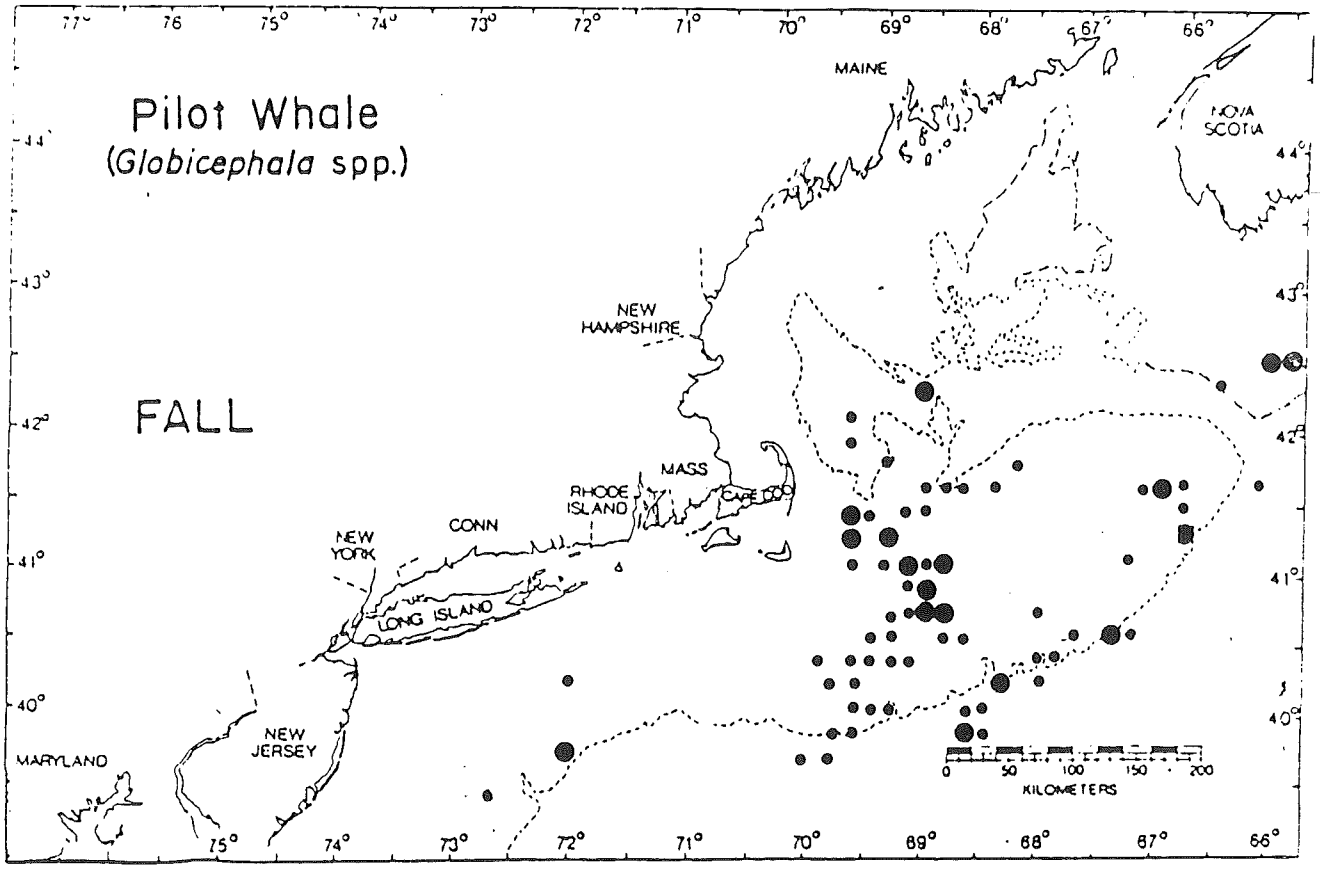
Pilot Whale
(Globicephala spp.)
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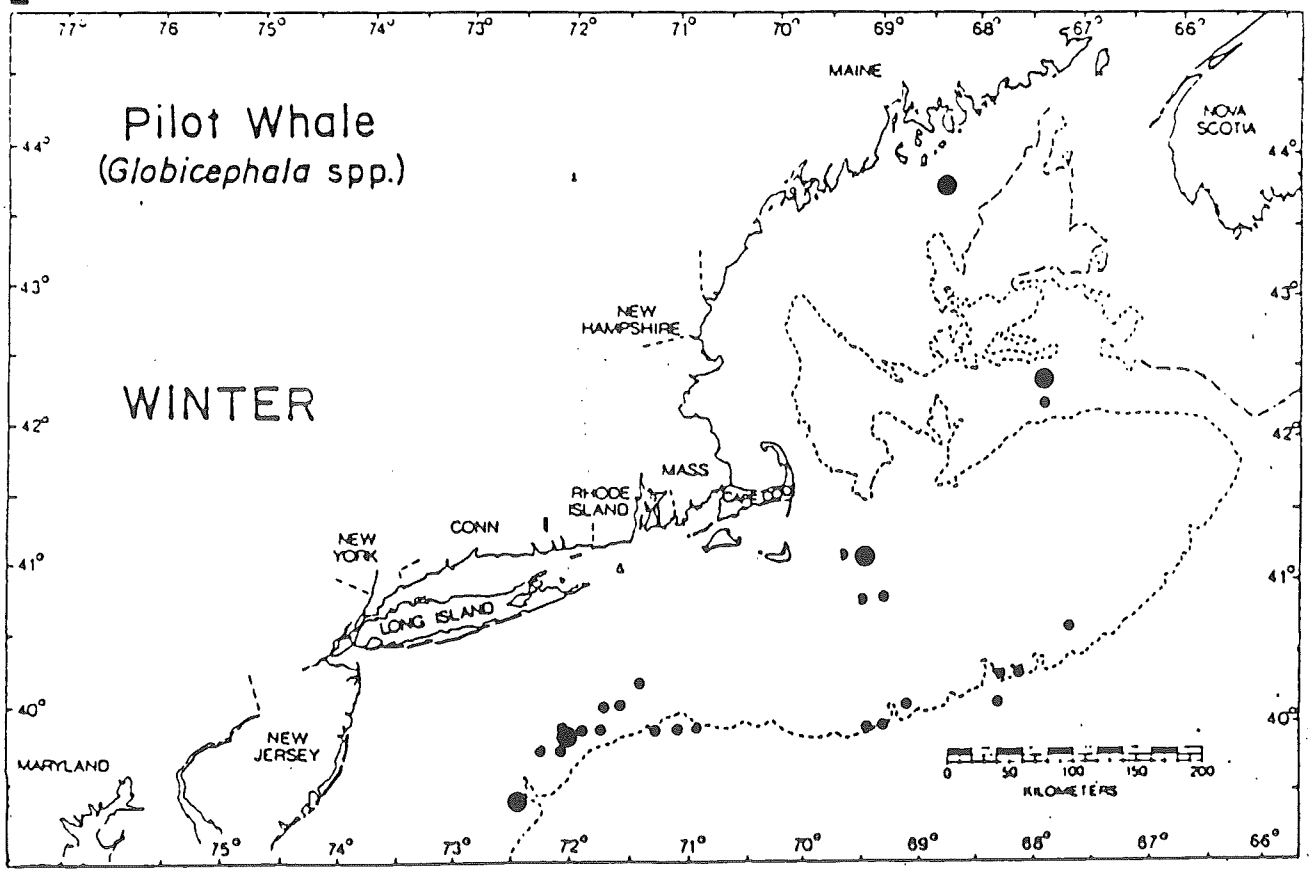
Pilot Whale
(Globicephala spp.)
WINTER
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MARYLAND
0 50 100 150 200
KILOMETERS

Harbor Porpoise Phocoena phocoena

The harbor porpoise is locally abundant in temperate waters of the northern hemisphere, principally in shallow shelf waters (Gaskin et al. 1974; Leatherwood et al. 1976; Prescott and Fiorelli 1980; Gaskin 1984). They have been reported from the Davis straits south to Cape Hatteras, North Carolina (Mitchell 1975c; Leatherwood et al. 1976; CETAP 1982; Payne et al 1984); within this range they are most common in the Bay of Fundy and off southwest Greenland (Neave and Wright 1968; Gaskin et al. 1974; 1975; Kapel 1975, 1977; Leatherwood et al. 1976; Gaskin 1977, 1984; Prescott and Fiorelli 1980; Kraus and Prescott 1981; Kraus et al. 1983; Gaskin and Watson 1985).

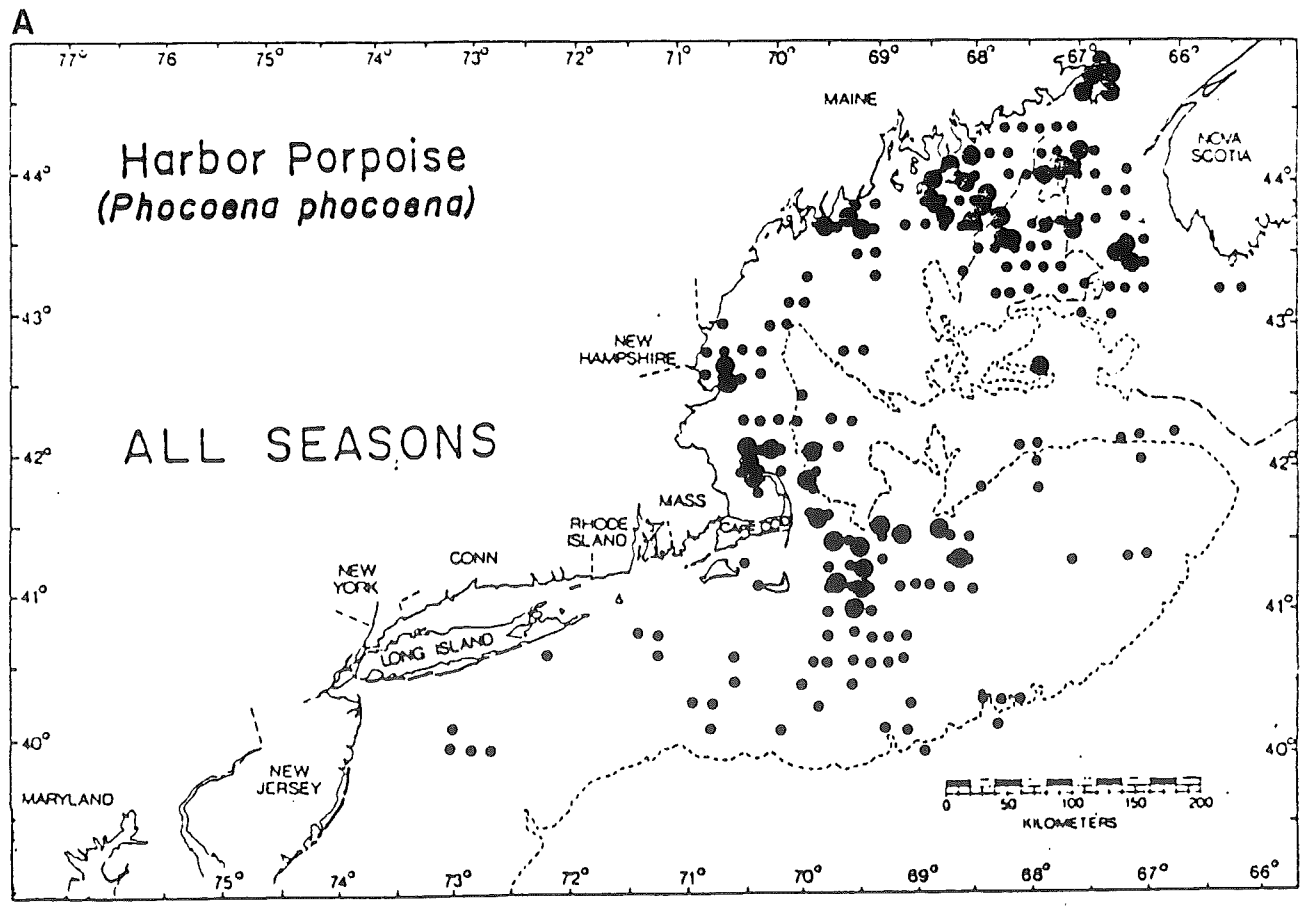
In the Bay of Fundy and northern Gulf of Maine in summer, harbor porpoise would be classified as "abundant" in comparison with all other areas examined (Gaskin 1977). Gaskin (1977, 1984) noted that densities of harbor porpoise in the lower Bay of Fundy - upper Gulf of Maine increased in late June to mid-July, remained high in August to September, then decrease throughout fall. These results are in agreement with results obtained previously by Neave and Wright (1968) (Figs. 48a-e). Prescott and Fiorelli (1980) indicated that the northern Gulf of Maine and the Bay of Fundy might support as much as 80% of the total summer population south of the Gulf of St. Lawrence. During the high abundance levels of summer in the northern Gulf of Maine (Fig. 48c), sightings throughout the southwestern Gulf of Maine (Jeffreys Ledge and Stellwagen Bank) and Cape Cod Bay are rare (CETAP 1982). In the winter (Fig. 48e), the distribution of harbor porpoise shifts markedly to the south and offshore. Sightings are scattered throughout the lower Gulf of Maine and Georges Bank and overall numbers are drastically reduced (CETAP 1982). Sightings south of 40°00'N latitude in coastal bays increase during this period (MBO, unpublished survey data 1984-1985). Prescott and Fiorelli (1980) suggest that other offshore Banks (i.e. Grand Banks) may also provide winter habitat for this species. By mid-spring sightings of harbor porpoise again are concentrated in the southwest Gulf of Maine - Great South Channel region, on Jeffreys Ledge and in portions of coastal Maine.

Estimates of harbor porpoise abundance in summer range from approximately 8,000 to 15,000 in the Gulf of Maine - Lower Bay of Fundy (Kraus et al 1983) to approximately 2,500 in the Gulf of Maine only (CETAP 1982). Kraus et al. (1984) suggested that aerial surveys locate approximately 14% of the total harbor porpoise present in an area. Therefore applying this factor to the aerial estimates of CETAP (1982) results in a modified estimate of approximately 16,000 harbor porpoise in the Gulf of Maine. This is in very close agreement to the findings of Kraus et al. (1983).

The diet of harbor porpoise consists of small schooling fishes, polychaetes and cephalopods (Rae 1965; Smith and Gaskin 1974). In the Gulf of Maine, herring, mackerel, squid and likely sand eel are important prey items (Katona et al 1983).

High levels of pollutants have been found in the tissue of harbor porpoise in the Bay of Fundy region (Gaskin et al., 1971, 1979; Gaskin and Smith 1979). As an abundant component of the marine system in that region, the harbor porpoise may be a good indicator of environmental contamination.

Figure 48. Relative distribution and abundance of harbor porpoise in the Gulf of Maine, including Georges Bank (north of 40°00'N latitude) by season.



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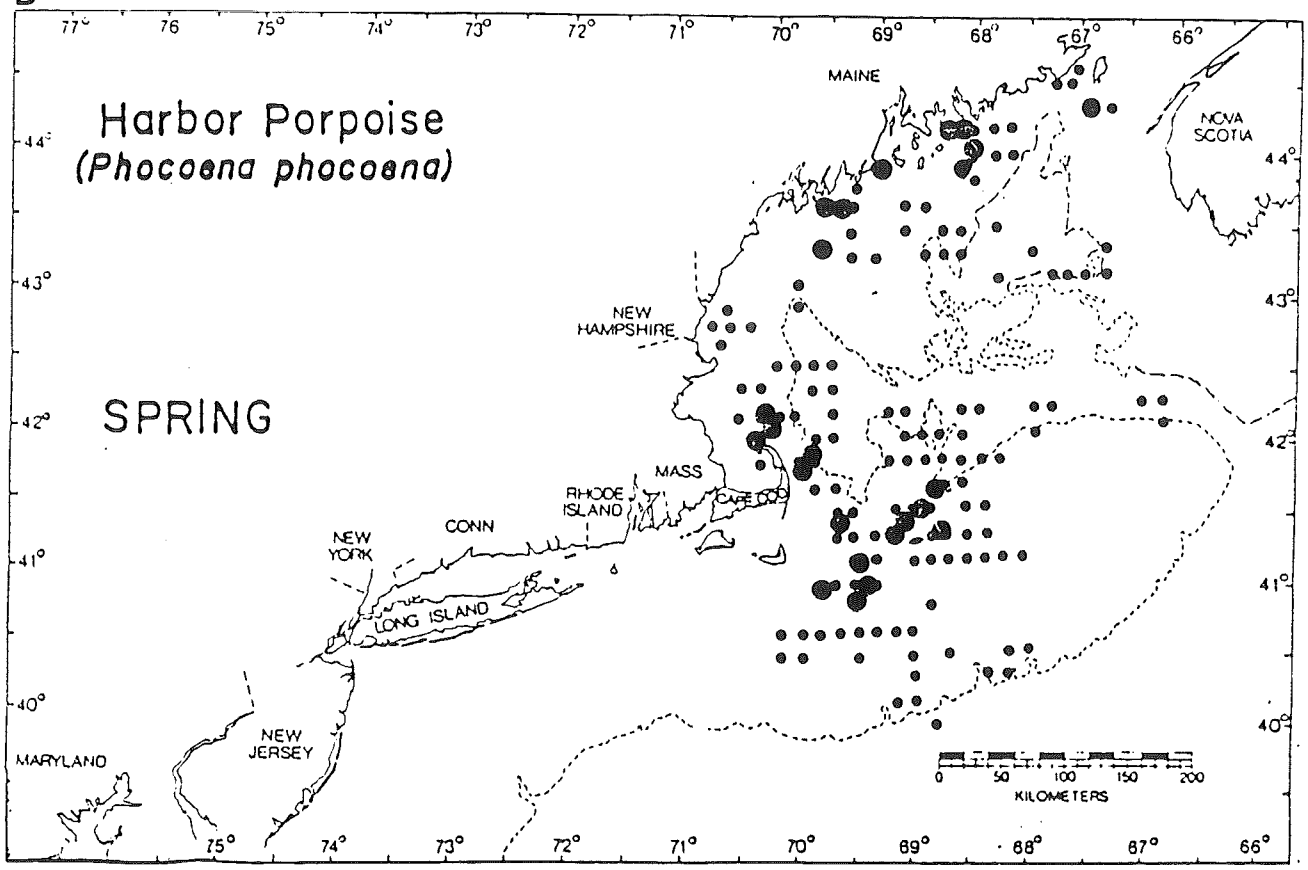
Harbor Porpoise
(Phocoena phocoena)
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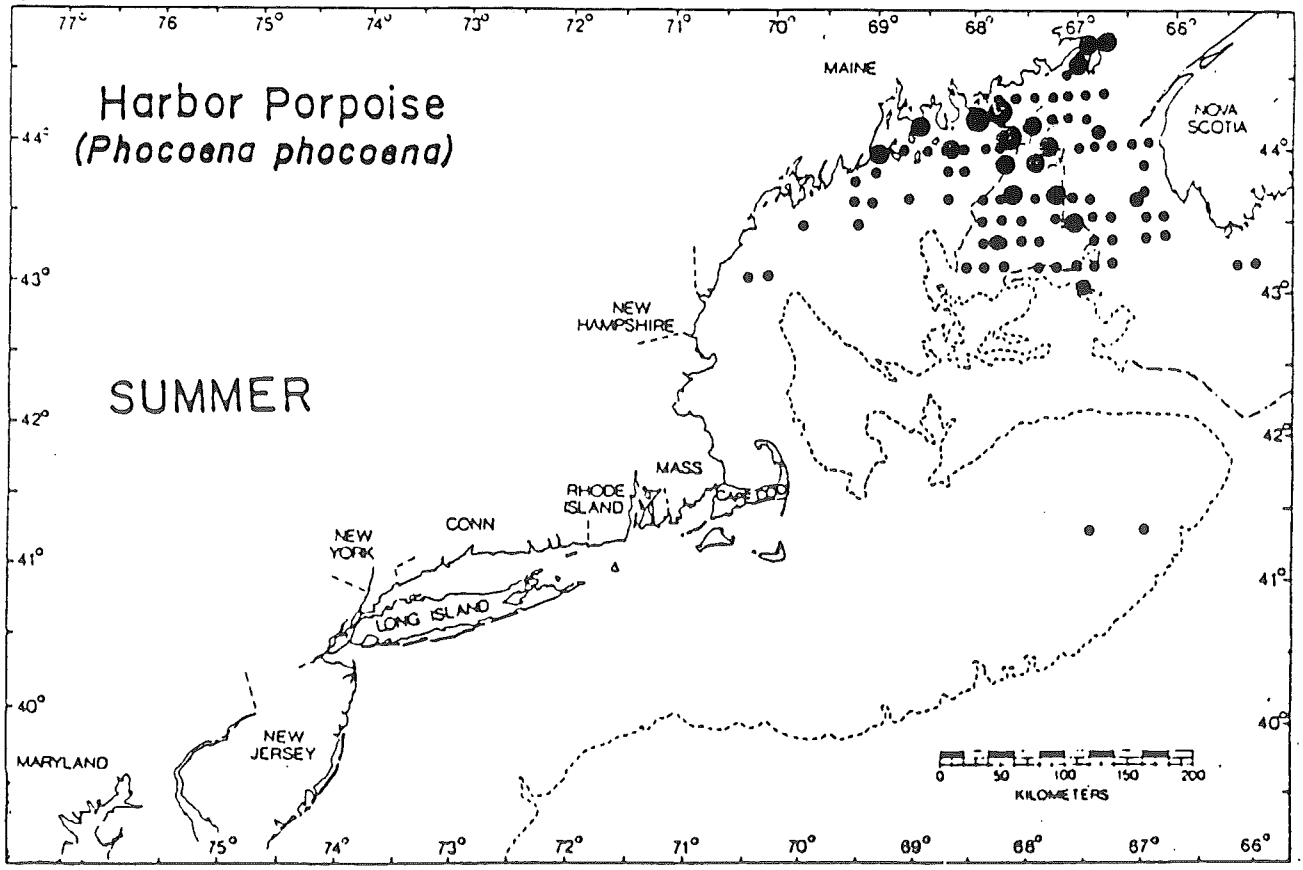
Harbor Porpoise
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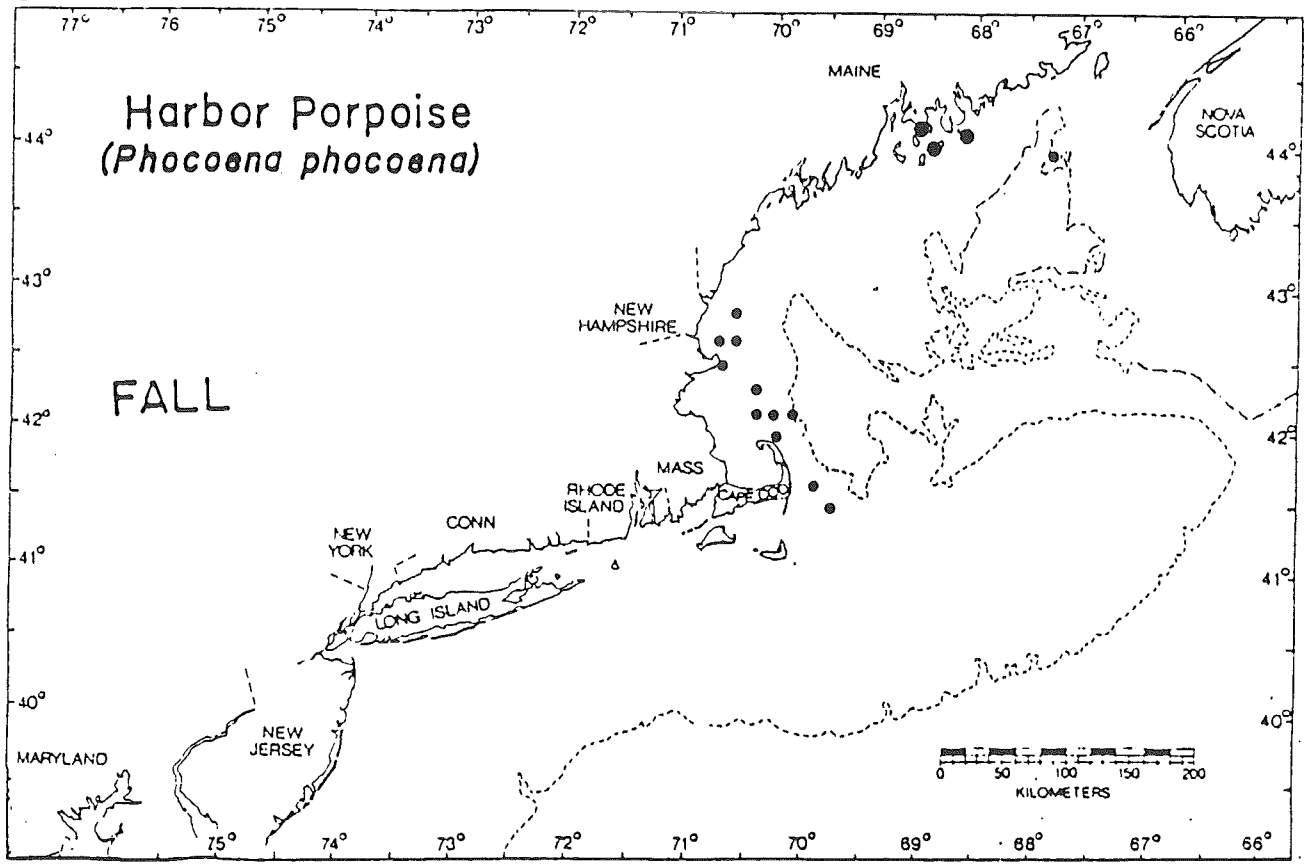
Harbor Porpoise
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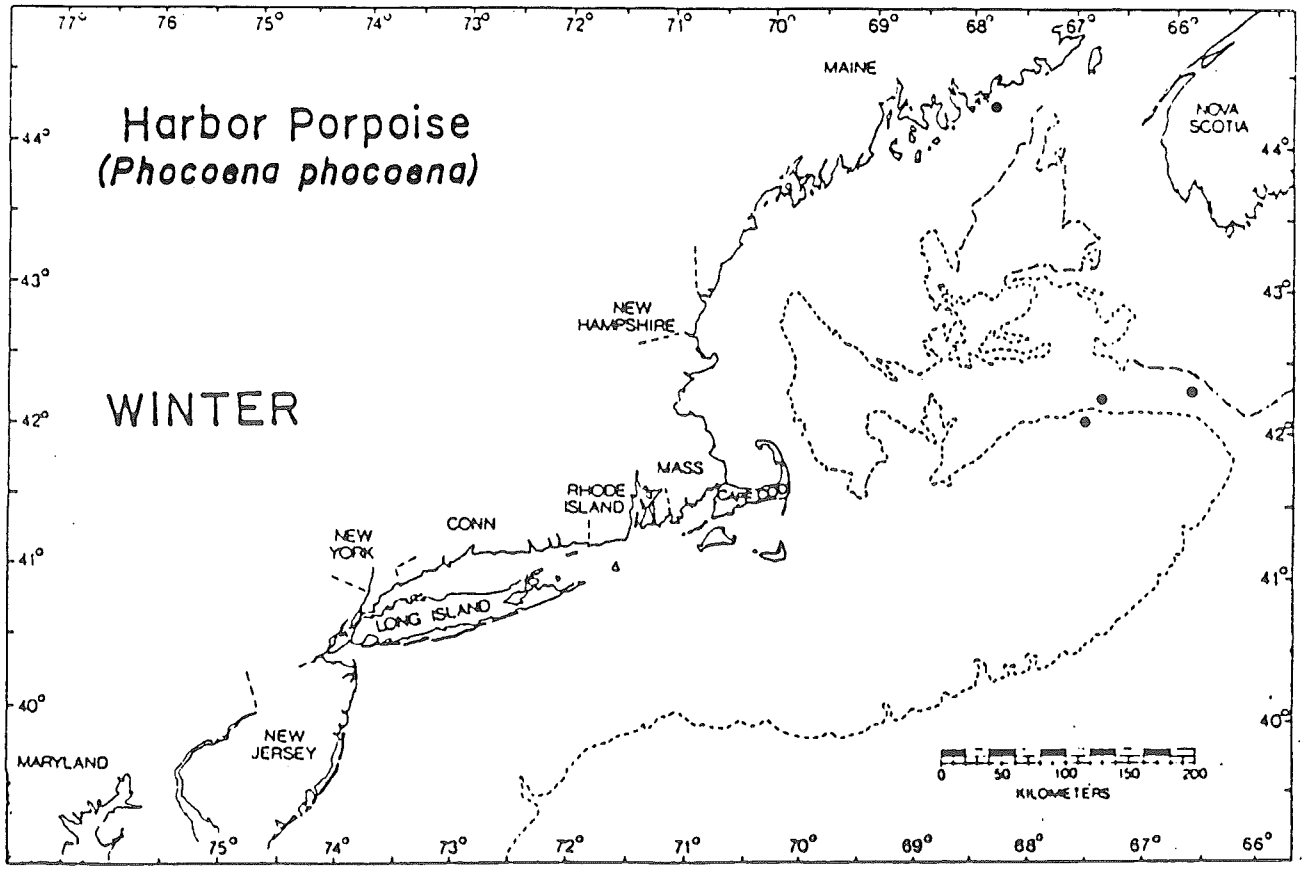
Harbor Porpoise
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PINNIPED SPECIES ACCOUNTS

Harbor seal *Phoca vitulina*

Harbor seals are the most abundant pinniped species occurring in the eastern United States. They are common from Labrador to Long Island, New York, and are found occaisionally as far south as South Carolina (Brimley 1931) and Florida (Caldwell and Caldwell 1969). Though not the dominant species, they also are quite prevalent in eastern Canada. Along the eastern North American coast, harbor seals are widely distributed in nearshore waters. They prefer sheltered and undisturbed rocky ledge haulout sites of coastal bays and estuaries from Maine south to Plymouth, Massachusetts, and isolated sandy beaches and shoals south of Plymouth. Their present breeding range in the northwest Atlantic extends from ice - free waters of the Arctic to New Hampshire, though previously harbor seals bred as far south as Cape Cod Bay in the first half of the twentieth century (Katona *et al.* 1983). They are now only seasonal residents in southern New England (south of Maine), appearing in late September and remaining until late May (Payne and Schneider 1984). The present geographical and breeding ranges probably are a direct result of a continued state - offerred bounty on harbor seals in southern New England which remained in effect in Massachusetts until 1962. The bounty undoubtedly resulted in 1) an overall reduction of seal numbers throughout southern New England, 2) limited southward dispersion of seals from Maine rookeries (Payne and Schneider 1984), 3) likely led to the extirpation of breeding activity south of Maine (Katona *et al.* 1983), and, 4) the present seasonal occurrence of harbor seals south of Maine. To date, all breeding activity, which occurs from late April to mid-June (Katona *et al.* 1983), takes place north of Massachusetts.

Since the passage of the Marine Mammal Protection Act in 1972, the abundance of harbor seals in New England has increased steadily. The greatest concentration of seals occurs along the northern Maine coast in Machias and Penobscott Bays, and off Mount Desert and Swans Islands (Katona *et al.* 1983). Current population estimates derived from aerial surveys show that the Maine population is increasing and is now 12,000 to 15,000 animals (Katona *et al.* 1983). Approximately 4000 seals (25% of the New England population) overwinter south of Maine; 60% of these animals occur on, or adjacent to, Cape Cod, Massachusetts (Payne *et al.* 1985).

Harbor seals are opportunistic feeders, eating species which are regionally and seasonally dominant (Boulva 1976; Pitcher 1980a, 1980b; Brown and Mate 1983), with a preference for small, schooling fishes (Boulva and McLaren 1979). Katona et al. (1983) report that seals feed on fish and invertebrates as available, primarily herring, squid, alewife, flounder and hake. However, after analysing fecal samples collected south of Maine, Payne *et al.* (1985) report two distinct faunal communities taken by seals in southern New England. The community of fishes selected by harbor seals from the Isle of Shoals, New Hampshire was diverse, and was representative of the bottom fishes characteristic of the relatively deep waters of the Gulf of Maine. These included: Redfish *Sebastes marinus*, Cod *Gadus morhua*, Herring *Clupea harengus* and Yellowtail flounder *Limanda ferruginea*. In contrast, the prey selected from the relatively shallow waters adjacent to Cape Cod was numerically dominated (99%) by sand eel *Ammodytes americanus* (Payne *et al.* 1985).

Gray Seal *Halichoerus grypus*

Gray Seals are the most abundant pinnipeds in the southern reaches of eastern Canada from Labrador south through the Bay of Fundy. Approximately 40,000 to 50,0000 inhabit the Canadian Maritimes, and that stock is expanding (Beck 1983; Katona *et al*. 1983). Colonies in the Gulf of Maine are found in the Grand Manan archipelago of the Bay of Fundy, although these number less than one hundred (Richardson *et al*. 1974). Non-breeding colonies also are located in the Mt. Desert Rock - Penobscott Bay area (Katona *et al*. 1983). Katona *et al*. (1983) estimate a total of approximately 600 gray seals in the Maine area.

A Massachusetts population of 70 or more gray seals in the early 1940s was reduced by bounty killing to 20 or less by 1963 when the bounty was repealed (Sherman 1986). This population, located southwest of Nantucket Island, is the only actively breeding population in the eastern United States. Pupping occurs in mid-winter, although pup production has been very low in recent years (Shurman 1983). Despite the low pupping rate of the Nantucket population, the total overwintering population in Massachusetts exceeded 100 animals in 1986 (MBO, unpubl. data). This recent population growth probably is due to the immigration of seals from eastern Canada where the stock is expanding rapidly (Rough, in press). This hypothesis is strengthened by the repeated occurrence of animals in southern New England that were tagged as pups on Sable Island, Nova Scotia (Beck 1983; Shurman 1983).

Gray seals consume fish and invertebrates as available, the most common food items in the Bay of Fundy and eastern Canada are herring, cod, flounder, skate, squid and mackerel (Beck 1983; Katona *et al*. 1983). Shurman (1983) suggests that the Nantucket gray seals feed primarily on skates, alewives and sand eel, all of which are abundant in that area from mid-winter to late spring.

SEABIRD SPECIES ACCOUNTS

Approximately forty species or species-groups of marine birds are found throughout the year in the waters of the FADS and the CADS study areas (Table 15). Following are the accounts of the ten dominant species or species groups at each study site by season. In some instances, a minimum of ten species were not recorded within a season.

The data were collected by observers from the Manomet Bird Observatory aboard research vessels conducting standardized surveys in these waters between 1980-85. Each of the disposal study areas was divided into an inshore and an offshore component. Within the FADS study area, all observations of marine birds inshore of the designated dumpsite are discussed separately from those occurring offshore of the dumpsite (nearer Stellwagen Bank). Within the CADS study area, all observations recorded inshore of the 90m depth contour are discussed separately from those occurring in deeper waters. The CADS is located inshore of the 90m contour.

Table 15. Seasonal occurrence of seabirds in the Gulf of Maine.

Species	Winter	Spring	Summer	Fall
Common Loon *Gavia immer*	x	x	x	x
Red-throated Loon *Gavia stellata*		x		x
Northern Fulmar *Fulmaris glacialis*	x	x	x	x
Cory's Shearwater *Calonectes diomedia*			x	x
Greater Shearwater *Puffinus gravis*	x		x	x
Sooty Shearwater *Puffinus griseus*			x	
Manx Shearwater *Puffinus puffinus*			x	x
Leach's Storm-Petrel *Oceanodroma luecorhoa*			x	
Wilson's Storm-Petrel *Oceanicus oceanites*		x	x	x
Northern Gannet *Morus bassanus*	x	x	x	x
Red Phalarope *Phalaropus fulicaria*	x			x
Northern Phalarope *Phalaropus lobatus*		x	x	
Pomarine Jaeger *Stercorarius pomarinus*		x	x	x
Parasitic Jaeger *Stercorarius parasiticus*			x	x
Glaucous Gull *Larus hyperbureus*	x			x
Iceland Gull *Larus glaucoides*	x			x

Table 15 (continued).

Species	Winter	Spring	Summer	Fall
Great Black-backed Gull *Larus marinus*	x	x	x	x
Herring Gull *Larus argentatus*	x	x	x	x
Ring-billed Gull *Larus delawarensis*	x		x	x
Laughing Gull *Larus atricilla*	x	x	x	x
Bonaparte's Gull *Larus philadelphia*	x			
Black-legged Kittiwake *Rissa tridactyla*	x	x		x
Common Tern *Sterna hirundo*		x	x	
Arctic Tern *Sterna paradisaea*			x	
Least Tern *Sterna albifrons*			x	
Alcidae spp.	x	x	x	
White-winged Scoter *Melanitta deglandi*	x	x	x	x
Black Scoter *Melanitta negri*	x			x
Surf Scoter *Melanitta perspicillata*	x	x		x
Common Eider *Somateria mollisima*	x	x		x
Red-breasted Merganser *Mergus serrator*	x			x
Double-crested Cormorant *Phalacrocorax auritas*	x	x	x	x
Great Cormorant *Phalacrocorax carbo*	x			x
Oldsquaw *Clangula hyemalis*	x	x		x

Northern Fulmar (*Fulmarus glacialis*)

Dietary opportunists, fulmars feed at the surface as secondary and tertiary carnivores and as scavengers on zooplankton, fish, squid, and offal from fishing vessels (Fisher 1952; Palmer 1962; Ainley and Sanger 1979; Hunt *et al*. 1981; Powers 1983).

Fulmars were recorded throughout the year in the Gulf of Maine, however, greatest densities occurred in the winter. Flocks of several thousand fulmars were noted each winter in the Gulf, often associated with fishing vessels (Powers 1983).

With respect to the FADS, fulmars were recorded inshore of the disposal site only in spring, while offshore of the disposal site in waters including, and contiguous to, the Foul Area, fulmars were recorded spring-fall. Greatest densities in this area occurred in the fall (Table 16). In waters including and adjacent to the CADS, fulmars again were more abundant seaward of the disposal site than inshore of the disposal site (Table 17). Greatest concentrations in this area occurred in winter when the mean density of birds exceeded 1 bird/km^2.

Shearwater *spp*.

Four species of shearwaters were recorded from late spring to early winter, though patterns of distribution varied between species. All species feed at or in near-surface waters as secondary and tertiary carnivores on fish, squid and crustaceans (Palmer 1962; Cramp *et al*. 1977; Brown *et al*. 1981; Powers 1983); greater *Puffinus gravis* and manx *P. puffinus* shearwaters also scavenge offal from fishing vessels (Bent 1922; Brown *et al*. 1981).

Greater shearwaters are the dominant shearwater in the Gulf of Maine from late May to early December (Payne *et al* 1984). Greatest densities of this species occurred in the summer and fall from Stellwagen Bank south through the Great South Channel. Flocks of more than 10,000 birds were observed in this region in the fall, often in association with fishing vessels (Powers 1983). Sooty shearwaters were recorded from April to November; however greatest densities occurred in the summer (Payne *et al*. 1984). Cory's shearwaters were found in the Gulf of Maine throughout the summer and fall; however, the majority of the population in the shelf waters off the northeastern United States remains south of the Gulf of Maine from Georges Bank to Cape Hatteras, North Carolina. Manx shearwaters occurred in the Gulf of Maine in summer and fall, specifically on Stellwagen Bank and south through the Great South Channel; however densities never exceeded 0.1 birds/km^2 (Payne *et al*. 1984).

As in the entire Gulf of Maine, greater shearwaters were the most abundant shearwater in waters adjacent to both the FADS and CADS. Greatest densities near both areas occurred in the summer and fall (Table 16-17), and there was a marked increase in the densities of birds offshore of the disposal sites relative to waters inshore of the disposal sites. Sooty shearwaters were seen adjacent to the FADS only in summer and adjacent to the CADS only in the fall. Cory's shearwaters were recorded only near the FADS and only in summer. No manx shearwaters were observed in waters adjacent to either site.

Storm-Petrel spp.

Two species of storm-petrels were recorded throughout the study area from April to November. Both feed principally at the surface as secondary carnivores on zooplankton, and to a lesser extent as tertiary carnivores on small fish and cephalopods (Cramp 1977; Ainley and Sanger 1979; Powers 1983). Wilson's storm-petrels Oceanites oceanicus also scavenge offal from fishing and whaling vessels (Cramp 1977) and carrion (Payne et al. 1983).

Greatest densities of Wilson's storm-petrels occurred along the southwestern boundary of the Gulf of Maine and in the Great South Channel in summer (Payne et al. 1984). Powers and Backus (1981) also found heavy concentrations of Wilson's storm-petrels in these regions. Leach's storm-petrels Oceanodroma leucorhoa were found from April to November, but were more common to the north on the Southern Scotian Shelf (Powers 1983). South of the Scotian Shelf, Leach's storm-petrels were most abundant along the Gulf of Maine/Georges Bank boundary and in shelf waters along the New England coast in summer.

Adjacent to the FADS, Wilson's storm-petrels were very common in summer, although much greater densities were recorded offshore of the disposal site (Table 16). Wilson's storm-petrels were present in spring to summer adjacent to the CADS but in numbers much less than observed near the FADS in the same season (Table 17). However, densities at the CADS were greater offshore of the foul area. Leach's storm-petrels were only recorded near the CADS in fall in very small numbers.

Northern Gannet (Sula bassanus)

Gannets feed as tertiary carnivores principally on schooling fish (Palmer 1962) and to a lesser extent on squid (Palmer 1962; Powers 1983). They will also scavenge offal from fishing vessels (Palmer 1962) and take fish from near surface fishing nets (Cramp et al. 1977).

Gannets are abundant in the Gulf of Maine fall through spring, being uncommon only north and east of Cape Cod in summer. Greatest densities occur from Stellwagen Bank south through the Great South Channel in fall. In fall, most of the birds are subadults, while in spring, the majority of birds are adults. In relation to the FADS, gannets were abundant in waters within and adjacent to the Foul Area from fall through spring (Table 16) and were the most abundant bird recorded during the winter-spring aerial surveys. Large concentrations were observed feeding near feeding groups of cetaceans. There was no appreciable difference in the densities recorded area between waters inshore and offshore of the disposal site. Gannets were abundant in the CADS region fall-spring; however, greater densities occurred offshore of the disposal site (Table 17).

Phalarope *spp*.

Both species of phalaropes found in shelf waters feed at the surface as secondary carnivores on planktonic crustaceans, and the eggs and larvae of fish and squid (Ainley and Sanger 1979). Red phalarope *Phalaropus fulicaria* are recorded predominantly in spring and fall, seasons which correspond to their north and south migrations. The spring northward movement of phalaropes occurs primarily along the outer edge of the shelf (60-200 m), where hydrographic features may lead to increased concentrations of zooplankton (Powers and Backus 1981; Powers 1983).

Red phalaropes were not recorded in waters adjacent to the FADS or the CADS in any season as the majority of birds remain offshore during their migrations. Northern phalaropes do not occur in such large flocks during their migration; however, most birds migrate closer to the coast. This species was recorded only in summer in waters contiguous to the disposal sites, and was the most abundant bird near the CADS during this season (Table 17).

Jaeger *spp*.

Two species of jaegers were recorded. Jaegers feed as secondary and tertiary carnivores on crustaceans, fish and cephalopods and offal from fishing vessels (Ainley and Sanger 1979; Powers 1983). At sea, jaegers feed at the surface or by pirating other birds. Pomarine Jaeger *Stercorarius pomarinus* was the most commonly observed jaeger in all seasons.

Parasitic jaegers *S. parasiticus* were present but uncommon throughout shelf waters with greatest densities found in fall through the Great South Channel to the inner-shelf waters south of Cape Cod.

Pomarine jaegers were the only jaegers recorded adjacent to either disposal site and they were seen near the FADS and the CADS in both summer and fall.

Gull spp.

Eight species of gulls were recorded. All feed as secondary and tertiary carnivores on crustaceans, fish, and as scavengers of offal (Ainley and Sanger 1979; Powers 1983); the large gulls also feed as upper level carnivores on birds, eggs and carrion (Bent 1921; Ainley and Sanger 1979; Powers 1983). Glaucous Larus hyperboreus and Iceland L. glaucoides gulls were recorded fall through spring in the Gulf of Maine often attending fishing vessels with large flocks of herring L. argentatus and great black-backed (L. marinus) gulls. Great black-backed gulls and herring gulls were observed in the Gulf of Maine throughout the year and were the dominant gull species (Tables 15-16). Great black-backed and herring gull distributions were greatly influenced by fishing activity; the highest densities were found among fishing fleets from Jeffreys Ledge south to the Great South Channel and east along the Northern Edge of Georges Bank (Powers 1983). Seasonally, mean densities of both species were greatest in fall and winter. In summer, a large component of both species moved inshore in the Gulf of Maine, possibly in response to the increase in breeding activity and inshore fishing effort during that time. In summer, areas of greatest concentration were from Massachusetts Bay south to the Great South Channel and west across Nantucket Shoals. Ring-billed gulls L. delawarensis were observed throughout the shelf waters of the Gulf of Maine in summer and fall; however, greatest numbers were found in coastal and inner shelf water well south of Cape Cod. Bonaparte's gulls L. philadelphia were recorded in coastal waters in fall and winter, with heaviest concentrations occurring south of the Gulf of Maine. Black-legged kittiwakes Rissa tridactyla were common in the Gulf of Maine from September to May. Peak densities occurred locally on Jeffreys Ledge and Stellwagen Bank, south to the Great South Channel and west across Nantucket Shoals to Cox Ledge. Densities of 500-600 birds/km^2 were found on Stellwagen Bank in fall (1981) and in the Great South Channel in winter (1982), where as many as 10,000 to 20,000 kittiwakes were present with large numbers of greater shearwaters and herring gulls (Powers et al. 1982).

Herring and great black-backed gulls were abundant in waters adjacent to both disposal sites throughout the year (Tables 16-17). There was no apparent difference in the density of birds found inshore of the disposal site and the density recorded offshore of the disposal site. During the aerial surveys, both herring and great black-backed gulls were observed in large flocks attending fishing vessels and feeding aggregations of cetaceans. Iceland and glaucous gulls were recorded near the CADS only in winter. Bonaparte's gulls were recorded in the vicinity of the FADS in winter, while laughing and ring-billed gulls were recorded near the same foul area in summer.

Black-legged kittiwakes occurred near the disposal sites in large numbers in the fall and were the most abundant bird species recorded in waters contiguous to both disposal sites in winter (Tables 16-17).

Alcid spp.

Five species of alcids were recorded in coastal and offshore waters of the Gulf of Maine from November through May (Razorbill Alca torda, Thick-billed murre Uria lomvia, Common murre Uria aalge, Dovekie Alle alle, and Atlantic Puffin Fratercula artica); another species the Black guillemot Cepphus grylle was found only in coastal waters in the Gulf of Maine in winter. Alcids are pursuit-divers which feed as secondary and tertiary carnivores on macroplankton, cephalapods and fish (Ainley and Sanger 1979; Powers 1983). Puffins feed almost exclusively on fish (Nettleship 1972) including species of the genera Ammodytes, Clupea, Gadus, and Mallotus (Powers 1983).

Razorbills were present off the northeastern United States from late November to May, and were most common in shoal areas around Cape Cod, into the Great South Channel, and along the northern edge of Georges Bank (Powers 1983). Murres (thick-billed and common) were recorded uncommonly in winter across the shelf from Long Island east and north to the southern Gulf of Maine and in spring in the central Gulf of Maine (Powers 1983). Dovekies were recorded from December to May in the Gulf and to the south across Nantucket Shoals. Black guillemots are strictly coastal inhabitants and were recorded only seldomly in winter along the coastal regions in the Gulf of Maine. Puffins were recorded primarily in winter and spring, although sightings in the Gulf extend to early summer (Powers 1983).

Because of the difficulty in identifying alcids at sea, for the purpose of this report, all alcid species were lumped to form one group heretofore called the family, Alcidae. Alcidae were commonly recorded near the FADS in winter and spring, and near the CADS in winter (Tables 16-17). The relatively high density of Alcidae recorded near the CADS in summer is due to large numbers of black guillemots nesting along the Maine coast during the season.

Table 16. Seasonal mean densities of the 10 most abundant seabirds (birds/km^2) with standard deviations in each season in the contiguous waters inshore of the FADS and offshore of the FADS.

INSHORE OF THE DISPOSAL SITE

Species	Winter	Spring	Summer	Fall
Herring Gull	5.542 (18.994)	2.922 (6.534)	1.653 (3.525)	5.540 (9.056)
Great Black-backed Gull	5.341 (17.045)	1.286 (2.139)	2.109 (4.823)	3.988 (6.574)
Black-legged Kittiwake	6.729 (34.865)	0.307 (0.998)		4.981 (15.690)
Northern Fulmar		0.245 (1.091)		
Common Eider	1.124 (5.513)	1.143 (4.918)		7.605 (47.649)
Oldsquaw	0.138 (1.032)	5.152 (20.928)		13.836 (90.908)
White-winged Scoter	16.450 (113.699)	0.230 (1.346)	0.047 (0.412)	0.689 (2.760)
Surf Scoter		0.094 (0.548)		0.389 (2.733)
Ring-billed Gull				
Bonaparte's Gull	1.090 (6.991)			
Laughing Gull			0.053 (0.350)	0.846 (3.153)
Common Tern			0.044 (0.241)	
Common Loon			0.031 (0.204	
Red-throated Loon				
Red-breasted Merganser	0.173 (1.165)			
Alcidae spp.	0.229 (1.087)	0.322 (0.804)		
Cory's Shearwater			0.037 (0.330)	
Greater Shearwater			2.547 (8.940)	3.951 (12.107)
Sooty Shearwater			0.375 (1.425)	
Wilson's Storm-Petrel			2.950 (6.549)	
Northern Phalarope				
Pomarine Jaeger				
Double-crested Cormorant				
Northern Gannet	0.785 (1.431)	0.155 (0.352)		2.300 (6.027)

Table 16. (continued)

OFFSHORE OF THE DISPOSAL SITE

Species	Winter	Spring	Summer	Fall
Herring Gull	2.148 (2.806)	7.312(19.893)	7.640(25.079)	32.538 (95.698)
Great Black-backed Gull	4.714 (8.753)	7.209(22.514)	3.325(12.721)	5.616 (8.586)
Black-legged Kittiwake	12.651(52.138)	0.849 (2.359)		52.579(149.995)
Northern Fulmar	0.334 (1.552)	0.130 (0.360)		0.491 (1.502)
Common Eider	0.218 (1.617)	0.123 (0.489)		0.207 (1.077)
Oldsquaw	0.163 (0.917)			0.066 (0.346)
White-winged Scoter				
Surf Scoter				
Ring-billed Gull			0.041 (0.248)	
Bonaparte's Gull	0.196 (1.456)			
Laughing Gull	0.049 (0.364)			0.152 (0.791)
Common Tern		0.007 (0.381)	0.147 (0.731)	
Common Loon		0.090 (0.291)		
Red-throated Loon		0.037 (0.212)		
Red-breasted Merganser				
Alcidae spp.	1.847(10.282)	0.269 (1.527)		
Cory's Shearwater			0.035 (0.219)	
Greater Shearwater			3.640(13.743)	65.532(204.160)
Sooty Shearwater			0.085 (0.280)	
Wilson's Storm Petrel			11.224(23.030)	
Northern Phalarope			0.162 (1.394)	
Pomarine Jaeger				0.076 (0.395)
Double-crested Cormorant			0.251 (1.826)	
Northern Gannet	0.920 (1.760)	1.110 (1.447)		3.317 (3.394)

Table 17. (continued)

OFFSHORE OF THE DISPOSAL SITE

Species	Winter	Spring	Summer	Fall
Herring Gull	5.442(12.656)	1.443 (2.239)	2.647 (8.633)	2.288 (4.100)
Great Black-backed Gull	7.028(16.651)	1.170 (1.880)	1.913 (5.015)	5.253(13.604)
Black-legged Kittiwake	7.953(20.867)			1.424 (3.162)
Iceland Gull				
Northern Fulmar	1.169 (5.837)	0.080 (0.272)		0.045 (0.270)
Common Eider	0.516 (2.274)			0.918 (2.479)
Oldsquaw				0.051 (0.304)
White-winged Scoter	0.043 (0.371)			
Greater Shearwater			0.901 (1.985)	0.259 (0.868)
Alcidae spp.	0.819 (6.071)			
Wilson's Storm-Petrel		0.040 (0.200)	3.764 (7.498)	
Arctic Tern				
Northern Phalarope		0.156 (1.061)		
Northern Gannet	0.136 (0.341)	0.845 (1.232)	0.038 (0.183)	1.847 (2.351)
Pomarine Jaeger			0.017 (0.117)	
Common Loon		0.205 (0.575)		0.070 (0.237)
Glaucous Gull	0.038 (0.187)			
Black Scoter	0.064 (0.557)			
Double-crested Cormorant		1.887 (8.338)		0.020 (0.121)
Red-throated Loon		0.044 (0.220)		
Sooty Shearwater			0.170 (0.441)	
Common Tern			0.100 (0.386)	
Leach's Storm-Petrel			0.017 (0.117)	

Table 17. Seasonal mean densities of the 10 most abundant seabirds (birds/km^2) wit standard deviations in each season in the contiguous waters inshore of the CADS and offshore of the CADS.

INSHORE OF THE DISPOSAL SITE

Species	Winter	Spring (No Data)	Summer	Fall
Herring Gull	2.758 (7.587)		0.718 (0.864)	1.842 (1.368)
Great Black-backed Gull	3.980(10.467)		1.608 (1.369)	0.474 (0.685)
Black-legged Kittiwake	5.693(13.302)			
Iceland Gull	0.050 (0.200)			
Northern Fulmar	0.343 (1.004)		0.342 (0.629)	
Common Eider	1.350 (3.904)			1.028 (2.721)
Oldsquaw	0.105 (0.340)			0.457 (1.209)
White-winged Scoter	0.146 (0.591)			0.114 (0.302)
Greater Shearwater	0.028 (0.159)			0.228 (0.604)
Alcidae spp.	0.252 (0.692)			2.203 (5.391)
Wilson's Storm-Petrel			0.440 (1.166)	
Arctic Tern			0.257 (0.680)	
Northern Phalarope			3.820(10.107)	
Northern Gannet			0.228 (0.604)	0.319 (0.576)
Pomarine Jaeger			0.114 (0.302)	
Common Loon				0.114 (0.302)
Glaucous Gull				
Black Scoter				
Double-crested Cormorant				
Red-throated Loon				
Sooty Shearwater				
Common Tern				
Leach's Storm-Petrel				

VIII. OBSERVATIONS OF NON-ENDANGERED CETACEANS AND PINNIPEDS IN WATERS WITHIN AND CONTIGUOUS TO THE FOUL-AREA DISPOSAL SITE (FADS) AND THE CAPE ARUNDEL DISPOSAL SITE (CADS)

M. T. Weinrich and L. A. Selzer

1. Behavior and observations of non-endangered cetaceans in waters within and contiguous to the Foul Area Disposal Site.

Minke Whales Balaenoptera acutorostrata

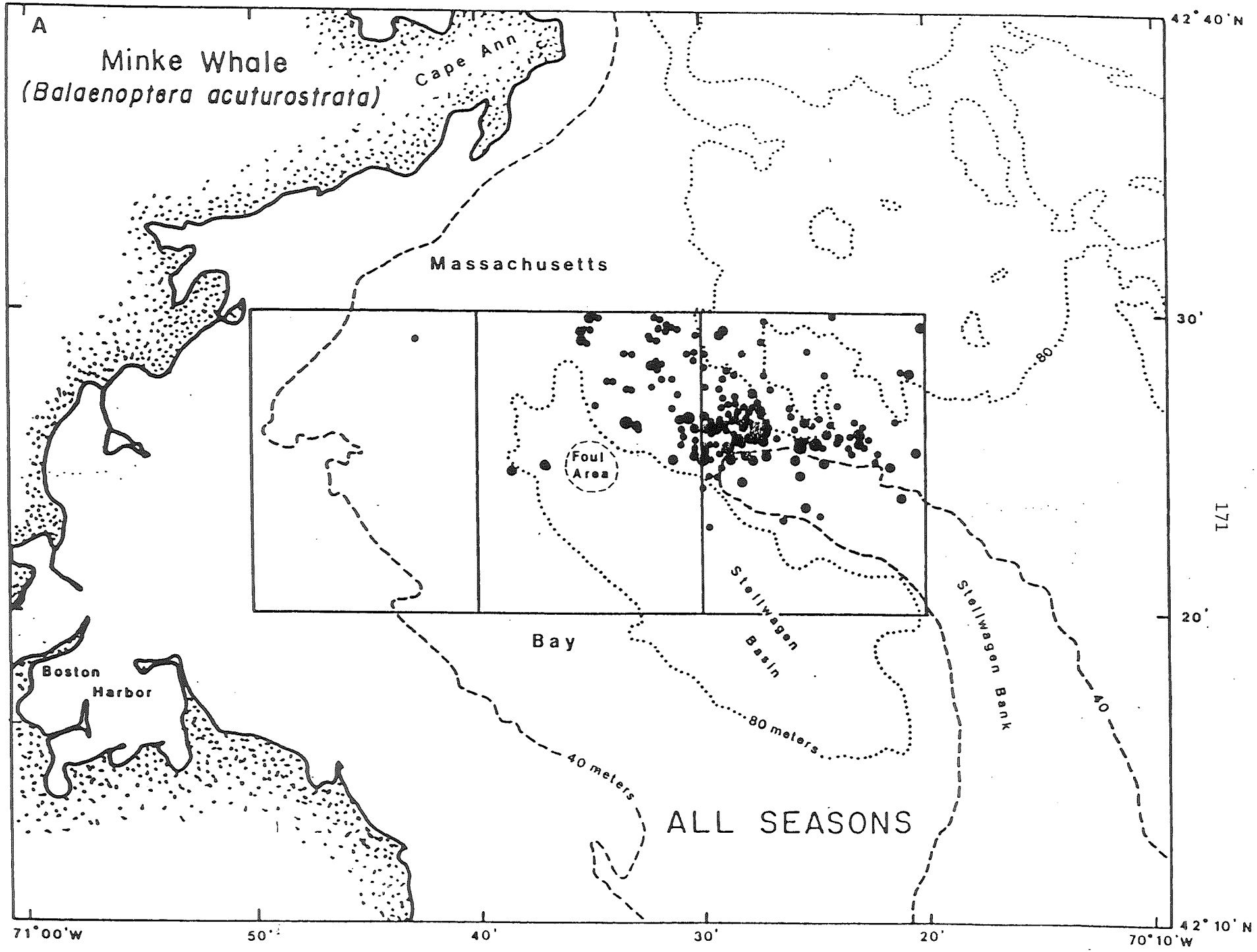
Minke whales commonly are observed in the northern Stellwagen/southern Jeffreys Ledge area from March until November of each year (Figs. 49a-e). Overwintering in the area may occur (Fig. 49e), although survey coverage is limited during the winter period. While all areas receive some use by minkes, southern Jeffreys Ledge seems to be preferred .

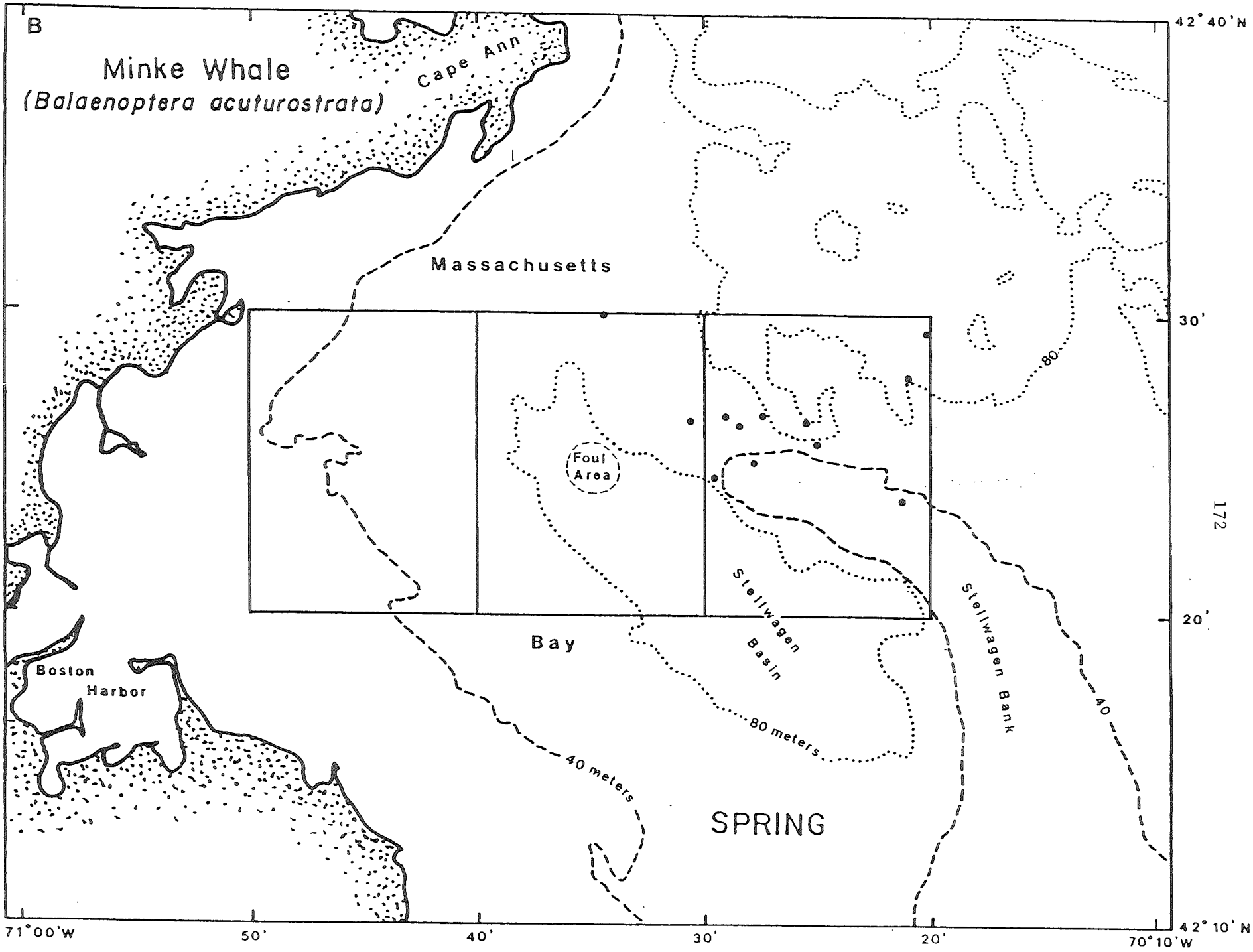
There are two peaks in minke whale abundance during the year: 1) Minkes were seen commonly in the spring, and during this time, they were usually alone, with no other conspecifics in the vicinity. 2) However, the largest concentrations were observed during late summer and early fall. Aggregations of 15 to 20 animals were not uncommon at this time. During 1984 these concentrations were found only on Jeffreys Ledge. During 1985 they also were seen on northern Stellwagen. Aggregations of minke whales often are in the immediate vicinity of fin whales.

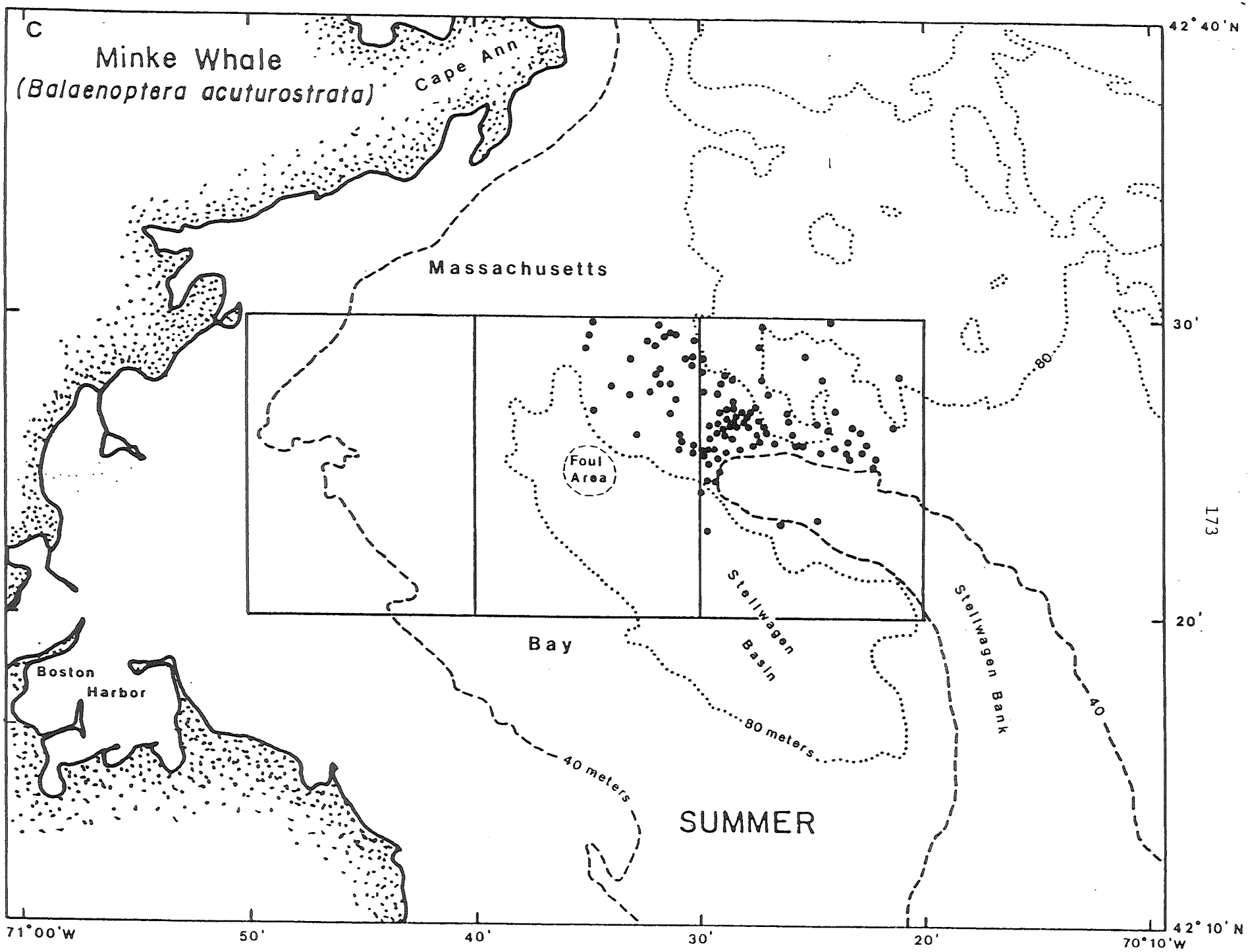
Surface feeding by minke whales has been reported, but most feeding seems to take place below the surface. Breaching, commonly reported in other areas, has only been observed in the FADS area on three occasions. Only twice have minkes small enough to be considered calves been observed within FADS.

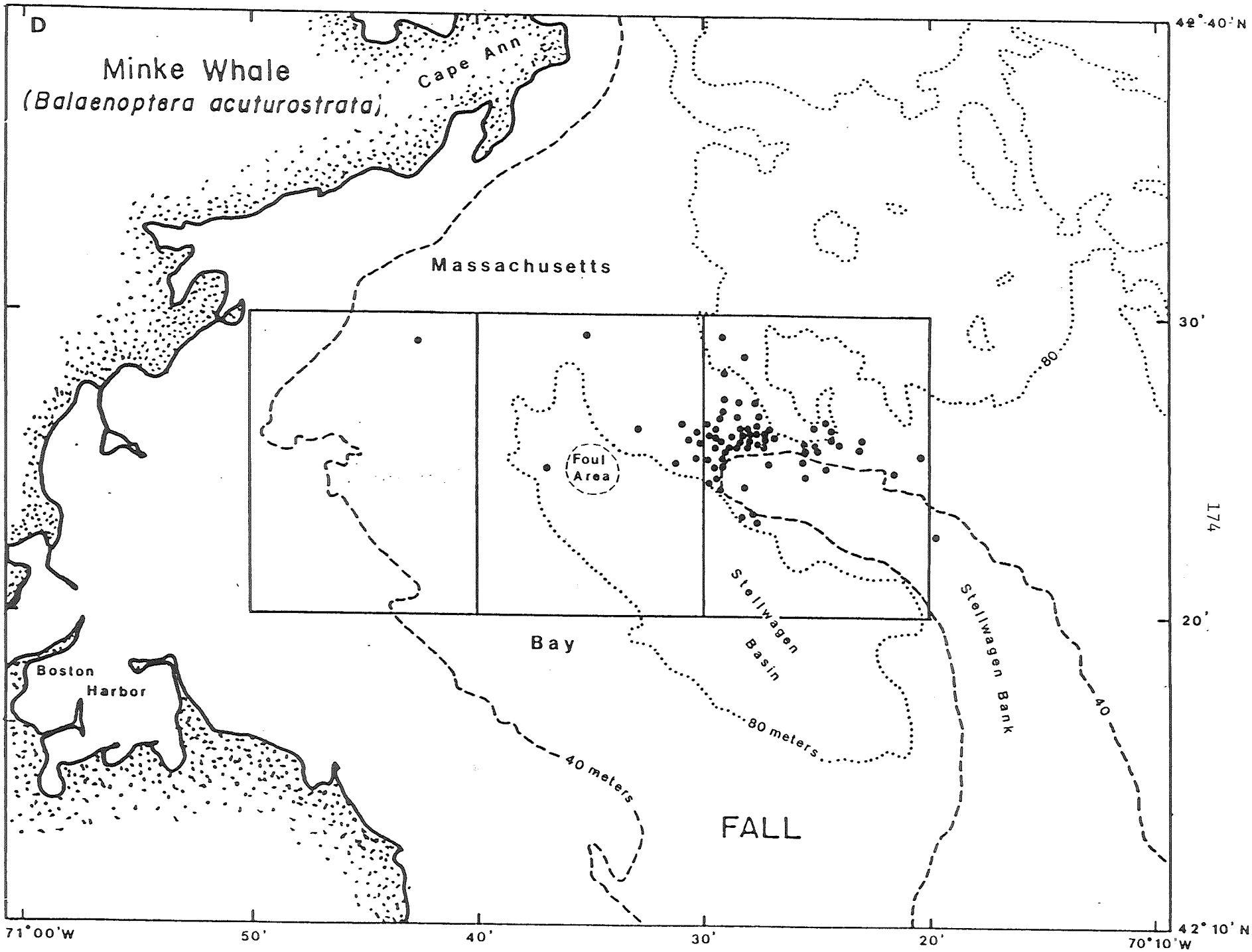
Figure 49. Sightings of Minke whales within the waters of the Foul-Area Disposal Site study area by season.

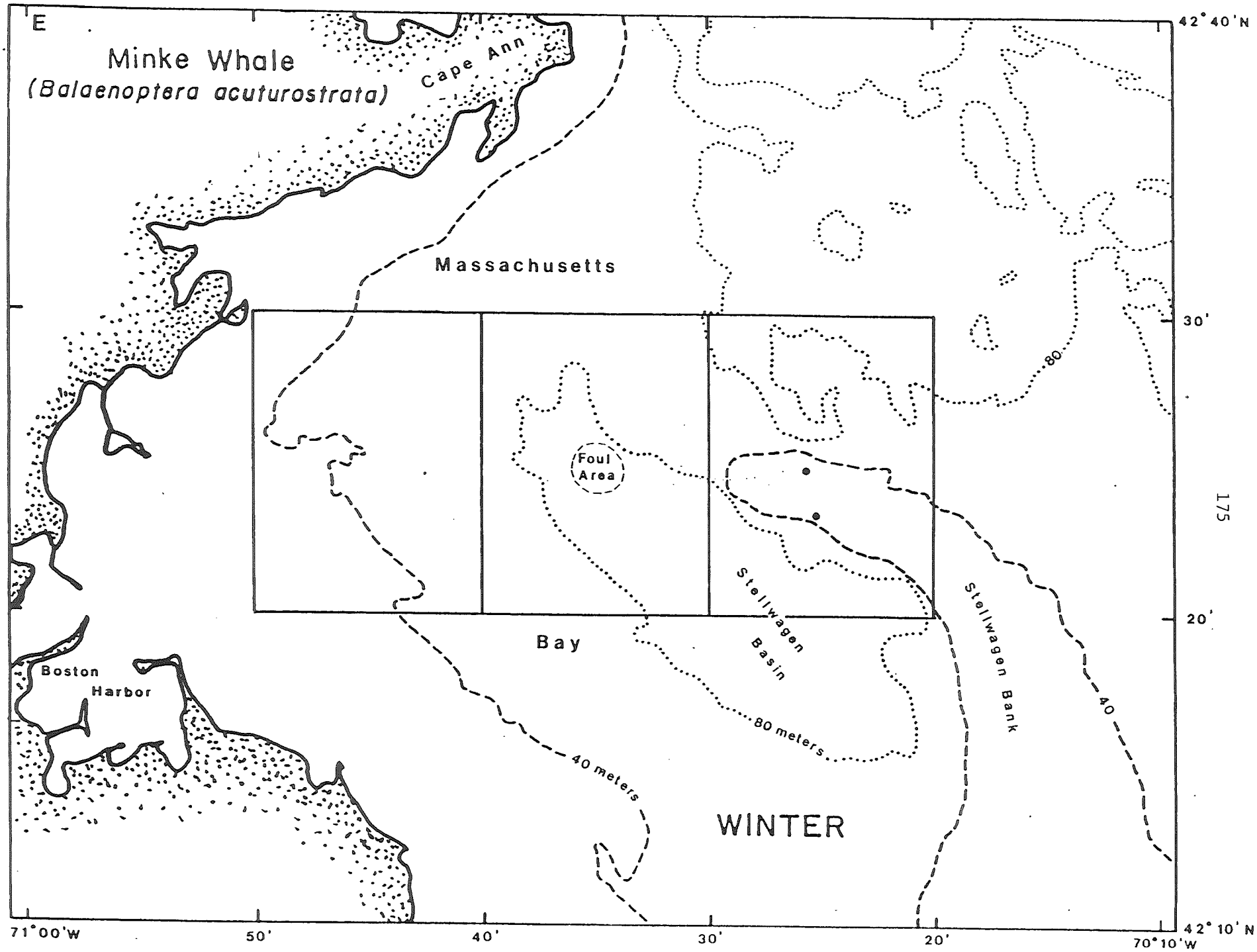
Sources: Data from the Cetacean Research Unit; Hain et al. 1981; Payne et al. 1984; MBO unpubl. data, 1985-1986; Gulf of Maine Cetacean Sighting Network 1975-1981.


A
Minke Whale
(Balaenoptera acuturostrata)
Cape Ann
Massachusetts
Bay
Foul Area
Stellwagen Basin
Stellwagen Bank
80
40
80 meters
40 meters
Boston Harbor
ALL SEASONS
42° 40' N
30'
20'
42° 10' N
71° 00' W
50'
40'
30'
20'
70° 10' W


B
Minke Whale
(Balaenoptera acuturostrata)
Cape Ann
Massachusetts
Foul Area
Bay
Stellwagen Basin
Stellwagen Bank
80
40
80 meters
40 meters
Boston Harbor
SPRING
42°40'N
30'
20'
42°10'N
71°00'W
50'
40'
30'
20'
70°10'W


C
Minke Whale
(Balaenoptera acuturostrata)
Cape Ann
Massachusetts
Bay
Foul Area
Stellwagen Basin
Stellwagen Bank
80
40
80 meters
40 meters
Boston Harbor
SUMMER
42° 40' N
30'
20'
42° 10' N
71° 00' W
50'
40'
30'
20'
70° 10' W


D
Minke Whale
(Balaenoptera acuturostrata)
Cape Ann
Massachusetts
Bay
Foul Area
Stellwagen Basin
Stellwagen Bank
80
40
80 meters
40 meters
Boston Harbor
FALL
42°40'N
30'
20'
42°10'N
71°00'W
50'
40'
30'
20'
70°10'W


E
Minke Whale
(Balaenoptera acuturostrata)
Cape Ann
Massachusetts
Bay
Foul Area
Stellwagen Basin
Stellwagen Bank
80
80 meters
40 meters
40
Boston Harbor
WINTER
42°40'N
30'
20'
42°10'N
71°00'W
50'
40'
30'
20'
70°10'W

White-sided Dolphins Lagenorhynchus acutus

White-sided dolphins are present in the northern Stellwagen/southern Jeffreys area throughout the year. Although CETAP (1982) indicates a decrease in abundance during the winter months, data from winter cruises in 1984 and 1985 (MBO unpubl. data) indicate the presence of large numbers of white-sided dolphins throughout the winter .

Sightings of white-sided dolphins occur throughout the year (Figs. 50a-e), with only a slight decrease in sighting frequency occurring during late spring and late fall. Abundance appears greatest from early spring to summer. White-sided dolphins appear to be found in areas not typically considered high use areas for some other species. Their distribution in the FADS most resembles that of fin whales, with which they are often seen.

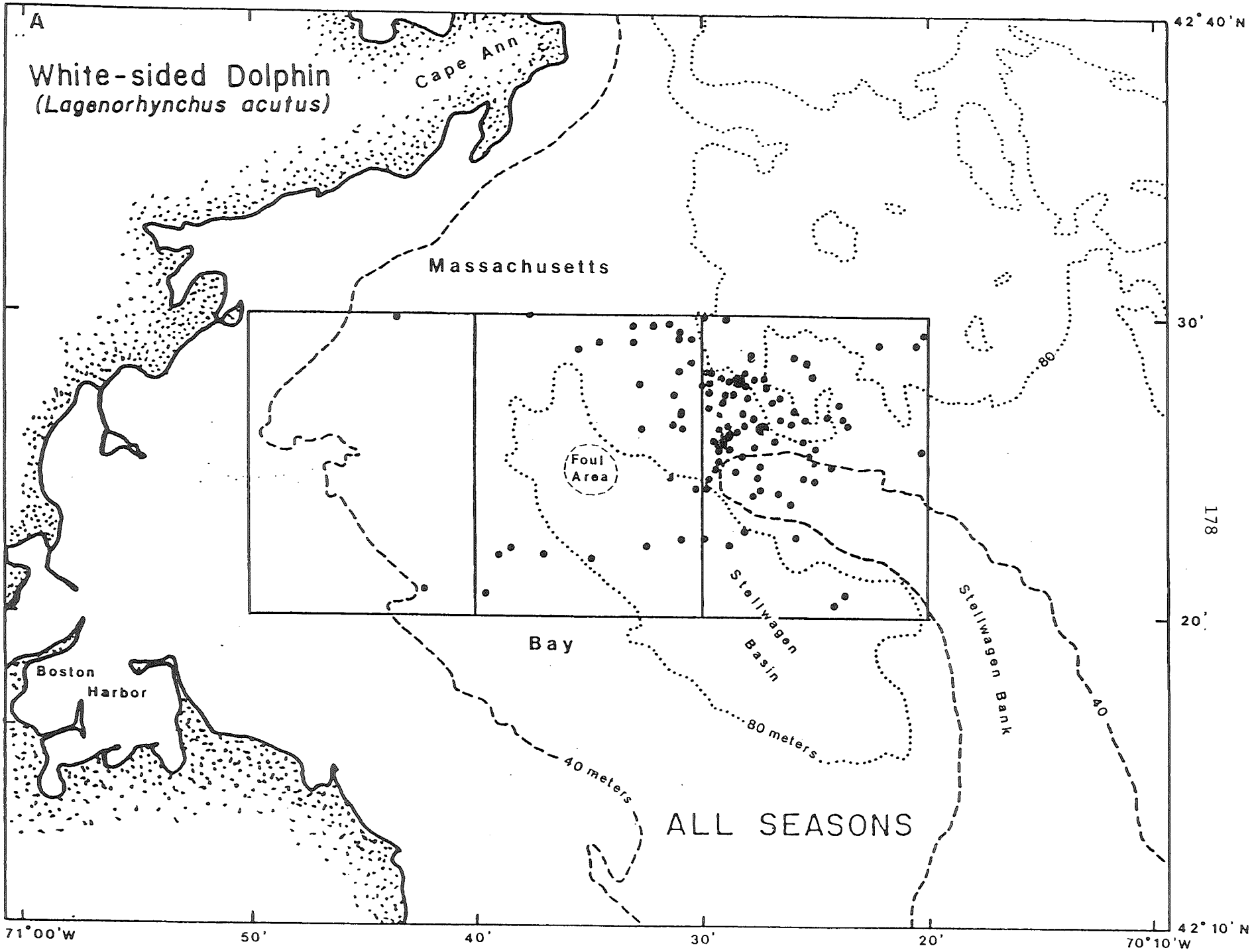
Group size ranged from 10 to over 1,000 animals; most groups were between 25 and 150. Dolphin pods with calves (Fig. 51) were observed throughout the year, although there was a slight increase in calf sightings during late summer. However, calves have been seen as early as March. Observed behaviors include leaping, bow riding, and feeding. They are often seen bow riding fin and humpback whales as well as vessels.

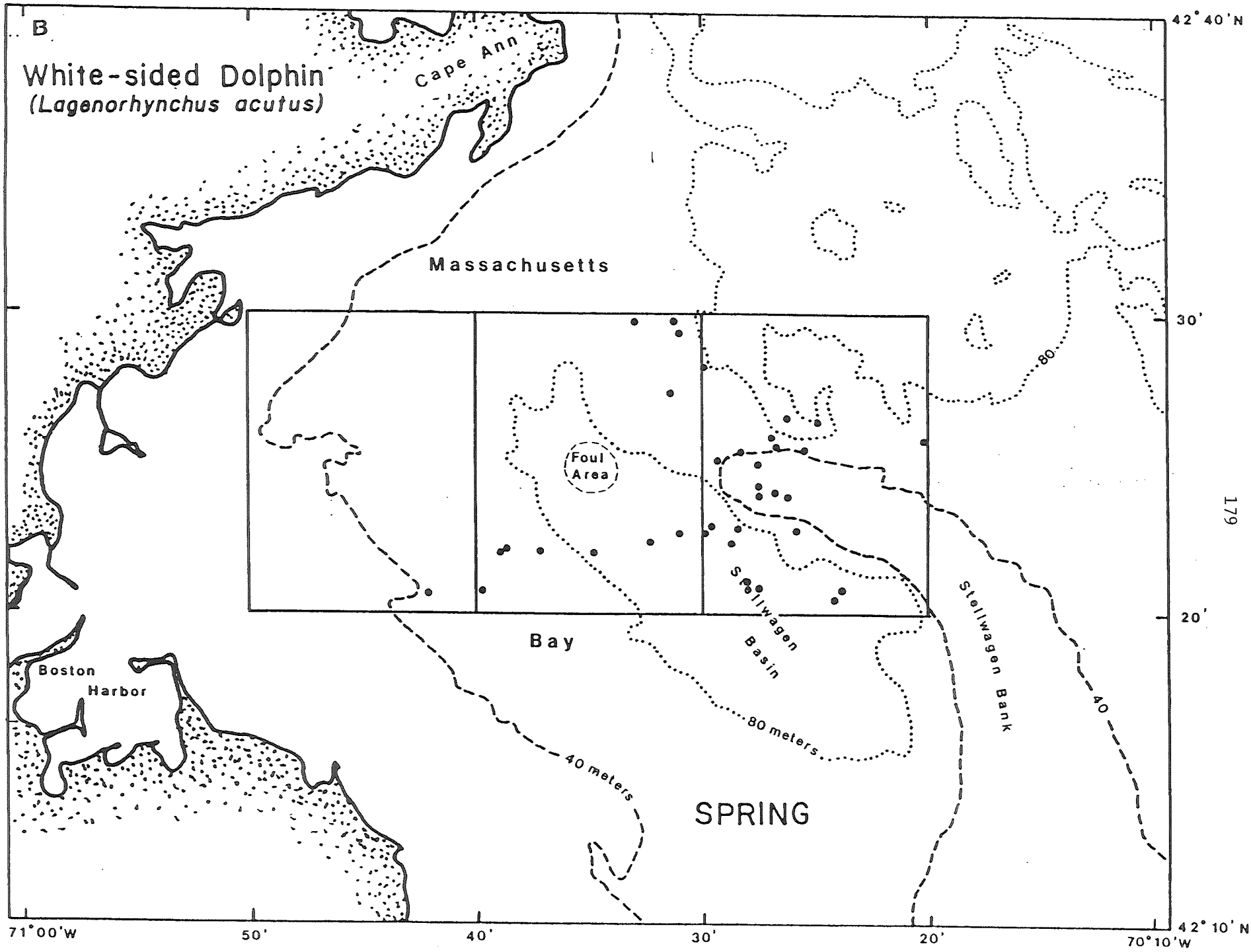
White-beaked dolphins (Lagenorhynchus albirostris)

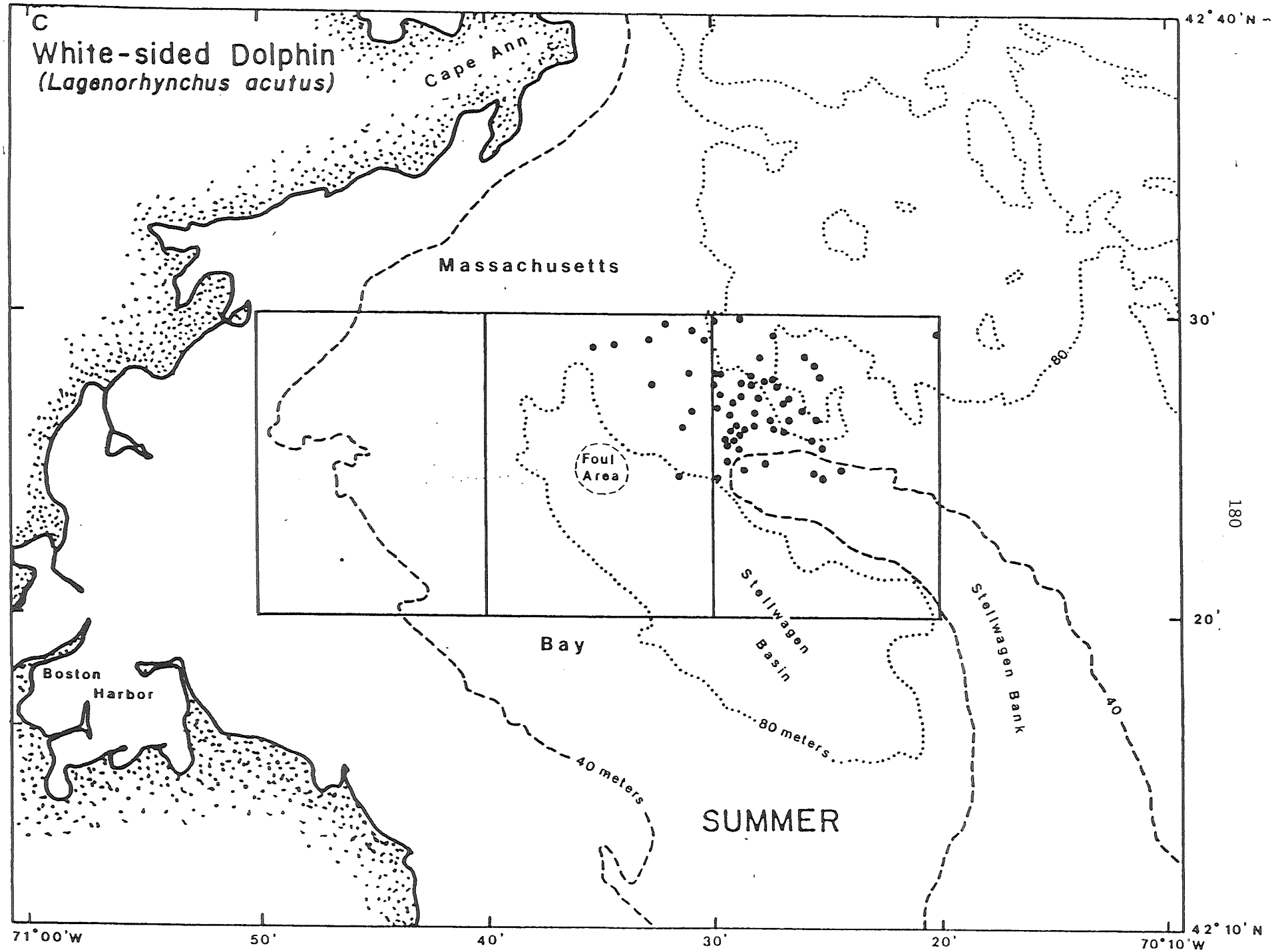
White-beaked dolphins are seen infrequently during early spring. The species is a casual visitor to the FADS region.

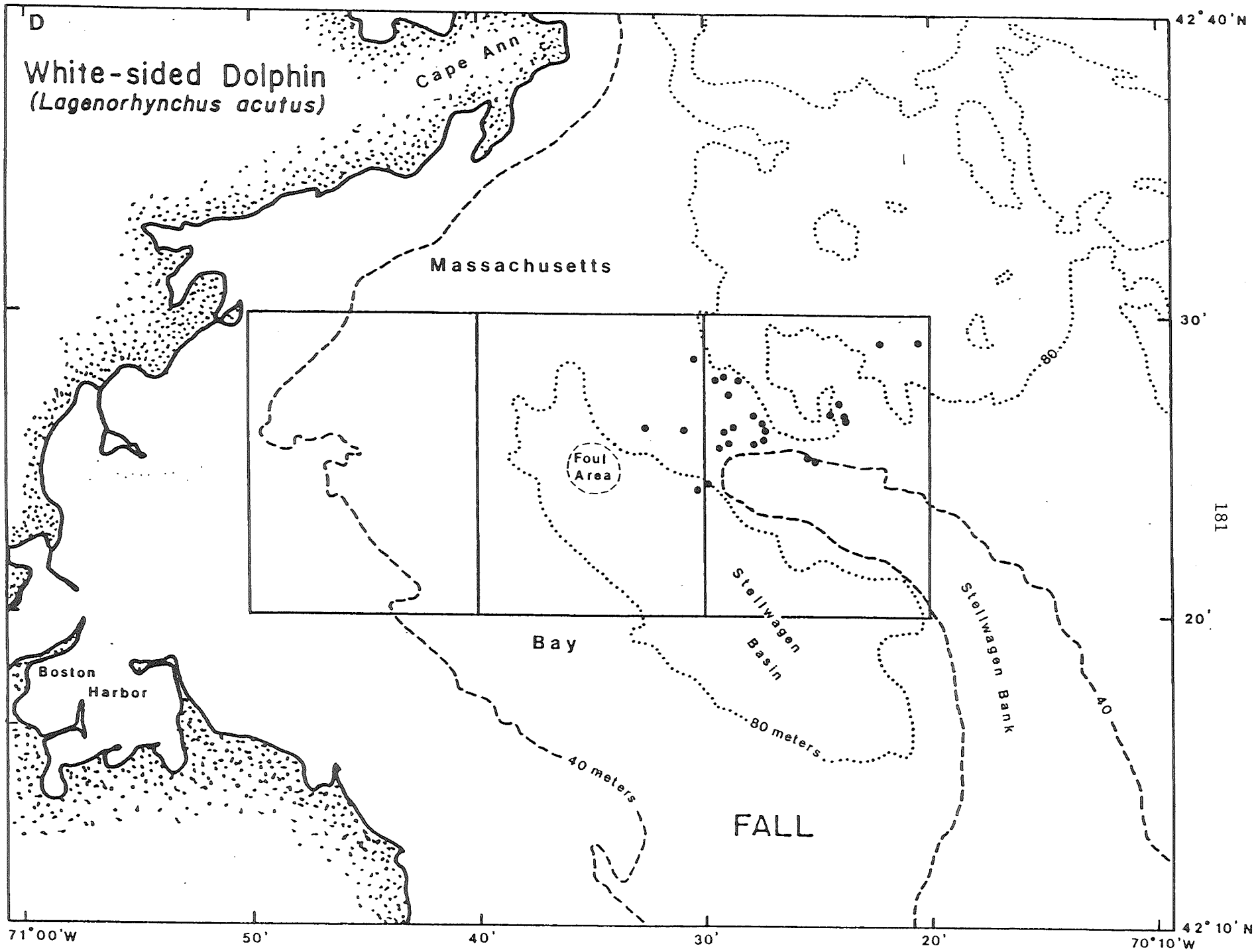
Figure 50. Sightings of white-sided dolphins within the waters of the Foul-Area Disposal Site study area by season.

Sources: Data from the Cetacean Research Unit; Hain et al. 1981; Payne et al. 1984; MBO unpubl. data, 1985-1986; Gulf of Maine Cetacean Sighting Network 1975-1981.


A
White-sided Dolphin
(Lagenorhynchus acutus)
Cape Ann
Massachusetts
Bay
Foul Area
Stellwagen Basin
Stellwagen Bank
Boston Harbor
80
40
80 meters
40 meters
ALL SEASONS
42°40'N
30'
20'
42°10'N
71°00'W
50'
40'
30'
20'
70°10'W


B
White-sided Dolphin
(Lagenorhynchus acutus)
Cape Ann
Massachusetts
Bay
Foul Area
Stellwagen Basin
Stellwagen Bank
80
40
80 meters
40 meters
Boston Harbor
SPRING
42°40'N
30'
20'
42°10'N
71°00'W
50'
40'
30'
20'
70°10'W


C
White-sided Dolphin
(Lagenorhynchus acutus)
Cape Ann
Massachusetts
Bay
Foul Area
Stellwagen Basin
Stellwagen Bank
80
40
80 meters
40 meters
Boston Harbor
SUMMER
42° 40' N
30'
20'
42° 10' N
71° 00' W
50'
40'
30'
20'
70° 10' W


D
White-sided Dolphin
(Lagenorhynchus acutus)
Cape Ann
Massachusetts
Bay
Foul Area
Stellwagen Basin
Stellwagen Bank
80 meters
40 meters
80
40
Boston Harbor
FALL
42°40'N
30'
20'
42°10'N
71°00'W
50'
40'
30'
20'
70°10'W

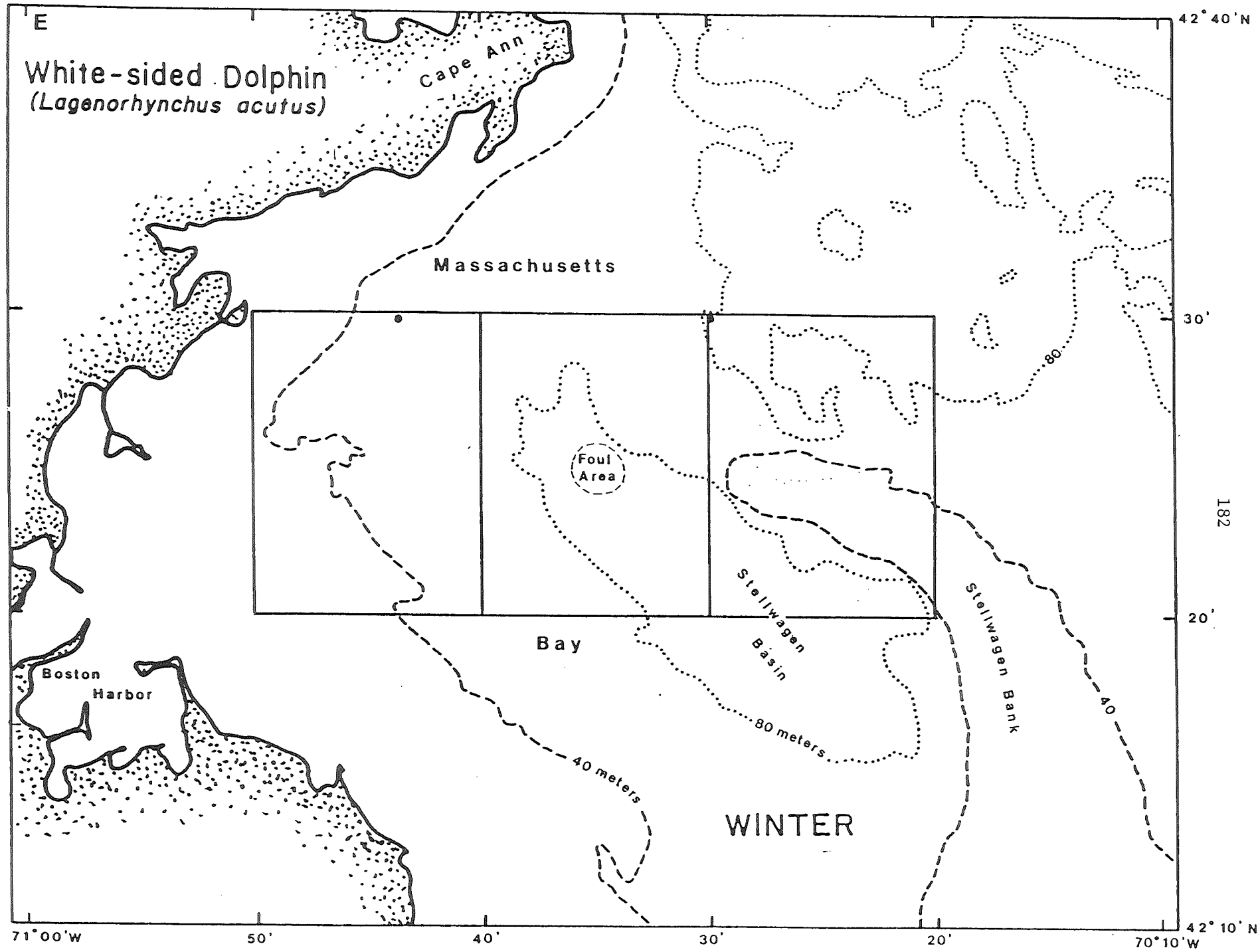
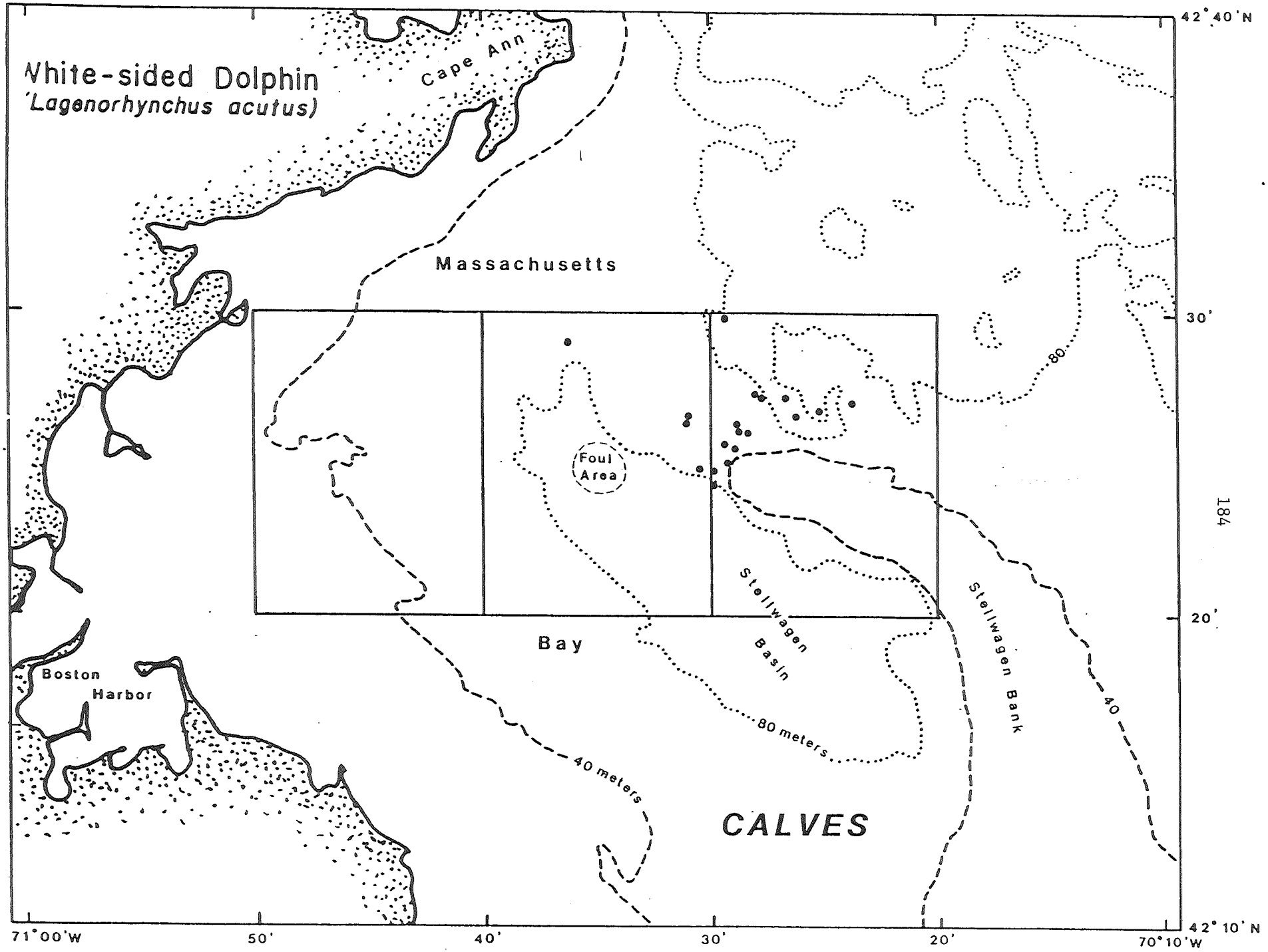

E
White-sided Dolphin
(Lagenorhynchus acutus)
Cape Ann
Massachusetts
Bay
Foul Area
Stellwagen Basin
Stellwagen Bank
80
40
80 meters
40 meters
Boston Harbor
WINTER
42° 40' N
30'
20'
42° 10' N
71° 00' W
50'
40'
30'
20'
70° 10' W

Figure 51. Sightings of white-sided dolphins with calves within the waters of the Foul-Area Disposal Site study area by season.


White-sided Dolphin
(Lagenorhynchus acutus)
Cape Ann
Massachusetts
Bay
Foul Area
Stellwagen Basin
Stellwagen Bank
80
40
80 meters
40 meters
CALVES
Boston Harbor
42°40'N
30'
20'
42°10'N
71°00'W
50'
40'
30'
20'
70°10'W

Harbor Porpoise Phocoena phocoena

Harbor porpoise are observed infrequently after early spring. Sightings are common during late March and early April (Table 18). Only one sighting occurred outside this period (Table 18). Their distribution in the FADS during winter is unknown.

Most sightings involve small groups of two to seven animals. No more than 15 individuals have been observed in any one day.

This species usually is observed on the northwest corner of Stellwagen (Fig. 52). Preliminary data indicate that this western tip is used more than any other. If so, Stellwagen Basin and adjacent areas in quadrant II may be important spring habitat for this species.

In addition to those species described above, several other cetaceans are observed with varying frequency around FADS. In the fall, pilot whales (Globicephala malaena) have been sighted in the northern Stellwagen/southern Jeffreys area. This species appears to prefer Jeffreys Ledge, but are seen in quadrant III several times each year during October and November.

A single sighting of grampus (Grampus griseus) occurred in August 1985. A pod of 15 to 25 individuals was sighted regularly in the waters of northern Stellwagen for a two week period. The pod contained three to four calves, several adult females, several juveniles, and one to two adult males. Occurrence of this species at this location is considered uncommon.

Figure 52. Sightings of harbor porpoise within the waters of the Foul-Area Disposal Site study area for all seasons.

Sources: Data from the Cetacean Research Unit; Hain et al. 1981; Payne et al. 1984; MBO unpubl. data, 1985-1986; Gulf of Maine Cetacean Sighting Network 1975-1981.

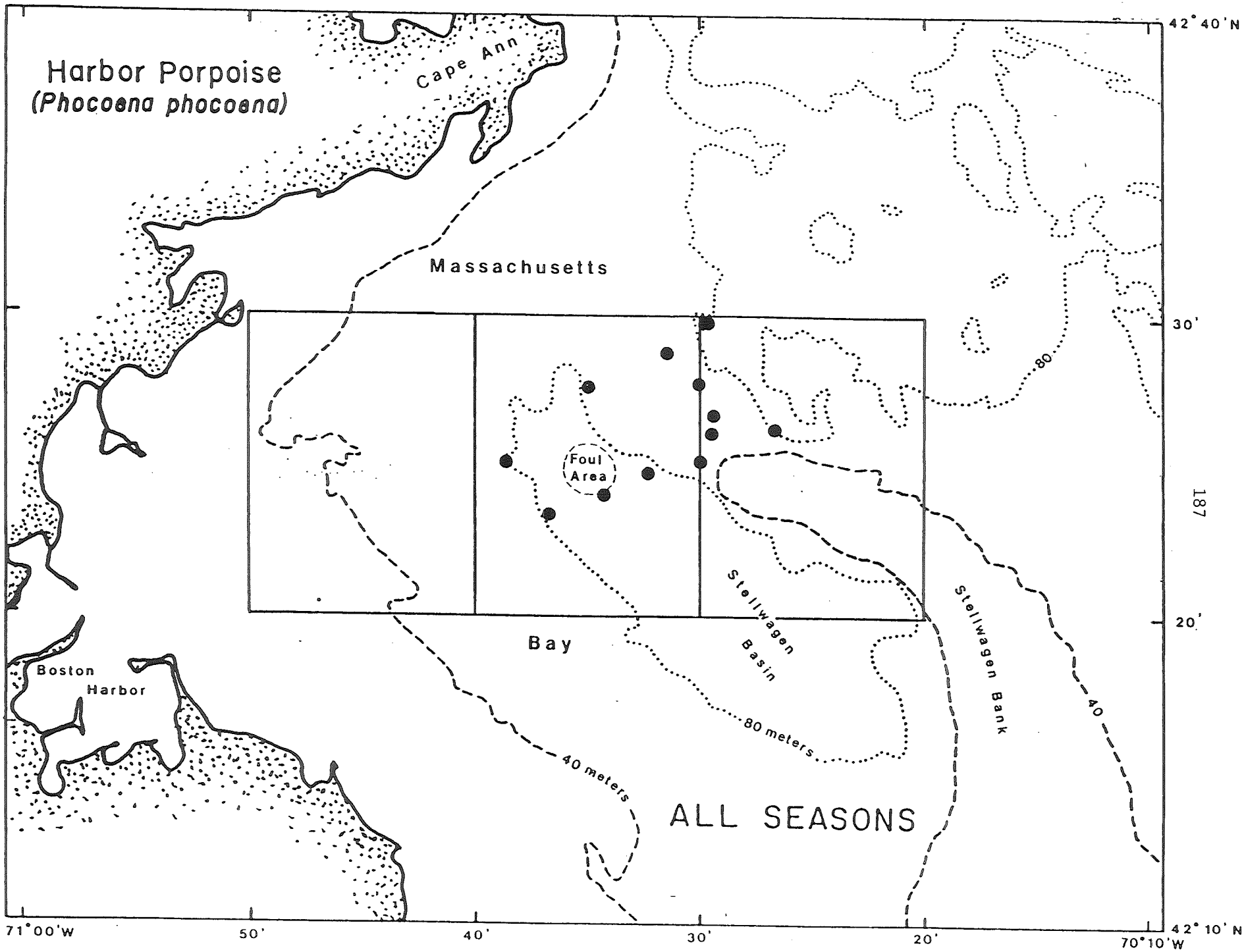

Harbor Porpoise
(Phocoena phocoena)
Cape Ann
Massachusetts
Bay
Foul Area
Stellwagen Basin
Stellwagen Bank
80
40
80 meters
40 meters
Boston Harbor
ALL SEASONS
42° 40' N
30'
20'
42° 10' N
71° 00' W
50'
40'
30'
20'
70° 10' W

Table 18. List of all Harbor Porpoise *Phocoena phocoena* sightings in the waters of the Foul-Area Disposal Site (FADS).

DATE	LOCATION	NUMBERS SEEN
23 Mar 1985	42°25'N, 70°33'W	1
	42°29'N, 70°34'W	1
	42°25'N, 70°38'W	1
03 Apr 1985	42°29'N, 70°31'W	1
	42°28'N, 70°30'W	2
	42°27'N, 70°29'W	8-10
07 Apr 1985	42°26'N, 70°26'W	1
	42°25'N, 70°30'W	1
18 Apr 1985	42°26'N, 70°29'W	1
28 Apr 1985	42°30'N, 70°30'W	1
	42°24'N, 70°26'W	3
05 May 1985	42°27'N, 70°25'W	1

2. Behaviors and observations of non-endangered cetaceans in waters within and contiguous to the Cape Arundel Disposal Site

Minke Whales *Balaenoptera acutorostrata*

Minke whales were recorded in waters adjacent to the CADS (Fig. 53) in summer and fall (Table 19). No minkes were observed in this area in spring, although they were recorded regularly on Stellwagen Bank and Jeffreys Ledge in this season. This distributional pattern is consistent with those suggested by Hain *et al*. (1981), CETAP (1982) and Payne *et al*. (1984). Minke whales are concentrated south of the CADS in winter and spring, but are recorded regularly into the northern reaches of the Gulf of Maine by early summer. Their distribution remains extended throughout the entire Gulf until late fall when they again concentrate in the southern portion of their range which is centered about the Great South Channel and Nantucket Shoals. Minkes were observed within the 10' block containing the CADS, and probably are regular visitors to this area. No calves were recorded in the vicinity of the CADS, and while no surface feeding behavior was observed in this area, it is likely that subsurface feeding is occuring throughout their range.

Pilot Whales *Globicephala* spp.

Pilot whales were recorded only once in the CADS area (Table 19, Fig. 53); however this sighting was consistent with the known distribution of this species (Hain *et al*. 1981; CETAP 1982; Payne *et al*. 1984). Pilot whales move northward along the shelf edge from mid-winter to spring, and by early summer they are concentrated in the vicinity of Georges Bank. At this time, many animals continue northward to the Grand Bank and the Scotian Shelf, while others move deep into the Gulf of Maine. Sightings within the Gulf of Maine are most common from late summer to late fall, and at this time, pilot whales were observed in the 10' block containing the CADS. Throughout the fall, pilot whales move south along the western edge of the Gulf of Maine and it is at this time that sighting frequency peaks within Cape Cod Bay and south into the Great South Channel.

Harbor Porpoise *Phocoena phocoena*

Harbor porpoise are abundant in the Gulf of Maine from late spring until late fall (Gaskin 1977, 1984; Prescott and Fiorelli 1980); however they are concentrated in the northern Gulf of Maine - Bay of Fundy in the summer and in the southern Gulf of Maine in spring and fall (Prescott and Fiorelli 1980). During the winter, they are observed primarily south and offshore of the Gulf of Maine (CETAP 1982). In the CADS area, harbor porpoise were observed in mid-spring and late fall (Table 16), periods that coincide with their seasonal migration north in the spring and south and offshore in the fall. However, no harbor porpoise were recorded in the immediate vicinity of the CADS, and both sightings occurred in waters greater than 20 meters (Fig. 53).

Killer Whale *Orcinus orca*

A single killer whale was recorded in the immediate area of the CADS in August 1980 (Table 19, Fig. 53). The training of this sighting is consistent with others of this species in the Gulf of Maine (Katona et al. 1976; CETAP 1982). Killer whales are thought to follow schools of bluefin tuna into the southwestern Gulf of Maine at this time. Killer whales probably are rare visitors to the CADS area.

Additional Sightings:

Ocean Sunfish *Mola mola*

Ocean sunfish are strongly pelagic and prefer the warmer waters well south of Cape Cod, Massachsuetts (Bigelow and Schroeder 1953). However, they occur in the Gulf of Maine in late summer and fall, having drifted in with the prevailing currents, and at this time can be seen anywhere along the western end of the Gulf. Thus, a sighting of 23 sunfish just south of the CADS (but within the 10' block of latitude) is not extraordinary. However, the cold waters of the Gulf of Maine are reported to be beyond the tolerance level of this species (Bigelow and Schroeder 1953) and it is likely that all animals that remain in the Gulf of Maine do not survive.

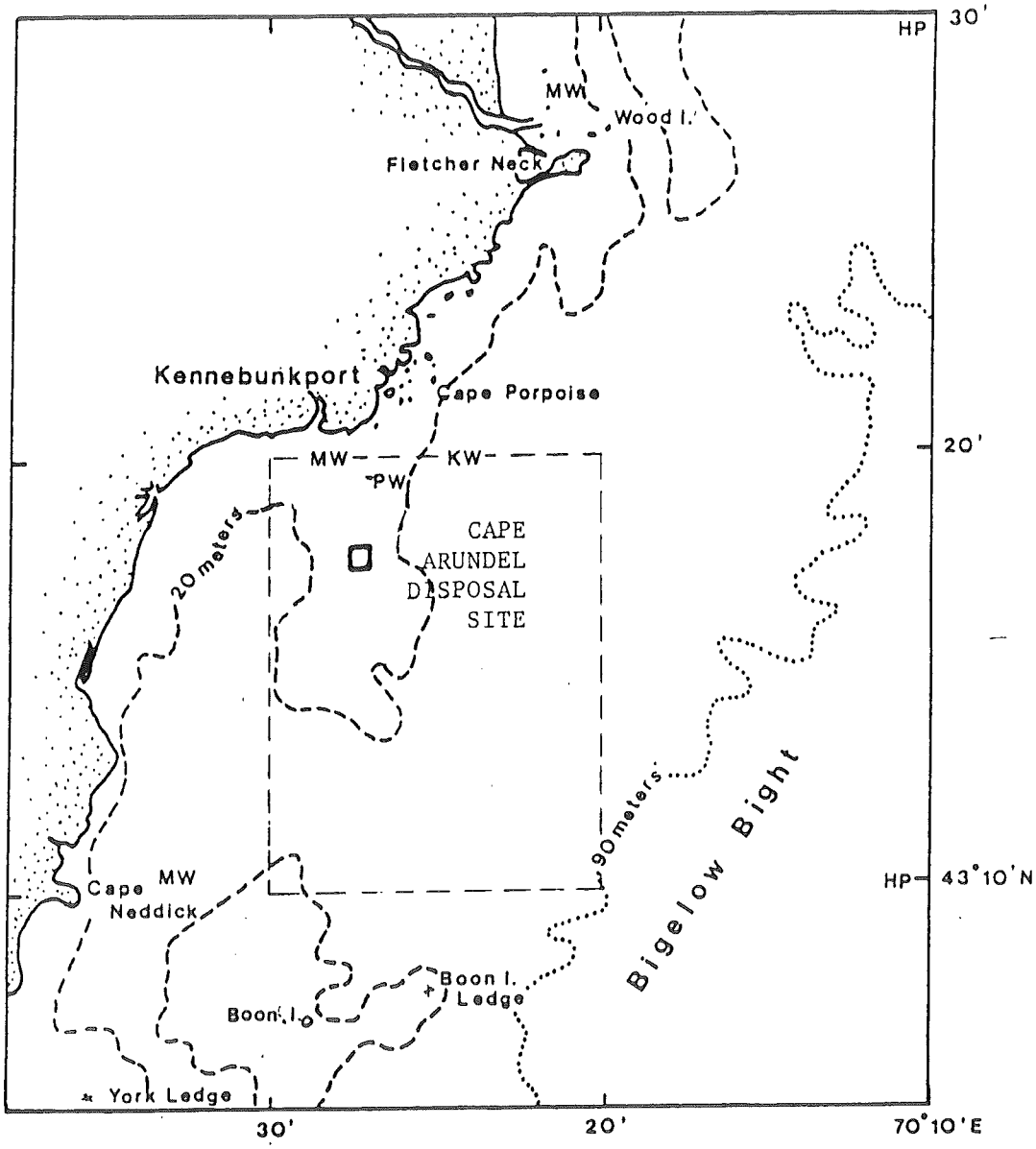


Figure 53. Sightings of all non-endangered cetaceans within the waters of the Cape Arundel Disposal Site study area for all seasons. (MW = minke whale, HP = harbor porpoise, KW = killer whale, PW = pilot whale.)

Table 19. Observations of non-endangered species of cetaceans in waters immediately surrounding the Cape Arundel Disposal Site.

SPECIES	DATE	LOCATION	NUMBERS
Minke Whale	10 Jul 1980	43°29'N, 70°22'W	1
	13 Aug 1980	43°20'N, 70°29'W	1
	16 Oct 1980	43°10'N, 70°35'W	1
Pilot Whale	11 Aug 1980	43°20'N, 70°28'W	1
Harbor Porpoise	16 May 1976	43°10'N, 70°10'W	1
	07 Nov 1978	43°29'N, 70°30'W	2
Killer Whale	19 Aug 1980	43°21'N, 70°25'W	1
Additional Sightings:			
Ocean Sunfish *Mola mola*	22 Aug 1976	43°13'N, 70°30'	12

I. Distribution of Harbor Seals Relative to the Foul Area and Cape Arundel Disposal Sites

Harbor seals primarily are inhabitants of coastal waters, although they will cross open water and have been found up to five miles offshore during the high tide feeding cycle (MBO unpub. data). During their southward migration in late fall, harbor seals move down the coast from Maine to Cape Cod Bay. While most animals probably hug the coast from Cape Ann, Massachusetts south through Boston harbor to Cohasset, Massachusetts, it is likely that some animals swim directly south across the mouth of the harbor and thus pass through the FADS. It also is likely that this occurs during the reverse migration north in late spring. Throughout the winter there exists a large haulout site (100-300 seals) at Cape Ann and an equally large site at Cohasset (Payne et al. 1985). There also are several smaller haulout sites (1-50 animals) located within Boston harbor, although the sum total at these sites probably does not exceed 100 animals (MBO unpub. data). Harbor seals are not site-specific, therefore there probably is a constant flux between adjacent haulout sites, resulting in passage through the FADS. Finally, it is likely that seals using the haulout sites adjacent to the FADS move into the FADS to feed during the high tide cycles. Currently there is no breeding activity occurring on ledges contiguous to the FADS.

In contrast, there are active pupping ledges at Cape Arundel, Maine, and along the coast to the north and the south. Richardson et al. (1974) reported approximately 200 seals in the Cape Arundel area, though with the near doubling of the New England population since that time, the current numbers probably are higher. It is likely that seals using the Cape Arundel haulout sites feed at some time within the CADS. The seasonal movements of harbor seals between pupping ledges in Maine and wintering areas in southern New England (fall-spring) likely occurs through the CADS area.

II. Distribution of Gray Seals in relation to the Foul Area and Cape Arundel Disposal Sites

From mid-winter to late spring, gray seals may be found anywhere along the New England coast, but the majority of sightings occur north of Cape Arundel and south of Cape Cod. In Massachusetts, gray seals rarely are reported from sites north of Monomoy Island N.W.R., Cape Cod. It is likely that their use of the CADS and the FADS is at most transitory as they move south from eastern Canada in mid-winter and north again in late spring.

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THE DISTRIBUTION OF THE HUMPBACK WHALE, *MEGAPTERA NOVAEANGLIAE*, ON GEORGES BANK AND IN THE GULF OF MAINE IN RELATION TO DENSITIES OF THE SAND EEL, *AMMODYTES AMERICANUS*

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ABSTRACT

The distribution of the humpback whale, *Megaptera novaeangliae*, (based on shipboard sighting data) is significantly correlated ($r = 0.81$, df = 13) with the number of sand eel, *Ammodytes americanus*, per standardized tow (based on NMFS/NEFC groundfish surveys) by strata within the Gulf of Maine. A demonstrated increase in the number of humpback whale sightings in the southwest Gulf of Maine since 1978 concurrent with an increase in the number of sand eel in the same area supports the hypothesis that within the Gulf of Maine the present distribution of humpback whales is due to the distribution of their apparent principal prey, the sand eel. A similar correlation between humpback whale sightings and sand eel abundance on Georges Bank was not significant ($r = 0.24$, df = 18) despite dense patches of sand eel in that region. Therefore, within the combined Gulf of Maine-Georges Bank regions, factors other than simply prey availability must influence the feeding distribution of the humpback whale. We argue that the bottom topography of the Gulf of Maine and the foraging behavior of the whales are critical factors influencing their present feeding distribution.

In the northwest Atlantic, the major summer concentrations of humpback whales, *Megaptera novaeangliae*, occur off the coasts of Newfoundland-Labrador and off the coast of New England in the Gulf of Maine which includes Georges Bank (Katona et al. 1980; Whitehead et al. 1982). During this period feeding is their principal activity. The major winter concentrations in the western North Atlantic occur along the Antillean Chain in the West Indies, principally on Silver and Navidad Banks which lie north of the Dominican Republic (Winn et al. 1975; Balcomb and Nichols 1978; Whitehead and Moore 1982). During this season conception and calving are their primary activities; food does not seem to be an important determinant of the humpbacks in these areas (Whitehead and Moore 1982).

Humpbacks have been generally considered coastal animals (Mackintosh 1965). However, their migratory routes between regions of winter breeding and summer feeding in the northwest Atlantic (based on sighting data) occur in deeper, slope waters off the continental shelf (Hain et al. 1981; Kenney et al. 1981; Payne et al. 1984). Several possible offshore routes between winter and summer grounds suggest reasonably distinct stocks (Katona et al. 1980). Kenney et al. (1981) suggested that for the Gulf of Maine stock, the Great South Channel (Fig. 1) is the major exit-entry between the Gulf of Maine feeding area and the deeper, offshore migration route.

Humpback whales have been described as generalists in their feeding habits (Mitchell 1974). The reported prey of humpbacks in the Gulf of Maine are Atlantic herring, *Clupea harengus*; Atlantic mackerel, *Scomber scombrus*; pollock, *Pollachius virens*; and the American sand eel, *Ammodytes americanus* (Gaskin 1976; Katona et al. 1977; Watkins and Schevill 1979; Kraus and Prescott 1981). In recent years, observations of feeding humpbacks indicate that sand eels have become an increasingly important prey item in the Gulf of Maine (Overholtz and Nicolas 1979; Hain et al. 1982; Mayo 1982).

Kenney et al. (1981) hypothesized that the observed distribution of the Gulf of Maine humpback stock was due to the distribution of sand eel, their apparent principal prey species. However, the present distribution of the humpback whale in the Gulf of Maine and throughout the remaining shelf waters of the northeastern United States is not so clearly related to the distribution of sand eel as was suggested. Although we recognize an important predator-prey interaction between humpbacks and sand eel, we hypothesize that behavior and bottom

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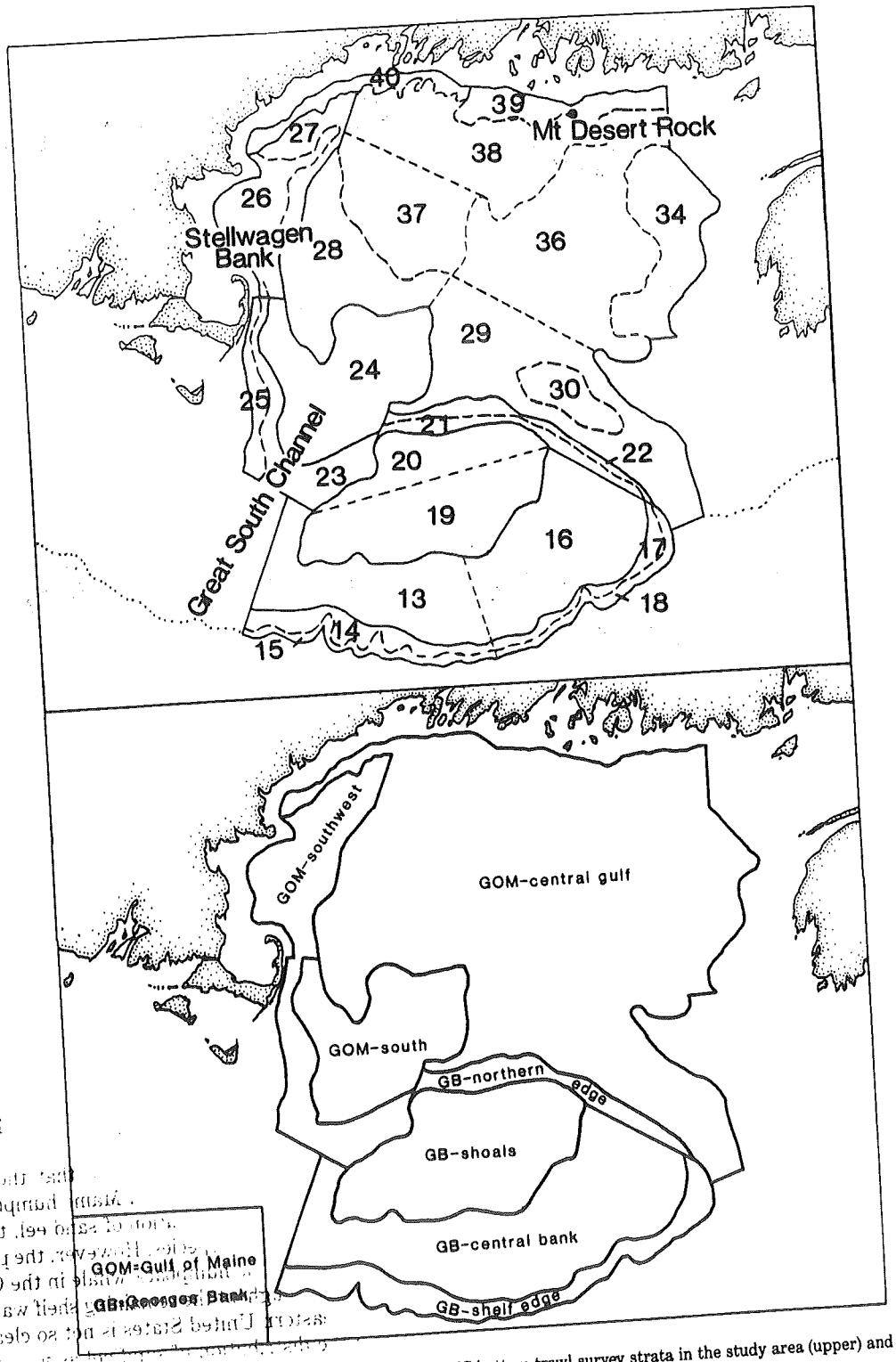

FIGURE 1.—The geographical areas and NMFS/NEFC bottom-trawl survey strata in the study area (upper) and the combined strata into regions (lower) referred to throughout the text.

topography are also critical factors in the foraging strategy of humpbacks, hence the present distribution of these whales. We base this hypothesis on observed sightings of humpbacks throughout the shelf waters of the northeastern United States in relation to sand eel abundance, and on an apparent shift in the center of feeding areas used by humpbacks in the Gulf of Maine since the mid-1970's.

METHODS

The collection of fisheries data used in these analyses was carried out by National Marine Fisheries Service/Northeast Fisheries Center (NMFS/NEFC) scientists and technicians on domestic research vessels during standardized spring bottom-trawl surveys. These surveys measure trends in finfish population abundance and have been used to monitor changes in the size and composition of finfish biomass (Clark and Brown 1977; Grosslein et al. 1980).

Meyer et al. (1979) found that spring (March-May) bottom-trawl surveys accurately reflect trends in sand eel abundance. Therefore, the fisheries data we examined were from these surveys, 1978-82. The stratified mean catch per tow of sand eel was calculated for each region and considered proportional to the population size within each region. We transformed the mean catch into logarithmic values; then, using a two-way analysis of variance (F-statistic), we compared sand eel population size by region and year.

The survey area includes shelf waters from Cape Hatteras north to Nova Scotia and has been spatially stratified by the NMFS/NEFC, based principally on depth and latitude (Grosslein 1969). Sampling stations are randomly assigned within a stratum and the number of stations allocated to strata approximately in proportion to the area of each stratum (Grosslein 1969). In this study, individual stratum have been combined into regions (Fig. 1), in a manner consistent with NMFS/NEFC management units. The two important regions emphasized are the Gulf of Maine and Georges Bank.

Sightings of humpback whales were recorded by observers from the Manomet Bird Observatory (MBO) on NMFS/NEFC research vessels conducting standardized surveys. Observations were recorded continuously along the predetermined cruise path between the sampling stations (following Payne et al. (1984)) in 15-min periods where each period represents a transect. Thus, the duration of each observation period was constant, but the linear km surveyed within each 15-min period depended upon vessel speed. The location (latitude-longitude) of each 15-min observation and the location and number of humpback whales observed were recorded and assigned to appropriate regions to facilitate direct comparisons between the observed number of humpbacks per linear km (humpbacks/effort) and potential prey densities.

Humpback whales are generally present in the study area from spring through fall (March-November) and absent during the winter (CETAP 1982). Therefore, sighting data and effort for winter months were excluded from the analyses. We also examined sighting data collected only during optimum sea conditions less than Beaufort (Kenney et al. 1981) (<16 nmi/h). Difference between the number of humpbacks/effort sighted by region and year were also compared by a two-way analysis of variance (F-statistic).

A coefficient of correlation (r) from the linear regression between the stratified mean catch of sand eel (log) and the number of humpbacks/effort was used to determine whether concentrations of humpback whales co-occurred with patches of sand eel within regions of the Gulf of Maine and Georges Bank.

A $P < 0.05$ was considered statistically significant.

RESULTS

Distribution of Sand Eel

The stratified mean number of sand eel varied significantly between regions on Georges Bank ($F = 14.14$, df = 3, 12) and in the Gulf of Maine ($F = 16.90$, df = 2, 8). On Georges Bank, sand eel were very abundant on the shoals with catches ranging from 1.117 sand eel/tow (log value) in 1978 to 2.846 (log value) in 1982 (Table 1). Sand eel were absent from most tows along the northern and shelf edges. Sand eel were also abundant in the southwest Gulf of Maine ranging from 0.670 sand eel/tow (log value) in 1978 to 2.422 in 1981 (Table 1). Sand eel were not abundant in the deeper, central Gulf of Maine. This patchy distribution reflects a known preference of the sand eel for sand-bottom substrates (Bigelow and Schroeder 1953) characteristic of submarine banks and shoals. No significant differences were found between the stratified mean catch per tow (log value) by year.

Distribution of Humpback Whales

Since 1978, the observed number of humpbacks/effort in the Gulf of Maine has steadily increased

TABLE 1.—Stratified mean number of sand eel per tow ± SE (in parentheses) and the number of sampling tows (lower number) by region and year.

Region	1978	1979	1980	1981	1982
Georges Bank					
shoals	1.117	1.200	2.752	1.850	2.846
	(0.233)	(0.305)	(0.590)	(0.499)	(0.691)
	15	30	15	15	15
northern edge	0.000	0.256	0.000	0.747	0.000
	—	(0.211)	—	(0.464)	—
	9	16	8	8	8
shelf edge	0.100	0.000	0.000	0.000	0.000
	(0.707)	—	—	—	—
	15	14	14	10	14
central bank	0.941	0.410	0.236	0.654	0.034
	(0.182)	(0.202)	(0.132)	(0.396)	(0.341)
	21	38	18	19	19
Gulf of Maine					
central gulf	0.000	0.012	0.141	0.055	0.000
	—	(0.012)	(0.101)	(0.545)	—
	64	61	47	45	47
southern	0.000	0.625	0.116	1.077	0.116
	—	(0.422)	(0.115)	(0.617)	(0.115)
	9	12	6	6	6
southwest	0.670	1.286	1.240	2.422	0.860
	(0.371)	(0.289)	(0.384)	(0.756)	(0.318)
	20	34	16	18	21

(Table 2). Over 90% of the humpbacks/effort observed each year in the combined Georges Bank-Gulf of Maine waters were seen in the Gulf of Maine. The increased number of humpbacks/effort observed was significantly different between regions in the Gulf of Maine ($F = 7.098$, $df = 2, 8$). The greatest concentrations of humpbacks in the Gulf of Maine are located in the southwest region (Table 2). Between 1978 and 1982, 82% of the total humpbacks/effort in the Gulf of Maine were observed in the southwest region. The importance of this region for feeding humpbacks has been previously reported (Kenney et al. 1981; Hain et al. 1982).

Although there were no significant differences between the number of humpbacks/effort seen by year ($F = 0.824$, $df = 4, 12$) or region ($F = 0.609$, $df = 3, 12$) on Georges Bank, the number of humpbacks/effort observed on the bank has steadily declined since 1978. Sixty percent of the humpbacks/effort observed on Georges Bank between 1978 and 1982 occurred during 1978 (Table 2).

We examined the apparent increase in the southwest Gulf of Maine more thoroughly by dividing it into two smaller components (Table 3), a southern which extends from the Great South Channel north along the outside of Cape Cod (NMFS/NEFC strata 23, 25, from Figure 1) and a northern which centers on Stellwagen Bank (NMFS/NEFC strata 26, 27, from Figure 1). The number of humpbacks/effort observed within the southwest Gulf of Maine-northern segment steadily increased by an order of magnitude from 1.86×10^{-2} whales/effort in 1978 to 29.01×10^{-2} whales/effort in 1982. Therefore, the observed increase in the number of humpbacks/effort in the southwest Gulf of Maine since 1978 has occurred primarily in the northern half of this region (NMFS/NEFC strata 26, 27).

TABLE 2.—The number of humpback whales per linear km $\times 10^{-2}$ (humpbacks/effort) seen during shipboard observations and the total number of linear km surveyed (in parentheses) by region and year.

Region	1978	1979	1980	1981	1982
Georges Bank					
shoals	—	0.189	—	—	—
	(480.9)	(529.0)	(190.0)	(342.6)	(744.5)
northern edge	1.500	—	—	—	—
	(200.0)	(176.8)	(66.5)	(89.8)	(222.7)
shelf edge	—	—	—	—	0.225
	(230.0)	(213.6)	(115.6)	(207.0)	(198.6)
central bank	0.168	0.285	0.299	—	0.116
	(593.6)	(701.9)	(334.4)	(895.9)	(863.5)
Gulf of Maine					
central gulf	0.750	0.119	—	0.855	—
	(933.1)	(841.7)	(966.0)	(467.6)	(1,172.8)
southern	2.449	0.828	—	0.393	1.662
	(489.8)	(482.8)	(267.6)	(254.2)	(223.5)
southwest	1.174	2.817	7.679	11.172	6.814
	(681.2)	(745.4)	(547.0)	(454.9)	(692.5)

TABLE 3.—The number of humpback whales per linear km $\times 10^{-2}$ (humpbacks/effort) seen during shipboard observations and the total number of linear km surveyed (in parentheses) within the partitioned southwest Gulf of Maine.

Region	1978	1979	1980	1981	1982
Northern	1.864	2.655	10.794	22.469	29.014
(strata 26, 27)	(34.9)	(263.6)	(333.5)	(252.6)	(299.6)
Southern	0.556	3.113	2.811	1.987	3.308
(strata 23, 25)	(359.3)	(481.8)	(213.5)	(202.3)	(392.9)

Correlation Between Humpback Whale Distribution and Sand Eel Abundance

A significant correlation ($r = 0.81$, $df = 13$) exists between the observed number of humpbacks/effort and the log-mean number of sand eel/tow by region within the Gulf of Maine (Fig. 2). This indicates that within the Gulf of Maine the distribution of humpback whales do co-occur with dense patches of sand eel in that region. The greatest densities of sand eel in the Gulf of Maine and the greatest observed numbers of humpbacks/effort have both occurred in the southwest Gulf of Maine since 1978. This supports the hypothesis by Kenney et al. (1981) that within the Gulf of Maine, the

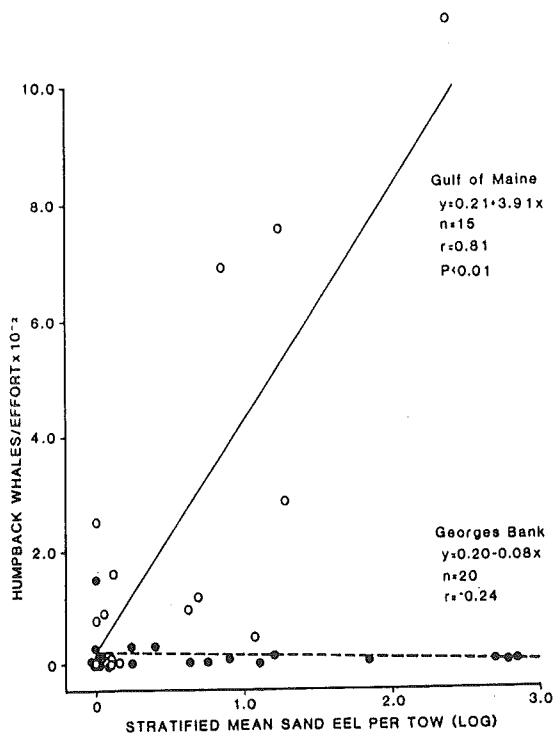

FIGURE 2.—The regression and correlation coefficient (r) between the stratified mean number of sand eel/tow (log value) and the number of humpback whales/effort × 10^{-2} by region and year on Georges Bank (closed circles) and in the Gulf of Maine (open circles).

observed distribution of the humpback whale was due to the distribution of sand eel.

However, the correlation between the observed number of humpbacks/effort and the log mean number of sand eel/tow by region on Georges Bank (Fig. 2) was not significant (r = 0.24, df = 18). The mean number of sand eel/tow (log value) on Georges Bank was greatest on the shallow shoals. Only one humpback whale was observed on the shoals between 1978 and 1982. Our data does not support any co-occurrance between humpback whale distribution and sand eel abundance on Georges Bank despite dense patches of sand eel in that region.

DISCUSSION

Our data suggest that the distribution of humpback whales in the Gulf of Maine-Georges Bank region is presently centered in the southwest Gulf of Maine. This distribution is correlated with dense concentrations of sand eel, a principal prey item, which has dramatically increased throughout shelf waters of the eastern United States including the southwest Gulf of Maine since the mid-1970's (Meyer et al. 1979; Sherman et al. 1981). This increase in sand eel followed a decline of Atlantic herring stocks from the mid-1960's to the mid-1970's (Anthony and Waring 1980; Grosslein et al. 1980), and possible replacement by sand eel of depleted fish stocks in the northwest Atlantic (Sherman et al. 1981). The correlations between the humpback distribution in the Gulf of Maine and sand eel abundance supports the theory by Kenney et al. (1981) that the present distribution of the whales in that region is due to the distribution of sand eel. A demonstrated shift in the humpback distribution since the mid-1970's from the upper Gulf of Maine-lower Bay of Fundy southward into the southwest Gulf of Maine also supports this theory.

A 10-yr summary of observations from Mt. Desert Rock, ME (MDR, Fig. 1) in the northern Gulf of Maine shows a dramatic decrease in the number of humpback sightings/observer hour since 1977 (Mullane and Rivers 1982). The maximum number of humpbacks observed in that summary occurred in 1975 (98 whale sightings, 0.123 humpbacks/observer hour). Only 10 humpbacks were seen from 1978 to 1982, and the maximum number of humpbacks/effort since 1975 has been 0.005/observer hour in 1982. This decline in the number of humpbacks at MDR coincides with the increased numbers of humpbacks observed in the southwest Gulf of Maine. Twelve of the 17 humpbacks photo-identified from 1975 to 1977 at MDR have subsequently been seen in the southwest Gulf of Maine, principally on Stellwagen Bank. At least three of these whales have been observed during three different years on Stellwagen Bank since they were first identified at MDR (Mullane and Rivers 1982). In comparison, only one whale identified at MDR has consistently returned to the coastal waters of eastern Maine and New Brunswick. Katona et al. (1977) also listed the Grand Manan Banks, Briers Island-St. Mary's Bay, Nova Scotia, and the lower Bay of Fundy as areas of humpback congregations. However, humpbacks were not common in the Bay of Fundy during 1981 and 1982 (Kraus and Prescott 1981, 1982).

Shifts in the distribution of humpbacks caused by changes in the distribution and density of prey species have been shown elsewhere (Lien and Merdsoy 1979; Whitehead et al. 1980). We believe that the correlations between humpbacks/effort and mean sand eel catches in the southwest Gulf of Maine, and the demonstrated decline of humpbacks throughout the upper Gulf of Maine-lower Bay of Fundy concurrent with an increase in the numbers

of humpbacks in the southwest Gulf of Maine reasonably explains the present distribution of humpbacks within the Gulf of Maine. However, it does not adequately explain the paucity of humpbacks on Georges Bank (Table 2) and throughout the remaining shelf waters of the northeastern United States (Hain et al. 1981; Kenney et al. 1981; Payne et al. 1984), areas where sand eel have also increased since 1975. The nonsignificant correlation between humpbacks/effort and the log-mean catches of sand eel/tow on Georges Bank suggests that factors other than simply food concentrations, perhaps behavioral or environmental, may influence the humpback's feeding strategy and location.

Sutcliffe and Brodie (1977) reported that humpbacks are led into ecological or oceanographic boundaries (i.e., isopleths or shelf-edges) and feed in patchy areas of dense prey aggregations along these boundaries. A change in depth on the shelf is often accompanied by a concentration of near-surface zooplankton; in general, the more abrupt the change, the greater the concentration (Sutcliffe and Brodie 1977). Concentrations are especially noticeable along the edge of banks where the availability of prey is most affected (Jaansgard 1974). Reay (1970) found that sand eel concentrations are greatest on the edges of sandy banks where currents and prey (zooplankton) are optimum; thus the whales, in seeking the highest concentrations of prey, feed most frequently along the edges of the banks (Sutcliffe and Brodie 1977; Brodie et al. 1978). Observations of feeding humpbacks in the Gulf of Maine have occurred primarily along the edge of submarine banks or canyons (Hain et al. 1982; CETAP 1982).

If bottom topography influences feeding behavior of humpbacks (by concentrating prey), then the paucity of humpbacks on Georges Banks and throughout the mid-Atlantic Bight regions becomes more understandable. The floor of the broad mid-Atlantic Bight is gently sloping continental shelf with no relief until it steepens sharply at the shelf break, at about 200 m depth, to form the continental slope. Since the feeding behaviors for humpbacks described by Hain et al. (1982) occur principally over a shelf-floor with rugged relief, the strategies used by humpbacks seem most efficient in these waters. This also explains the present lack of sightings in the mid-Atlantic shelf waters and the offshore migration route between calving and feeding areas. It seems energetically advantageous for the humpback, a relatively slow-moving whale, to migrate over deep water with little apparent feeding, then feed on the densely concentrated prey along the bottom profiles of the Gulf of Maine.

We maintain that humpbacks are merely utilizing the first concentrations of prey available to them in spring, after they reach shelf-waters from their offshore migration route between winter-calving and summer-feeding grounds. The humpbacks seem to use the Great South Channel as an entry-exit into the Gulf of Maine (as hypothesized by Kenney et al. (1981)), and follow the bottom profile northward, using this profile to their feeding advantage until they reach the dense concentrations of sand eel available within the southwest Gulf of Maine. The quantities of sand eel available to humpbacks at this location have allowed the whales to remain throughout the feeding season; therefore, the recent paucity of sightings in the northern Gulf of Maine.

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