Biological Assessment of the Shellfish Component of the UNH Open Ocean Aquaculture Demonstration Project

NOVEMBER 24, 1998

Prepared for:

U.S. Army Corps of Engineers, New England Division
Regulatory Division
696 Virginia Road
Concord, MA 01742-2751

Prepared by:

Richard Langan, Ph.D.
Jackson Estuarine Laboratory
University of New Hampshire
Durham, NH 03824

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Biological Assessment of the Shellfish Component of the UNH Open Ocean Aquaculture Demonstration Project

1. Introduction

The University of New Hampshire, in partnership with the Portsmouth Commercial Fishermen's Cooperative and Great Bay Aquafarm, Inc. has been awarded funding by NOAA/Sea Grant to undertake a demonstration of the biological, engineering and economic feasibility of culturing finfish and shellfish in an exposed, open ocean environment. Due to differences in timelines for implementation of the shellfish and finfish components of the project, as well as the possibility of permitting issues that may be unique to one component or the other, permits are being sought separately for each of the two components. A permit application for the shellfish component of the project was submitted to the U.S. Army Corps of Engineers on August 6, 1998, for installation of the shellfish culture system. Since the proposed project location is within what could be considered the migratory corridor of a number of protected species, this Biological Assessment of the potential impacts of the shellfish component of the project is focussed on the possible interaction of endangered or threatened whales and sea turtles with the culture gear. This focus is based on discussions with Mr. John Caskey and Ms. Laurie Allen from the NMFS Northeast Fisheries Center, Protected Species Division. The following species are discussed in this assessment.

- Northern Right Whale (*Eubalaena glacialis*) Endangered
- Humpback Whale (*Megaptera novaeangliae*) Endangered
- Fin Whale (*Balenoptera physalus*) Endangered
- Leatherback Turtle (*Dermochelys coriacea*) Endangered
- Loggerhead Turtle (*Caretta caretta*) Threatened

2. Description of the proposed project

For the shellfish component of the UNH Open Ocean Aquaculture Demonstration Project, we propose to culture blue mussels (*Mytilus edulis*) using a submerged dynamic longline technology. The source of the culture organisms will be wild mussel seed, the collection of which will be conducted at inshore sites in Portsmouth Harbor and the Piscataqua River using vertical lines suspended from existing pier and dock structures. Seed collection lines are deployed in June when mussel larvae are most abundant. Growth and density is monitored during the summer season, and the seed mussels, approximately 15 mm in length are stripped from the lines and placed in mesh socks for growout at the open water site. Several locations in the estuary are currently being evaluated for seed collection.

The vicinity map (Fig. 1) shows the proposed growout location, which is approximately one nautical mile south of White Island, and approximately five miles due east of the U.S. mainland at Rye, NH. The site is within State of New Hampshire jurisdictional waters, and is located in Rockingham County. Separate permit applications for this activity have been submitted to the NH Fish and Game, the state regulatory agency for aquaculture, the New Hampshire Wetlands Board, and a Federal Consistency Document is being prepared for the New Hampshire Coastal Program. Monthly surveys have been conducted at the proposed site and the surrounding area since October 1997, during which we have made measurements of bathymetry, established vertical profiles of the physical and chemical properties of the water column, collected discrete water samples at various depths and analyzed them for a number of chemical and biological constituents, and taken grab samples of the sediment to develop a database of sediment grain size rates of mussels from locations in Maine waters with similar physical and biological conditions (C. Newell, personal communication), it is anticipated the growout period will be approximately twelve months from socking to harvest size. A description of the materials and their specifications is included in Table 1.

3. Physical Environment

This summary is based on 90+ years of hydrographic observations assembled and analyzed by the Bedford Institute of Oceanography (BIO) at Halifax, Nova Scotia as part of the Atlantic Fisheries Adjustment Program (AFAP) . The data set used for the discussion was prepared by BIO for a coastal region of the Gulf of Maine west of 70°W between approximately Casco Bay and Cape Ann and extending into Jeffreys Basin. Analyses are performed at standard depths between the surface and 100 m.

3.1 Hydrography of the Region

The hydrography of the Gulf of Maine is unique in that, unlike most of the world's oceans, water temperature increases with depth through the intermediate and deep layers. This rise in temperature, which is associated with a decrease in water density, is compensated by a rise in salinity with depth so that the water column remains stable. This structure is possible because the bottom waters of the Gulf's deep basins are fed via the Northeast Channel by warm and salty Atlantic Slope water.

Surface water in the Gulf of Maine cools during wintertime to nearly 0 degC, producing a layer of dense water which periodically sinks due to convection. This activity mixes and vertically cools much of the upper to intermediate waters of the region each winter. During the summer, a warm surface layer 10-20 m thick develops across the Gulf. This low density layer, which can warm to greater than 20 degC, isolates the surface layer from the waters below due to stratification. While Atlantic Slope water does not reach the coastal region near the Isles of Shoals, both the vertical structure and seasonal changes described above are quite evident.

3.2 The annual cycle of thermal and salinity structure in the Coastal Western Gulf of Maine.

The oceanographic "dead of winter" in the Gulf of Maine occurs during March when the region's average surface temperature dips to a minimum of 2.8 degC (37 degF). At this time, the region is fully mixed by wind and wintertime density overturn processes, as suggested by a vertical warming with depth which is less than 0.4 degC. Small vertical salinity changes between 32.1 psu at the surface and 32.6 psu at 100 m also suggest that the water column is well mixed.

The water column begins to warm in April. By May, the surface has been heated by 5.4 degC to 8.2 degC (46.8 degF) and the upper 10 m layer becomes isolated from the deeper waters. At the same time, bottom waters continue to cool, reaching a minimum of 3.7 degC (39 degF) during May. Surface salinity in the coastal waters drops dramatically to a minimum of 30.5 psu during May as spring runoff from Maine and New Hampshire rivers is carried southwestward by the Maine Coastal Current. Records show the surface salinity can fall as low as 28.2 psu during major runoff events.

Through summer and fall, the sun continues to warm the stratified 10-20 m thick surface layer,where temperatures reach a maximum of 16.2 degC (61 degF) in August. This average winter to summer temperature range of 13.4 degC (24 degF) can be as much as 150% greater during extreme years. Surface salinities increase through the summer and fall, reaching a maximum of 32.6 psu in December. After the springtime runoff is over, this salinity increase is mainly due to the continued evaporation of fresh water under the summer sun. Note that throughout the year,

3.5 Currents

A study conducted in 1989 measured near bottom currents approximately one mile to the northwest of the proposed shellfish culture site (Ward 1994). Velocities ranged from 10 to 30 cm/sec and were generally less than 15 cm/sec. The dominant direction was primarily north to south. Measurements were made during August and September when weather conditions were generally calm, and therefore are representative of tidal induced flow. During stormier periods, wind and wave action may produce significantly stronger currents and the direction may be altered. Site cruises in June, July and August included extensive measurements of current velocity and direction throughout the water column using an acoustic doppler current profiler (ADCP). Preliminary analysis of this data indicates that tidal currents at the site may be high as 30 cm/sec in the water column and that the flow direction is reasonably consistent with the 1989 study (Bub, unpublished data).

3.6 Weather

This meteorological climatology for the region is developed from a nine year record of routine weather observations made by an automatic NOAA National Buoy Data Center (NDBC) C-MAN station on the Isles of Shoals (IOSN3).

3.6.1. Air Temperature

The annual mean air temperature of 8.7 °C (48 °F) lies between a minimum monthly average of -1.6 degC (29 °F) during February and a maximum of 19.2 °C (67 °F) during August. Extremes of -20.9 °C (-6 degF) occurred during January 1988 and 32.3 °C (90 °F) occurred during June 1988.

3.6.2. Air Pressure

The annual mean pressure for the Isles of Shoals is 1017 mb (29.50 in Hg). Mean pressure ranges over the year are small between the minimum of 1013 mb (29.38 in Hg) during June and maximum of 1019 mb (29.55 in Hg) during September/October. A number of extreme minima less than 980 mb (28.42 in Hg) occur during the winter months with the lowest recorded pressure of 965 mb (27.98 in Hg) during a storm on March 14, 1993. The highest recorded pressure was 1047 mb (30.36 in Hg) on December 28, 1990.

3.6.3. Winds

On an annual average, winds most often flow from the northwest at 13.6 kt (6.9 m/s). Winds from all directions are possible although there is a preference for winds from the northwest to south (each greater than 10% of the time). The average wind is seldom calm (only 1.1% of the time). Monthly average wind speeds range from 10.7 kt (5.4 m/s) during July to 15.7 kt (8.0 m/s) during January. A maximum hourly average wind speed of 55 kt (28 m/s) occurred during September 1985, and the greatest recorded gust of 64 kt (32.6 m/s) was observed at the same time.

Winter winds are generally from the northwest at 15.9 kt (6.8 m/s). This offshore flow, which is responsible for cooling the ocean which produces convective overturn, is most often in the west to northwest quadrant. During spring, winds come around to the north at an average 13.4 kt (6.8m/s), although the variability of the season is suggested by a trimodal preference from the northwest, northeast or south. By summer, average wind speed drops to 11.3 kt (5.8 m/s) from the south. Winds from the west to south are most likely. During fall, average winds are 13.6 kt from the southwest, with winds from west to south most likely.

unpublished data).

4. Biological Environment

4.1. Infaunal Benthos

Single Shipek grab samples were collected at each of five or six sites from October 1997 through August 1998. The samples were washed on a 0.5mm mesh sieve, fixed in formalin with rose bengal, sorted, and preserved in isopropanol. The preserved samples were shipped to Taylor University for further identification and processing.

Analysis to Family level is complete for the October through December 1997 samples. Benthic environmental assessment studies in coastal waters have historically involved identification to species level, as has been the case for much of the ecological work in environmental assessments generally. In the past 10 or so years, however, there has been a movement towards assessing the effectiveness of using higher-than-species-level discrimination. Warwich (*Australian Journal of Ecology*, 18: 63-80, 1993) reviewed much of the literature on benthic studies in coastal waters, and concluded: "Many recent studies have shown that very little information is lost by working at a taxonomic level higher than species (e.g. Family or even phylum)." and "Indeed, there are theoretical reasons, and some empirical evidence, for supposing that community responses to human perturbations may be more easily detected above the noise of natural variability by working at high taxonomic levels..." Table C-1 (Appendix C) lists in rank-ordered fashion (based on the overall mean abundances at the six sampling sites) the taxa collected thus far. These data represent a baseline database from which possible impacts of the shellfish culture operation will be assessed.

Spionid polychaetes dominated all six sites (Table C-1). Most spionids are small, near-surface deposit feeders and some species are opportunistic, able to respond to various kinds of disturbances (e.g. increased organic enrichment) quickly by increasing their population size. Hence, they will be good indicators for detecting possible impacts from culture operations. From an overall community perspective, four polychaete families made up over 70% of the total abundances. Other dominant taxa included bivalves, crustaceans, and echinoderms (Table C-1, Fig. C-1). Total taxa in the benthic communities showed little temporal variability (Fig. C-2).

Compared to benthic communities in the nearby Piscataqua River estuary, the benthic communities at the proposed aquaculture culture study area were higher in total taxa and lower in abundances (Figure C-3). For example, total community densities near the mouth of the Piscataqua River in sandy sediments processed on a 0.5mm mesh, typically range from 800 to 1,600 individuals per 0.04 m^2 (Shipek grab sampling area); samples taken in the present study ranged from 100 to 300 per 0.04 m^2. Samples from the present study resulted in five polychaete families that have not been encountered in the estuary, as well as additional mollusc and echinoderm taxa. Such trends are to be expected when comparing nearshore oceanic communities with estuarine benthos because of the loss of stenohaline taxa in the estuary and generally increased organic loadings to estuarine benthos, and perhaps the loss of sensitive taxa. The existing benthic database should be sufficient to detect environmental impacts.

4.2 Fisheries Resources

Both commercial and recreational fisheries resources are present in the vicinity of the proposed aquaculture site. Though once renowned for rich fisheries resources, particularly Atlantic cod, the area surrounding the Isles of Shoals has experienced the same drastic decline in finfish stocks as the rest of the Gulf of Maine. Those species most affected include cod, haddock, pollock, American plaice or dabs, blackback flounder, witch flounder and yellowtail flounder.

The North Atlantic population of right whales is considered to be a distinct and possibly different species or subspecies from the southern hemisphere right whale (*E. australis*) and the north Pacific right whale (*E. glacialis japonica*) (Minasian et al. 1984; National Marine Fisheries Service 1991a). In the past, the North Atlantic Ocean supported two populations of right whales, an eastern population off Scandinavia, Iceland, Great Britain, France, and Spain, and a western Atlantic population off Canada and the United States The eastern Atlantic fishery stopped in about 1926, and it is uncertain if any right whales remain in the eastern North Atlantic population (Reeves and Brownell 1982; Brown 1986; Best 1993).

The North Atlantic right whale is among the rarest of the great whales and with its North Pacific counterpart, is the only whale species in danger of extinction (Crone and Kraus 1990). Estimates of the current size of the population in the western North Atlantic range from 200 individuals, based on mark-recapture methods (Kraus 1985) to a maximum value, based on aerial surveys, corrected for dive times, of 493 (CeTAP, 1982) Kraus et al. (1989) produced a photographic catalog of more than 240 individual right whales identified in New England waters, based on patterns of callosities on the head. The number of new animals seen each year, excluding calves, is low, indicating that most of the population in the Georges Bank/Gulf of Maine area has been identified and catalogued By 1992, more than 300 different right whales had been identified in the western North Atlantic (Kraus et al. 1992) Many of these identifications are old, and the individuals have not been re-sighted for several years; some may have died. Although Crone and Kraus (1990) give a best estimate of 350 individuals in the northwest Atlantic Ocean population off the United States and Canada.

Annual surveys conducted in the northwest Atlantic since 1979 (CeTAP 1982; Hamilton and Mayo 1990; Kraus et al. 1992) indicate that the northwestern Atlantic right whale population is increasing very slowly, if at all. Higher counts in recent years are due in large part to more intensive census efforts (Gaskin 1987). Gaskin (1987) estimated that the northwest Atlantic population could be increasing at a rate of 1 to 3 percent per year Finn (1992) produced a population model of the North Atlantic right whale that provided an estimate of the recovery rate of the population if mortality from ship strikes and entanglement in fishing gear were eliminated. The model predicted an average population growth rate of 0.5 percent per year Kenney (1992) estimated that there had been a significant increase in the right whales population in the western North Atlantic in the time since the cessation of whaling in 1935. Long-term trends in the number of right whale sightings in the Great South Channel, corrected for effects of changes in sighting effort, demonstrate a statistically significant increase of as much as 3.8 percent per year (Kenney 1991, 1992; Kenney et al., in press). This rate of increase is similar to that produced from the rate of calf production and increase in photo-identification. By comparison, estimated rates of increase of several populations of southern hemisphere right whales are in the range of 6.7 to 127 percent per year (Best 1991)

Kraus (1990) suggested that mortality from anthropogenic sources (e.g., ship strikes, entanglement in fishing gear) might be an important factor slowing population growth. Best (1988) suggested that, for species such as right whales, with a small absolute population size and a long reproductive cycle, even a small number of incidental deaths may have a large negative effect on the rate of population increase.

Distribution and migration

In the twentieth century, North Atlantic right whales have been sighted in waters as far north as Greenland, as far east as Bermuda, and as far south as the eastern Gulf of Mexico off Naples, FL (Schmidly and Scarbrough 1990; National Marine Fisheries Service 1991a). However, most of the population is concentrated seasonally in five high-use habitats (Kenney and Winn 1986):

and Kenney 1991). Right whales probably use a method similar to skim-feeding to feed on dense patches of zooplankton below the water surface. Mate et al. (1992), observed right whales in waters east of Jeffreys Ledge in 130 to 200 m of water surfacing with mud on their heads, indicating that the whales had been feeding on the bottom.

Right whales must focus their feeding efforts on very dense patches of zooplankton to fulfill their energy needs. A model of right whale energetics predicts that, in order to meet its metabolic needs, a right whale must focus its feeding on concentrations of prey 2 to 3 orders of magnitude higher than those in an average water column sample (Kenney et al. 1986). These predictions indicate that the geographic distribution of right whales on western North Atlantic feeding grounds is determined by the distribution of dense patches of *C. Finmarchicus* and other preferred prey species. These dense patches of zooplankton are caused by local physical/chemical oceanographic conditions that concentrate the primary nutrients which the phytoplankton utilize, and which in turn is the food source for the zooplankton.

Known Mortality Factors

Based on re-sightings of calves originally observed in the southern calving grounds in the northwest Atlantic feeding areas, Kraus (1990) estimated that approximately 17 percent of calves die within the first year of life. Mortality of neonates was estimated to be about 5 percent, so most of the mortality during the first year of life occurs between 6 and 12 months after birth, a period of long-range migrations of mother/calf pairs. During the second through fourth year, estimated mortality drops to about 3 percent. The rate of mortality of adults seems to be very low, probably less than 1 percent per year (Kraus 1990). Only 16 percent of the documented mortalities of western North Atlantic right whales between 1970 and 1990 were of adults; (National Marine Fisheries Service 1991a).

Biological factors that may decrease reproductive rate and success, or survival of juveniles and adults include inbreeding depression, inherently low reproductive rates (Reeves et al. 1978) competition for available prey with other copepod-feeding whales, particularly sei whales (Mitchell 1975; Mitchell et al. 1986), and finfish (Kenny et al.1986; Payne et al. 1990), and predation (Kraus et al. 1989). Although competition for food has been suggested as a factor limiting recovery of right whale populations, there is little evidence that it is a quantitatively important factor. Sei whales and blue whales, the only local species of whales that share the right whales' preference for zooplankton as food (Kenney and Winn 1986), have not had overlapping summer distributions historically (Kraus 1985).

The only known predator of right whales is the killer whale (*Orcinus orca*) At least 6 to 9 percent of the cataloged right whales bear scars from killer whale attacks, usually on the flukes (Kraus et al 1989; Kraus 1990) It is doubtful that such attacks would result in the death of adult whales. Young whales may be more vulnerable and killer whales have been observed in coastal areas of Florida in February when right whales are calving (Layne 1965).

During the 1980s, there was much concern that exploration for and possible development of oil and gas resources on the Atlantic continental shelf off the United States and Canada might result in degradation of right whale habitat There is no evidence that the limited oil exploration (and the associated physical and acoustic disturbance) on Georges Bank, on the Scotian Shelf and Grand Banks off Canada, and off the middle Atlantic states had any effect whatever on right whales or other species of cetaceans (Sorensen et al. 1984). Cetaceans were as abundant near active oil rigs on the outer continental shelf off New Jersey as they were in the same areas when no rigs were present. Boat traffic in the area of the rigs had no effect on piscivorous whales. Experience, mainly from offshore California and Alaska, has shown that most species of cetaceans adapt readily to the physical presence of exploration and production platforms and to the noises associated with seismic exploration and routine platform operations (Geraci and St. Aubin 1987).

ship activities not leading to collision do not appear to be an important impediment to long-term survival or recovery of northern right whale populations.

4.3.2. Humpback Whale (*Megaptera novaeangliae*)

Population Status and Trends

Humpback whales occur in all the oceans of the world, except possibly the Arctic (National Marine Fisheries Service 1991b). The unique feature of humpback whales that distinguishes them from all other baleen whales is their extremely long flippers that may be 5 m long. Humpback whales are about 4 m long at birth and reach a maximum size of about 18 m and a weight of about 48 metric tons (Winn and Reichley, 1985). Southern hemisphere humpbacks are larger than their northern hemisphere counterparts, and females are slightly larger than males.

Humpback whales were an important commercial species throughout most of their range, including New England waters until the middle of the twentieth century. The International Convention for the Regulation of Whaling, Washington, 1946, afforded the North Atlantic population of humpback whales full protection in 1955 (Best 1993). Humpback whales were afforded endangered species status in the United States in 1970 (US Fish and Wildlife Service 1986), and retain that status today. Although severely depleted by whaling, the species has shown good recovery over most of its range. Prior to exploitation, the worldwide population was thought to number more than 125,000 individuals (Braham 1984; National Marine Fisheries Service 1991b). Brahman (1984) estimated that the worldwide population of humpback whales in the early 1980s numbered no more than about 10,000 individuals. This probably is an underestimate. Best (1993) reviewed recent sighting data for 10 of the 11 stocks of humpback whales in the world's oceans and concluded that the oceans of the northern hemisphere and Australia support more than 17,500 humpback whales; data for Antarctic waters south of 30" S latitude are less certain. The three Antarctic humpback stocks may contain as many as 20,000 individuals, bringing the current world total to more than 37,000 individuals, representing approximately 30 percent of the pre-exploitation population size.

In 1932, the western North Atlantic population was estimated to contain as few as 700 animals (Breiwick et al 1983), but this may have been an underestimate (Reeves and Mitchell 1982). Katona and Beard (1990) estimated that the current size of the western North Atlantic stock is approximately 5,500. This compares well with the estimate of Braham (1984) of 5,275 to 6,289 individuals The western North Atlantic stock of humpback whales is considered to have recovered or to be near complete recovery (Braham 1984).

The humpback whale population can be divided into 11 to 13 breeding stocks each of which winters and reproduces in a different clearly-defined tropical and sub-tropical area, worldwide (National Marine Fisheries Service, 1991b; Best 1993) The western North Atlantic stock winters in the Lesser and Greater Antilles Islands of the eastern Caribbean Sea. During the spring and summer, whales from this stock split into several feeding aggregations that migrate to and feed along the coasts of Iceland, southwestern Greenland, Newfoundland and Labrador, the Gulf of St Lawrence, and the Gulf of Maine (Payne et al. 1986; National Marine Fisheries Service 1991b).

Humpbacks belonging to the Gulf of Maine feeding aggregation numbered approximately 240 individuals in 1986, as estimated by mark-recapture methods, (Katona and Beard 1990). This may be an underestimate since more than 600 humpback whales have been photo-documented in the Gulf of Maine since 1979, and more than 400 humpbacks were photo-documented in 1988 alone (National Marine Fisheries Service 1991b). Volganau and Kraus (1992) produced a mean population estimate for the Gulf of Maine of 447 individuals, and a range from 340 to 555 whales. Some whales from the St. Lawrence River estuary and Canadian Maritimes (Bay of Fundy and important food of humpback whales in the western Gulf of Maine, including Stellwagen Bank, Jeffreys Ledge, and the Great South Channel (Hain et al. 1982; Payne et al. 1986, 1990). This diet is supplemented in the Gulf of Maine region by euphausiids and mackerel (*Scomber scombrus*) when these species are locally abundant (Meyer et al. 1979; Overholtz and Nicolas 1978; Kenney 1984). The abundance of sand lance in the western Gulf of Maine rose substantially in the early and middle 1970s following over-fishing of their major competitors and predators. Before this time, humpback whales were rare in the western Gulf of Maine (Overholtz and Nicolas 1979). Since about 1978, the abundance of humpback whales has been significantly correlated with the abundance and distribution of sand lance in the Gulf of Maine (Kenney 1981; Payne et al. 1986, 1990). During summers when sand lance were not abundant on Stellwagen Bank (eg. 1986), humpback whales were rare there, apparently having moved to other high-use feeding areas, such as the Great South Channel and the southern Bay of Fundy to feed on sand lance or other, alternative foods, such as other small shoaling fish and euphausiids (Payne et al. 1990). The humpbacks that move from the western to the eastern part of the Gulf of Maine between Jeffreys Ledge and the Bay of Fundy during the summer feed primarily on herring, supplemented by euphausiids in late summer when they are locally abundant. Humpback whales have the most diverse repertoire of feeding behaviors among the great whales. They may feed singly or in closely coordinated groups. Groups of up to 20 may lunge in unison at surface schools of fish (Hain er al 1982; Wursig 1990). In lunge-feeding, a whale rushes a school of fish or euphausiids near the water surface at an angle of 20° to 40°, and occasionally to 90°, opens its mouth just before reaching the school, engulfing the school, and breaking the water surface with mouth agape (Watkins and Schevill 1979). An unusual feeding strategy employed by humpbacks is to create a bubble screen to herd schools of fish. Humpbacks also feed on schools fish and crustaceans located at mid-depths or near the bottom. Approximately 65 percent of the humpback whales feeding in Massachusetts Bay, particularly on Stellwagen Bank, have scuff marks on their lower jaws, suggesting that they have been feeding on or in the bottom (Hain 1991a). This may be a specialized behavior of humpbacks feeding on sand lance. When not schooling, sand lance spend much time buried in sandy sediments (Meyer et al. 1979)

Known Mortality Factors

Many of the natural and anthropogenic factors adversely affecting the survival and reproduction of right whales also affect survival and reproduction of humpback whales. Because humpbacks can exploit a greater variety of food items, they are less susceptible to natural fluctuations in individual species.

During the last 20 years, the most serious anthropogenic threats to humpback whales have been interactions with commercial fisheries (Hofman 1990a; Volgenau and Kraus 1991). Commercial fisheries may compete directly with the whales for a particular preferred species of fish, as has happened with the capelin fishery off Newfoundland, or the whales may become entangled in fishing gear, as happens in both Newfoundland and the Gulf of Maine (Hofman, 1990a; Volgenau and Kraus 1991).

Entrapment in fishing gear is the most frequently identified source of anthropogenic injury to humpback whales in the western North Atlantic stock (O'Hara el al 1986), particularly in cod traps off Newfoundland (Lien et al.1989 and Hofman 1990a). Nearly 600 humpback whale entanglements, leading to 93 verified deaths of whales (15 percent), were recorded in Newfoundland waters between 1979 and 1989 (Lien et al 1989b). Between 1975 and 1990, There were 47 reported humpback whale entanglements in the Gulf of Maine (Volgenau and Kraus 1991), leading to five deaths (10.6 percent of entangled whales). Entanglement scars are present on 12.4 percent of the flukes and 6.3 percent of the tail stocks of photodocumented humpback whales in the Gulf of Maine (Volgenau and Kraus 1991). The National Marine Fisheries Service with greatest numbers in temperate and boreal latitudes (Evans 1987). The estimated modern worldwide population is 105,000 to 125,000 individuals (Wursig 1990). They are the most abundant and frequently sighted of the endangered great whales that visit the Gulf of Maine. The size of the population in outer continental shelf waters off the eastern United States from Cape Hatteras to the Canadian border ranges from about 5,000 in the spring and summer to about 1,500 in the fall and winter (Hain et al. 1992). Mitchell (1974) estimated that approximately 7,200 fin whales occupy the outer continental shelf between Cape Cod and Labrador on a seasonal basis. About 2,000 fin whales visited Newfoundland waters each year in the early 1970s (Allen 1973), but the number seems to have dropped during the 1980s (Lynch and Whitehead 1984). The portion of the northwest population that visited the Gulf of Maine in the late 1970s and early 1980s range from about 3,000 individuals in the spring and summer to 200 individuals in the fall and winter (CeTAP 1982). The current population size in the Gulf of Maine probably is larger than the CeTAP (1982) estimates.

The size of the pre-exploitation population of fin whales in the western North Atlantic Ocean probably was between 30,000 and 50,000 individuals (CeTAP 1979) Hain et al. (1992) suggested that the 1992 population of fin whales off the northeast coast of the United States might be in the range of 9,000 to 10,000 animals. Thus, the North Atlantic fin whale population has recovered to about 25% of its pre-exploitation size.

Little is known about reproduction in North Atlantic fin whales. Presumably, reproduction takes place during their winter sojourn off the mid- and south-Atlantic states. Based on the distribution of strandings of neonates, some of which were premature, calving seems to take place in coastal or offshore waters south of New Jersey between October and January (Hain er al 1992). Hain et al. (1992) hypothesized that the Charleston Bight south of Cape Hatteras is the wintering ground for some of the fin whale population that occupies New England waters during the summer. No mating or breeding is known to occur in the Gulf of Maine.

Seasonal Distribution in the Gulf of Maine

In spring and summer, large numbers of fin whales are present in an arc extending from the Great South Channel, northwestward along the 40 to 50m contour east of Cape Cod from Chatham to Provincetown, across Stellwagen Bank, and along the 100 meter contour east of Cape Ann to the northeastern tip of Jeffreys Ledge (Hain et al.1992). They are common in waters out to the shelf edge but rarely are sighted in waters deeper than 2,000 m. Sixty-five percent of sightings are in water depths of 21 to 100 m. Fin whales also are rare in shoal waters of central Georges Bank, or deep waters of the central basin of the Gulf of Maine. During summer, fin whales extend their distribution to the central and northern parts of the Gulf of Maine and the periphery of Georges Bank in water depths of 40 to 200 m. This summer distribution is very similar to that of humpback whales, and the two species can be considered sympatric throughout much of their range in US waters of the Atlantic during the summer feeding season.

Only about 30 percent of the fin whales present in the summer remain in New England waters during the fall and winter. They largely abandon the northern Gulf of Maine, Jeffreys Ledge, and the area immediately east of Cape Cod.

Limited migration generally occurs in shelf waters from Cape Cod north as far as Labrador during the peak summer feeding period. Agler et al. (1990) reported several instances of photodocumented fin whales moving between Massachusetts Bay and coastal waters of Maine and the Bay of Fundy during summer months. Fin whales sighted in Gulf of Maine waters in one year often are re-sighted in the same area in subsequent years, indicating a high degree of feeding area fidelity (Seipt et al. 1990)

Many of the fin whales that occupy coastal waters north of 40"N latitude move south and offshore, starting in October, to wintering grounds off Long Island, the Delmarva Peninsula, the Outer Banks of North Carolina (CeTAP 1982; U.S. EPA 1988), and perhaps further south . Hain boat and other vessels in Massachusetts Bay (Watkins 1986) Fin whales react strongly to low frequency ship sounds which are near the frequency of their own vocalizations (15 to 100 Hz). In the early 1970s, they actively avoided approaching vessels and would often dive if approached, however, in recent years, they have either ignored small vessels or actually approached to investigate them.

There have been 72 verified strandings and nine "floaters" of fin whales along the US Atlantic coast during this century (Hain et al. 1992). Strandings have occurred most often on Cape Cod, Cape Hatteras, and Long Island. All strandings of neonates (less than 8 m long) occurred south of New Jersey. The cause of death of most of these whales is unknown. however, a yearling female fin whale stranded in New England in 1977 apparently died of massive infection of giant nematode parasites (*Crassrcauda boopis*) in the kidneys (Lambertsen 1986). This parasitic disease has a prevalence of nearly 95 percent in the Icelandic population of fin whales and appears to be very common in other fin whale stocks as well (Lambertsen 1986). The parasite may cause renal failure and mild anemia in severely infected whales. It may be passed from mothers to their suckling calves in the urine (the urethral opening and the mammary grooves are close together in most whales). Lambertsen (1986) suggested that crassicaudiosis is a major natural cause of mortality in fin whales.

4.4 Marine Turtles[2]

One species of endangered sea turtle, the leatherback (*Dermochelys corracea*) and one threatened species, the loggerhead (*Caretta caretta*) are possible summer visitors in the Gulf of Maine. Of these two species, there is a higher possibility that the leatherback would be observed in the vicinity of the Isles of Shoals since the loggerhead is rarely sighted north of Cape Cod.

4.4.1 Leatherback Turtle (*Dermochelys corracea*)

Population Status and Trends

Leatherback turtles are the largest and most distinctive of the sea turtles They reach a length of 150 to 170 cm and a weight of 500 and exceptionally 900 kg. Lacking a keratinized shell, they are covered instead with a tough hide. Leatherbacks have a layer of subcutaneous fat 6 to 7 cm thick and circulatory adaptations to reduce the rate of heat loss through the fins (Greer et al. 1973). They respond to drops in ambient temperature by increasing metabolic heat production and so can maintain an internal body temperature well above ambient water temperature (Standora et al. 1984; Paladino et al. 1990) A leatherback in 7.5°C seawater was able to maintain its core body temperature at 25°C (Friar et al. 1972). Thus, endothermy allows leatherbacks to survive and feed in colder temperate waters than other sea turtles can tolerate.

Leatherback turtles are the second most common turtle along the eastern seaboard of the United States, and the most common north of the 42" 00~N latitude. An estimated 16,000 leatherbacks live in the western North Atlantic Ocean, however, they are listed as endangered. Because they are a largely oceanic, pelagic species, estimates of their population status and trends have been difficult. In addition, only a small fraction of the North Atlantic population nests or

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2. General information on marine turtles was taken all and in part from the document entitled "Biological Assessment of the Dutra Sea Scallop Aquaculture Proposal with respect to potential impacts on Marine Mammals, Marine Reptiles and their Critical Habitat Cape Cod Bay-Truro Massachusetts" prepared by Smith and Dunk of Coler Colantonio, Inc. and Neff and Foster of Battelle Ocean Sciences. January, 1995. References and cited literature from that document are included to properly identify the original source of the information.

stunning.

Leatherbacks apparently are not frequently caught in commercial shrimp nets. However, they are susceptible to entanglement in fishing gear and plastic debris (Mager 1985). Because they are adapted to a pelagic existence, they have trouble maneuvering in fight places and swimming backwards, and have difficulty avoiding obstructions in shallow waters (Payne and Selzer 1986; NOAA 1991). Leatherbacks have been entangled in lobster gear (O'Hara et al. 1986) and fishing longlines (Balazs 1985) in New England waters. Records from the Sea Turtle Stranding and Salvage Network show that 45 leatherback turtles became entangled in lobster gear between 1983 and 1993 in coastal waters of New Jersey, New York, and southern New England (National Marine Fisheries Service 1994). Eleven of the entangled turtles died. The huge front flippers (often one meter long) of leatherbacks often bear cuts, chafing marks, or are severed altogether, possibly due to entanglement (Frety 1982).

Because of their preferred diet of gelatinous zooplankton, particularly jellyfish, leatherback turtles often ingest floating plastic debris, mistaking it for food (Wallace 1985; O'Hara 1989). Plastic bags blocked the stomach openings of 11 of 15 leatherbacks that washed ashore on Long Island during a two-week period (Balazs 1985). The largest leatherback ever recorded washed ashore dead on the coast of Wales entangled in fishing gear and with a large piece of plastic blocking the entrance to its small intestine (Eckert and Eckert 1988).

Although leatherbacks are not harvested commercially for meat or other products, there is extensive subsistence harvesting of the females that come ashore to nest throughout much of the tropical nesting range, including Guyana, Trinidad, and Columbia (National Research Council 1990) Egg collecting is also intense in some areas.

4.4.2 Loggerhead Turtle (*Caretta caretta*)

Population Status and Trends

The loggerhead sea turtle is listed as threatened under the Endangered Species Act. It is the most common and seasonally abundant turtle in inshore coastal waters of the Atlantic. Aerial surveys conducted by the National Marine Fisheries Service between Cape Hatteras, NC and Key West, FL between 1982 and 1984 were corrected for submergence time and yielded an estimated peak abundance of 387,594 individuals with carapace lengths of 60 cm or greater (Thompson 1988).

Most nesting in US territory occurs on sandy shores between North Carolina and Key Biscayne, FL, and research indicates that more than 20,000 loggerhead turtles nest along the Atlantic and Gulf of Mexico coasts of the United States each year.. There is some evidence of a small decline in the population of nesting females along the south Atlantic coast in recent years (Witherington and Ehrhart 1989). The estimated population of loggerhead turtles along the southeast coast of the United States remained relatively stable at about 387,000 individuals during the 1980s (Thompson 1988).

Seasonal Distribution

Loggerhead turtles are abundant during spring and summer months in coastal waters off New York and the middle Atlantic states. In the fall, they migrate southward to coastal waters off the south Atlantic states, particularly Florida, and the Gulf of Mexico. In the spring, they congregate off southern Florida before migrating northward to their summer feeding ranges (CeTAP 1982). During the winter, the turtles tend to aggregate in warmer waters along the western boundary of the Gulf Stream off Florida (Thompson 1988). Along the Atlantic coast, mating and nesting take place in the spring and summer. Nesting beaches along the Atlantic coast

5. Assessment of Biological Impacts

Risk of harm to the listed species will depend on; 1) the occurrence of the listed species in the proposed location of the aquaculture installation, 2) the likelihood of physical contact with the aquaculture gear if they do venture into the area, 3) the potential for entanglement with the gear if contact is made, and 4) the possibility of injury or death in the event of an entanglement.

The preceding description of the distribution of the listed species is quite general in nature and lacks precision for the area of the proposed site. More detailed local information on whale and leatherback turtle occurrence was obtained through conversations with local whale watching vessel captains (Captain Leo Axtin, Rye, NH), and naturalists that ride aboard these vessels (Ms. Suzanne Renselear, North Hampton NH). This information will be cited as "personal communication" in the discussions of the occurrence of individual whale or turtle species.

The proposed UNH aquaculture demonstration site, while not located in a critical habitat or high use areas for endangered whales and turtles, nor within the lobster and gillnet gear restriction zones (NMFS Take Reduction Plan), is located in what might generally be considered the migratory corridor of the five identified whale and turtle species, and therefore its presence can be considered a potential hazard to these species.

Since there is virtually no data on the interaction of the listed species with the type of gear proposed for this project, the potential for impact can only be based on the history of entanglements of whales and turtles with fixed fishing gear. Entanglements have occurred with a variety of fishing gear including gillnets, seines, cod traps, weirs, and lobster gear. There are, however, some generalizations that can be made regarding the characteristics of gear with which entanglements have occurred. Lines that float at the surface, small diameter vertical lines such as endlines from a trawl of lobster traps, non-sinking line connecting individual traps in a trawl, and loose twine as found in gillnets, seines, and fish traps have all been associated with entanglements (A. Blott, personal communication). Though similar to some fishing gear in the sense that it is fixed and remote, the submerged longline shellfish growout gear differs from fishing gear in a number of ways. Line diameters are much larger and under tension, there are no loose or floating lines, no loose twine, no bottom lines, and surface expression and vertical lines are minimal. Though the characteristics of the aquaculture gear are markedly different than the fixed fishing gear with which entanglements have occurred, the dearth of data on interaction of dynamic submerged longline gear with whales and turtles would dictate that caution must be exercised, and the risk of harm to protected species musty be considered. Since the likelihood of encounter and the behavior of each of the species differs, each will be considered separately.

Right Whale

There have been no documented sightings of right whales in the vicinity of the proposed site (S. Kraus, personal communication), and in a twenty year period, very few documented sightings within a several mile radius of the site (L. Axtin, personal communication). The probability of occurrence of right whales or other large whales such as humpback or fin whales, westward of Scantum Basin and Jeffreys Ledge (several miles east of the Isles of Shoals) is considered low by local whale watch vessel captains. However, since right whale movement is in the Gulf of Maine is dictated by food availability, it is possible that a right whale may venture inshore of it's normal migratory pathway into the vicinity of the site. If right whales do enter the vicinity of the site, there is some possibility that they may come in contact with the gear while feeding.

The minimal use of surface gear (lighted marker buoys only) presents little to no possibility of gear contact with a whale swimming or feeding at the surface. Bottom gear consists only of the large anchors (no bottom lines) so risk to whales feeding on bottom is also very minimal. Whales feeding or swimming in the water column could potentially come in contact with the subsurface

Leatherback Turtle

Of the two turtle species, the leatherback is more likely to encounter the aquaculture gear due to their more northerly distribution. The same components of the gear that present the greatest risk to whales (vertical lines and mussel socks) present the greatest risk to turtles. It is unclear whether leatherbacks would be able to see the gear in mid-water, or if they would avoid it if they did see it. If a turtle swam into the mussel socks and became entangled, it is unknown whether there would be sufficient line stress created by the turtle to break the 600 lb weak link attachment to the headline. However, unlike lobster buoy line, the mussel socks, due to their low flexibility and large diameter would not easily wrap around the flippers of a turtle. It is also unclear whether a leatherback could become entangled with one of the two vertical marker buoy lines. These lines, though not under tension like the anchor and headlines, are somewhat taut and are of large diameter. The line diameter, flexibility, and amount of slack in the line is considerably different than lobster buoy line Risk does exist that a leatherback entanglement could occur, however, it is difficult to quantify.

Another possible risk, though probably quite remote considering the leatherbacks' preferred diet, is inadvertent ingestion of the polypropylene "sock" netting if a turtle tries to eat some of the mussels growing through the mesh of the socks. It is unclear whether a leatherback would consider the mussels prey, or if so, whether it could actually tear through the mesh and eat some of the socking material. It is also unclear if the mesh socking material would cause a turtle digestive tract difficulties in the way plastic bags or other plastic materials do.

Loggerhead Turtle

Since loggerhead turtles are so rarely observed north of Cape Cod, the likelihood of a loggerhead coming in contact with the aquaculture gear is remote. If a loggerhead did happen to come into contact with the gear, they would be less likely than a leatherback to become entangled due to their greater maneuverability. They would, however, be at greater risk of ingestion of the polypropylene socking material since bivalve molluscs are one of their preferred foods.

6. Risk Summary

Based on historical sightings, documented migratory routes of the listed species, and information obtained from local vessel captains and naturalists, these is some possibility that one or more of the listed species could occur in the vicinity of the proposed aquaculture site. If one or more of the species does migrate into the area to feed, there is some possibility that they may encounter the aquaculture gear, and if so, based on the behavior of the individual species, some small and species related differential possibility that an entanglement could occur. If an entanglement did occur, there is yet again some possibility that a whale or turtle could be harmed. Each of these possibilities can be assigned a qualitative (low to high) probability value and overall risk can estimated by the cumulative probability of each of the categorical possibilities. Table 2 presents risk possibility categories, and a qualitative numerical representation of risk probability in each category for each of the listed species. Categories include: Occurrence, Contact, Entanglement and Physical Harm. Cumulative Risk was calculated by adding the estimated risk values in each category. An additive function was used for simplicity, though a truly probablistic model would employ a multiplicative or an overlapping probability distribution function. Risk probability values were assigned based on the relationship of the location of the proposed site to migratory areas and behavior of each of the species, the relationship of size and physical characteristics of the proposed gear deployment to the behavior of each of the species, and the history of entanglement in fishing gear for the species.

site every day during the seasons when whales and marine turtles would most likely be present. Additionally, the area within a one mile radius of the site is visited daily by one or more local lobstermen who are well aware of the project and associated issues. Any problems with the gear or interactions with mammals or turtles would likely be detected within a 24 hour period, and one of the organizations that responds to whale or turtle entanglements such as the Center for Coastal Studies in Provincetown, MA can be contacted and respond quickly to aid the entangled animal (Dr. Charles Mayo, Center for Coastal Studies, personal communication).

6. Site Inspection and Maintenance (Risk Category =Entanglement): Since the greatest risk for entanglement or any other impact would occur if the gear were to come loose from any attachment point, there will be a regular bi-weekly schedule of inspection and maintenance during the period April thru October, and monthly during the period November thru March. Inspections will include video monitoring of the moorings and attached lines, and SCUBA and video survey of the headline and mussel socks. Any wear or fatigue of materials will be remedied. All components of the gear will be marked to indicate ownership, and therefore responsibility will be accepted for any property or natural resource damage.

7. Conclusions

Based on migratory patterns and behavior of the protected species considered, and the size, location and physical characteristics of proposed aquaculture demonstration facility, the probability of harm to all species due to the presence of the facility is low. Lowest probability exists for the Loggerhead turtle, followed by the right whale and fin whale, humpback whale, and the Leatherback turtle.

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Table 1. Materials and Specifications

Anchors:

4,000 lb (end) and 6,000 lb (center) concrete anchors set with loop "eyes" of 1.5" polypropylene for anchor line attachment.

Anchor Lines and Headline:

1.5" Twisted polypropylene, safe working load limit 6000 lbs

Navigational Buoy Lines:

1.5" twisted nylon, safe working load limit 8,000 lbs

Sock Attachment line

3/16" braided nylon twine, breaking strength 600 lbs

Mussel socks:

3" diameter poylpropylene cylindrical mesh with a 17 mm stretched mesh size

Submerged Corner Buoys:

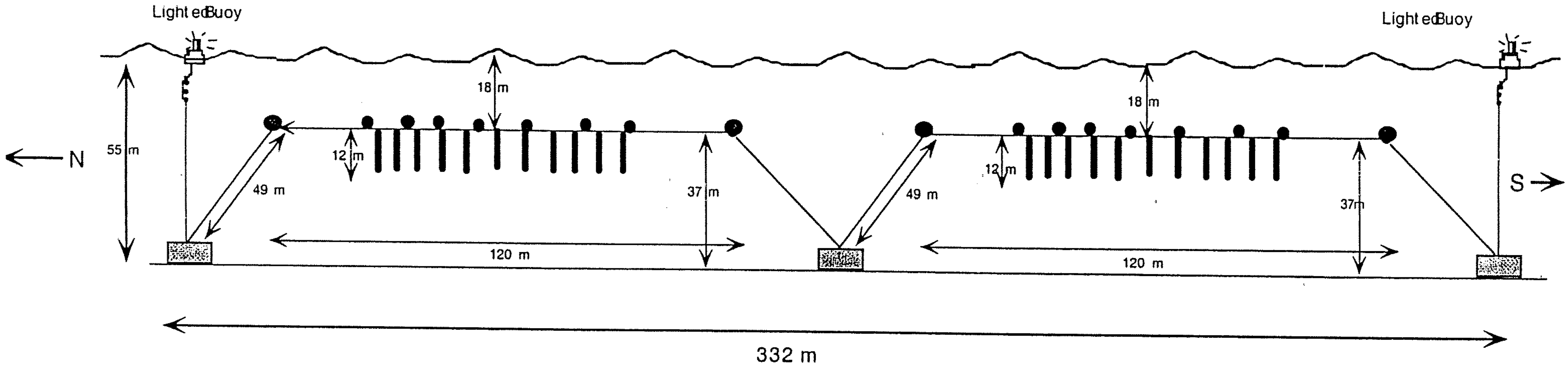
30" steel with a floatation capacity of 380 lbs

Headline Buoys:

16" polyethylene buoys with a floatation capacity of 78 lbs

Figure 1. Site Layout

Side View of Site Layout



Top View of Site Layout

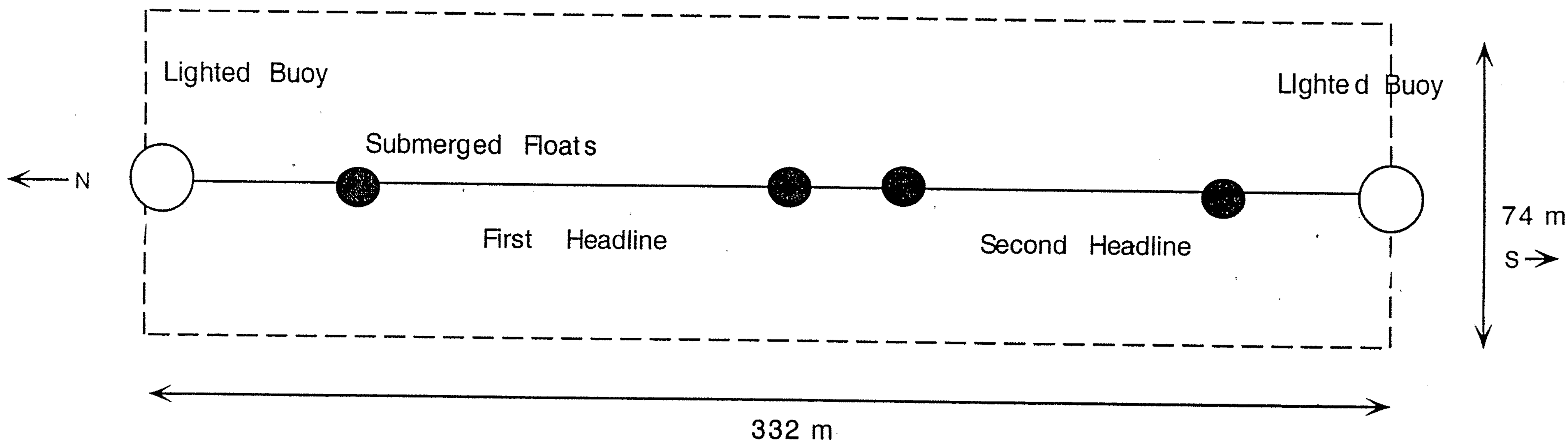
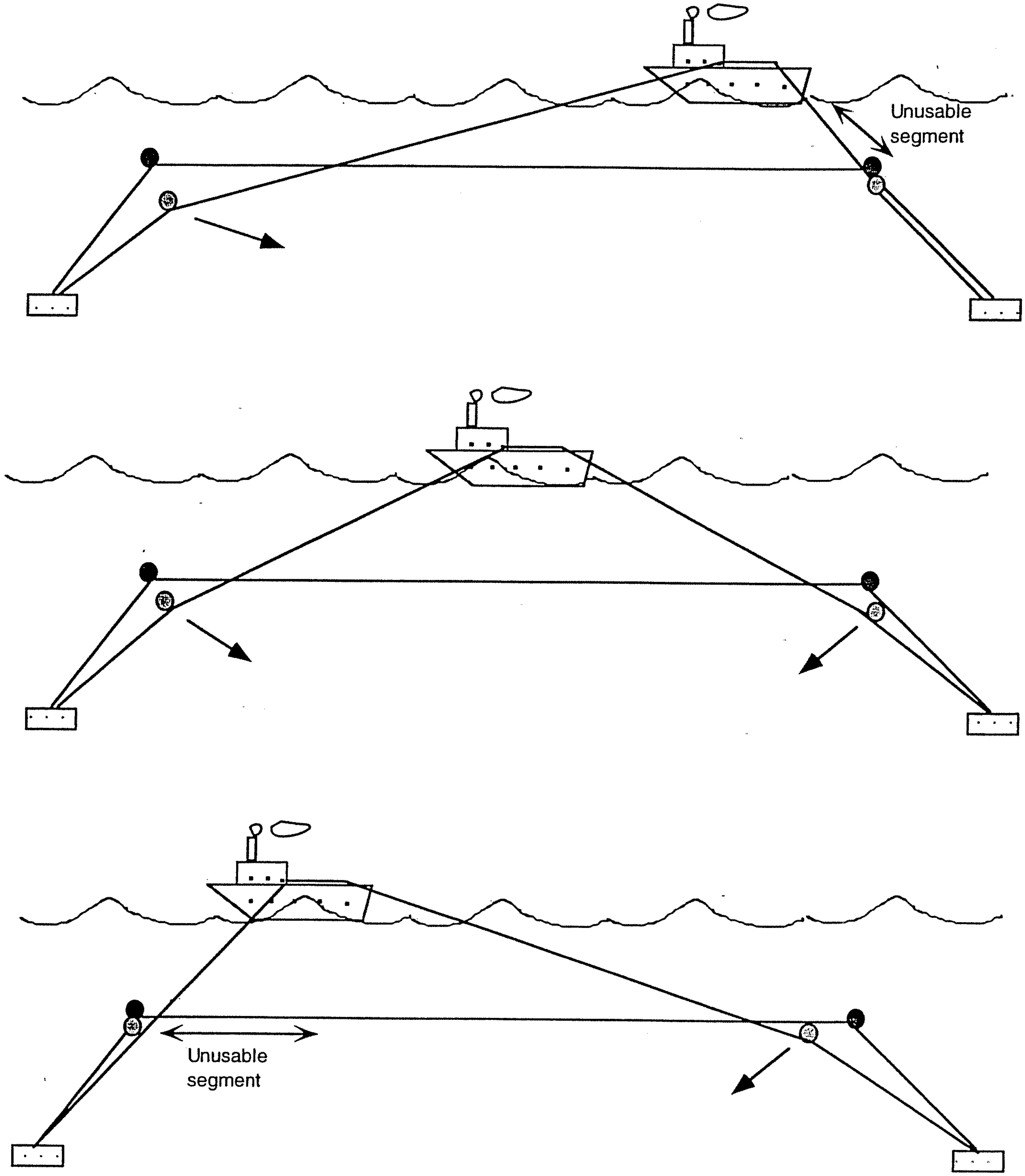


Figure 3. Schematic of Vessel Tending a Submerged Longline



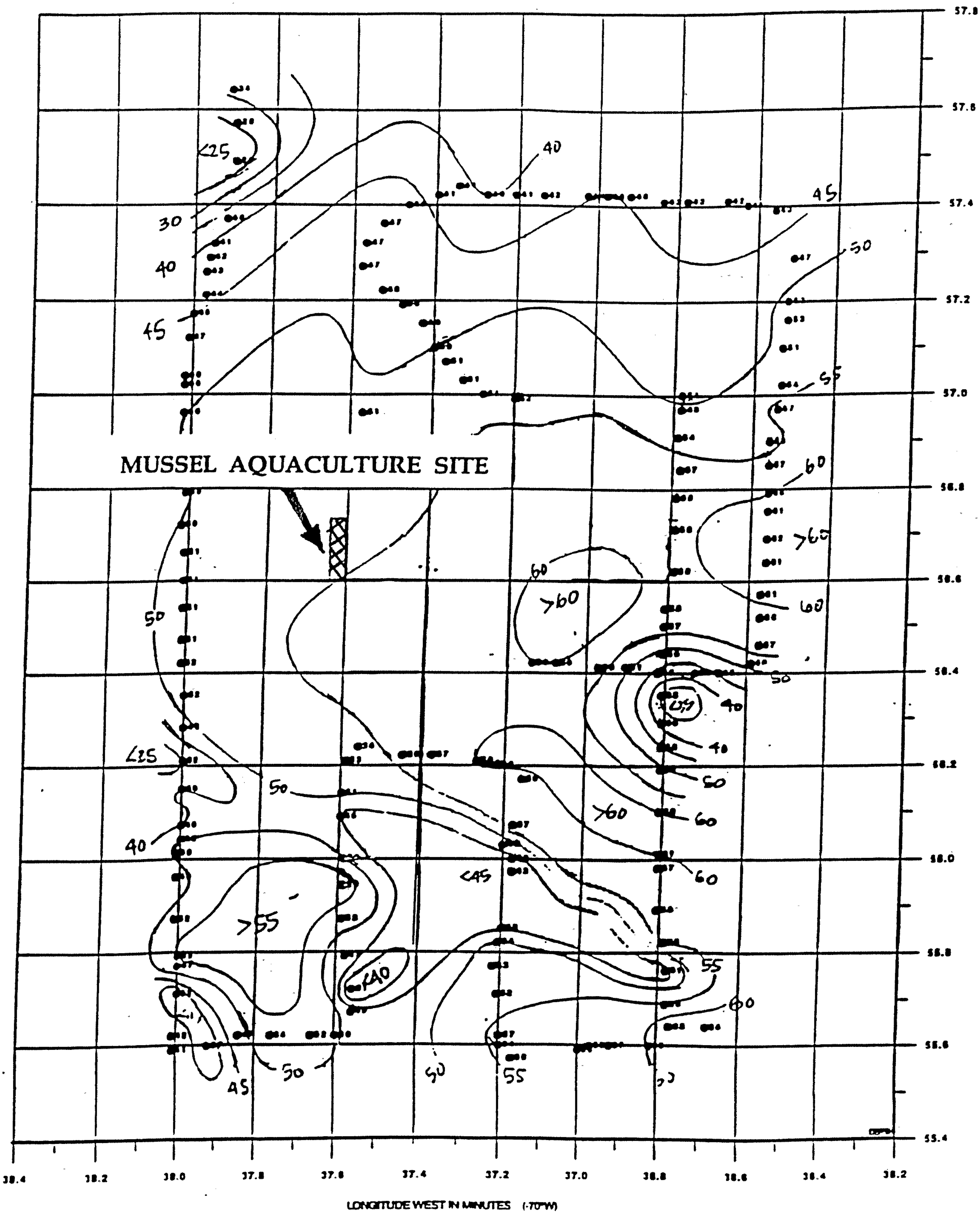
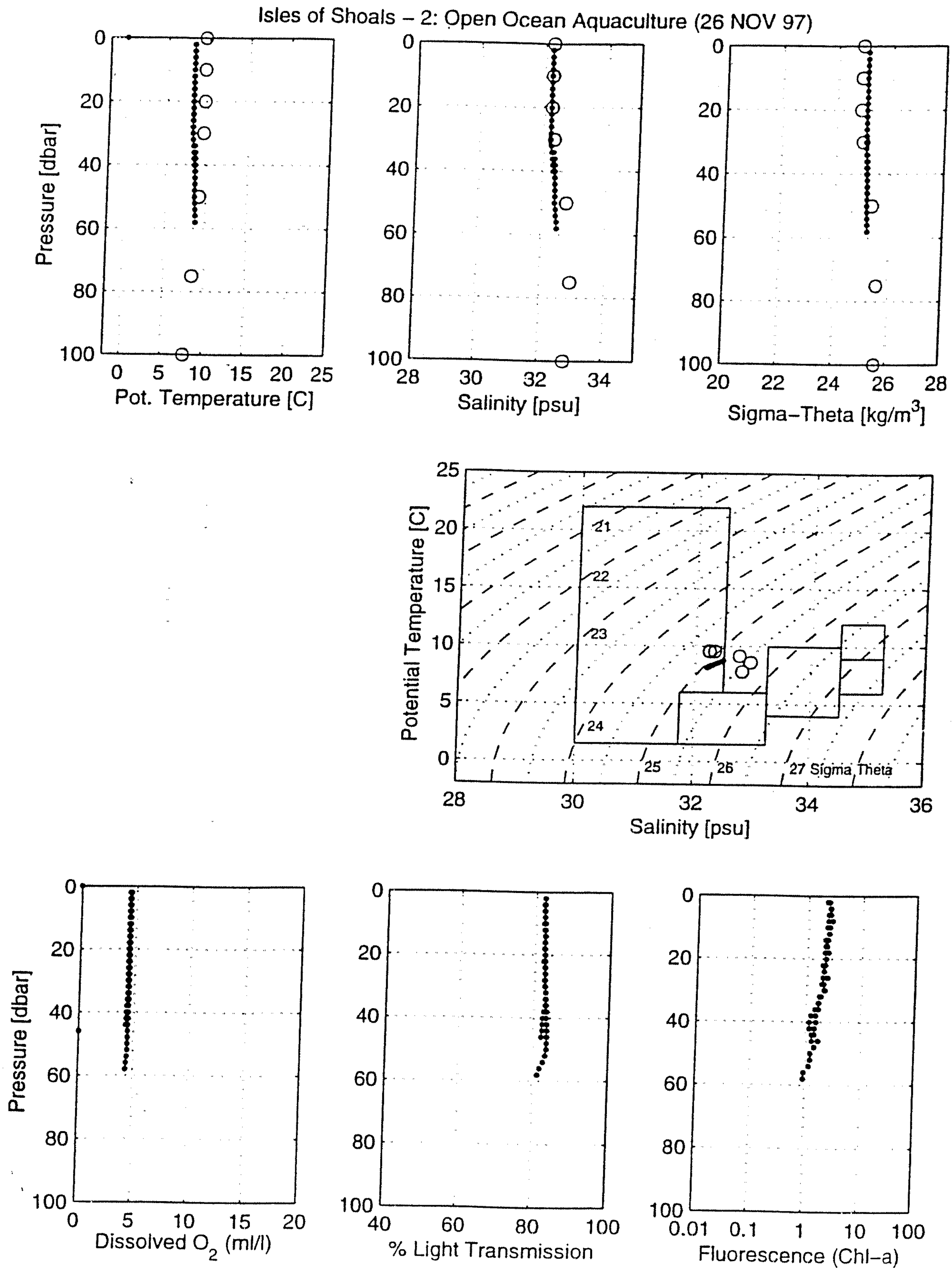


Figure 5. Proposed mussel aquaculture site location; cross-hatched area measures approximately 74 x 330 meters. Water depth contours shown in meters.

Appendix A

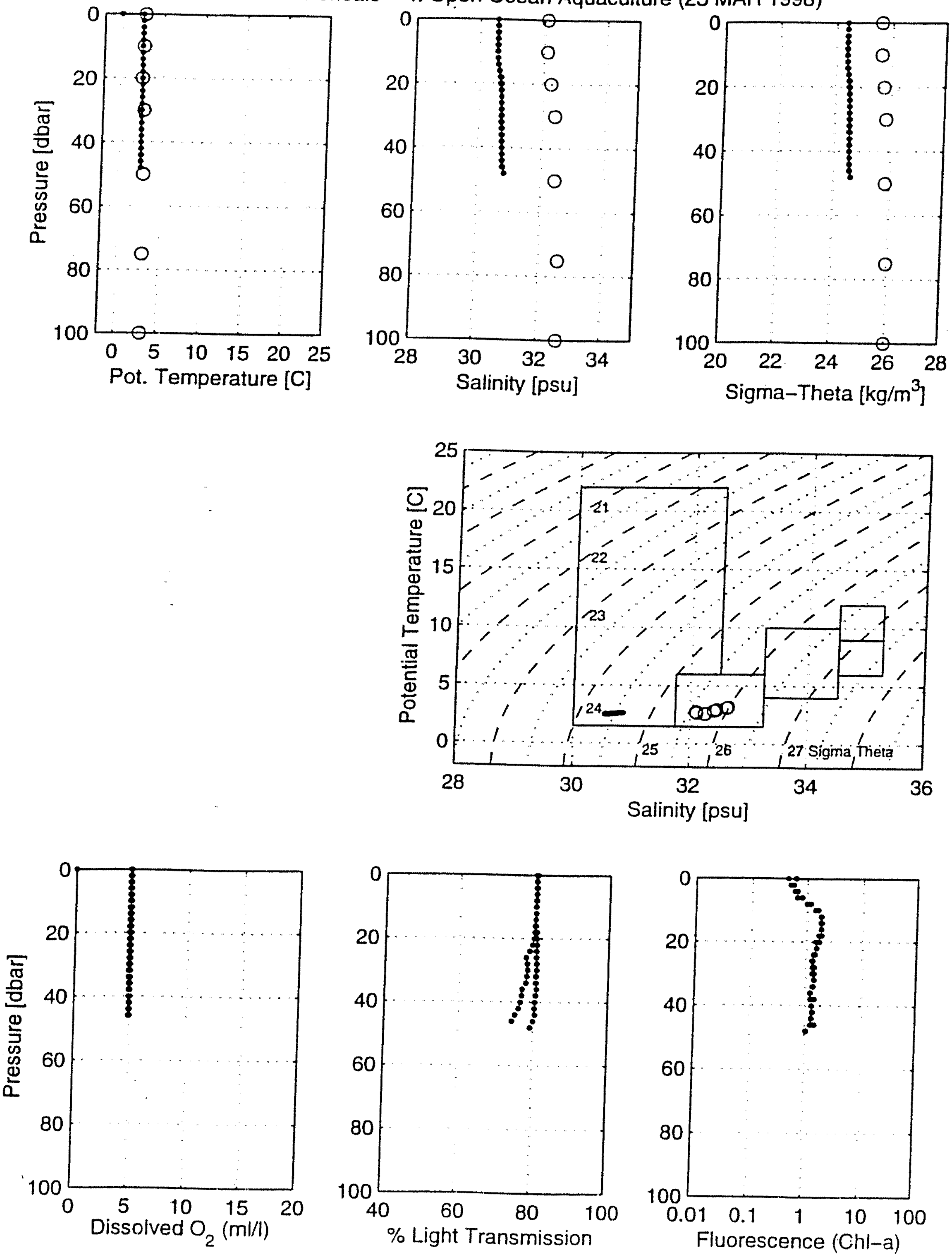
CTD water quality data for the proposed aquaculture site



ooa1197 – Composite of 2 survey CTDs ('o' shows BIO area climatology for month)
NOV 97

Run: 12–Aug–1998@09:37

Isles of Shoals - 4: Open Ocean Aquaculture (23 MAR 1998)

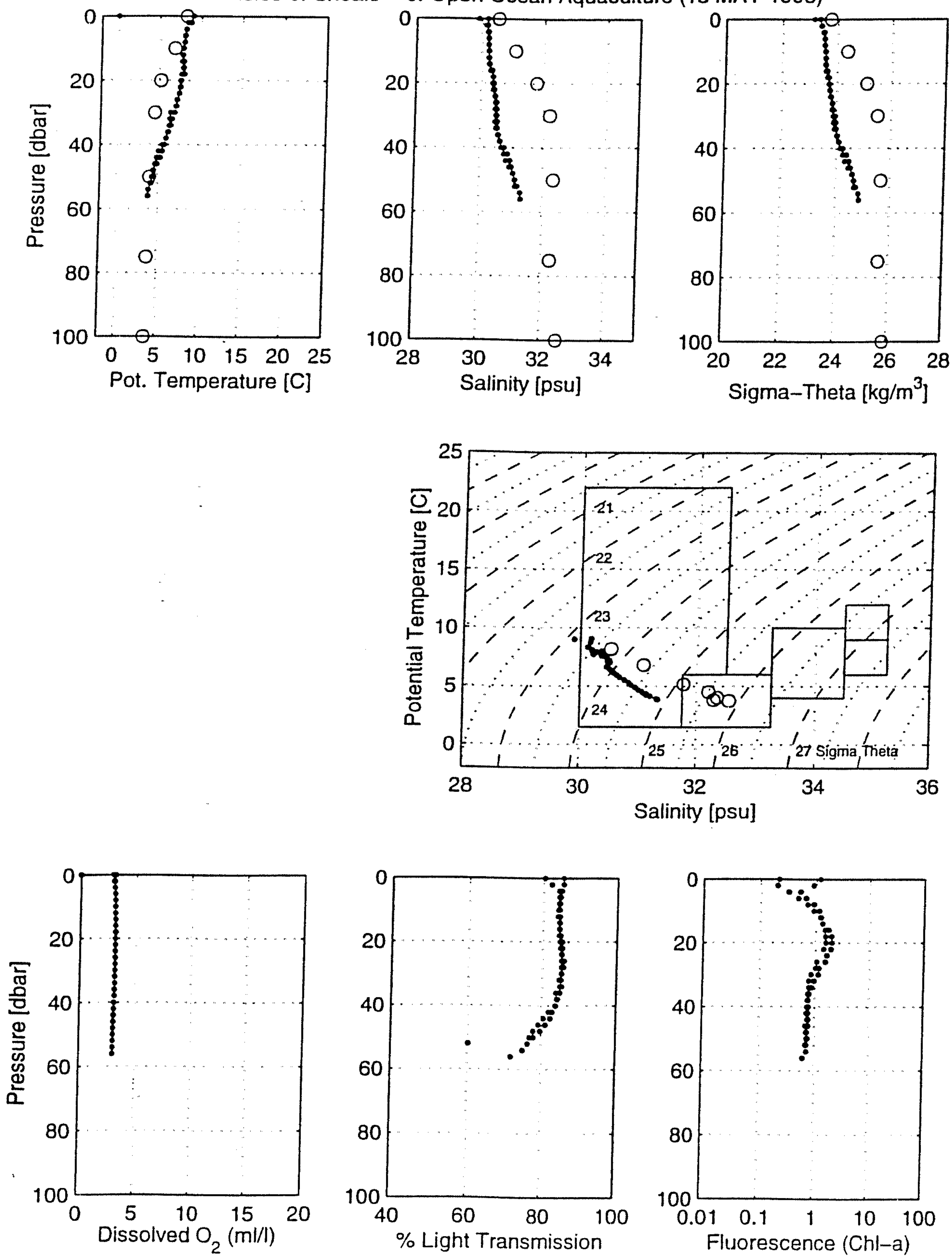


ooa0398 - Composite of 2 survey CTDs ('o' shows BIO area climatology for month)

MAR 98

Run: 12-Aug-1998@09:34

Isles of Shoals – 6: Open Ocean Aquaculture (15 MAY 1998)



ooa0598 – Composite of 2 survey CTDs ('o' shows BIO area climatology for month)

MAY 98

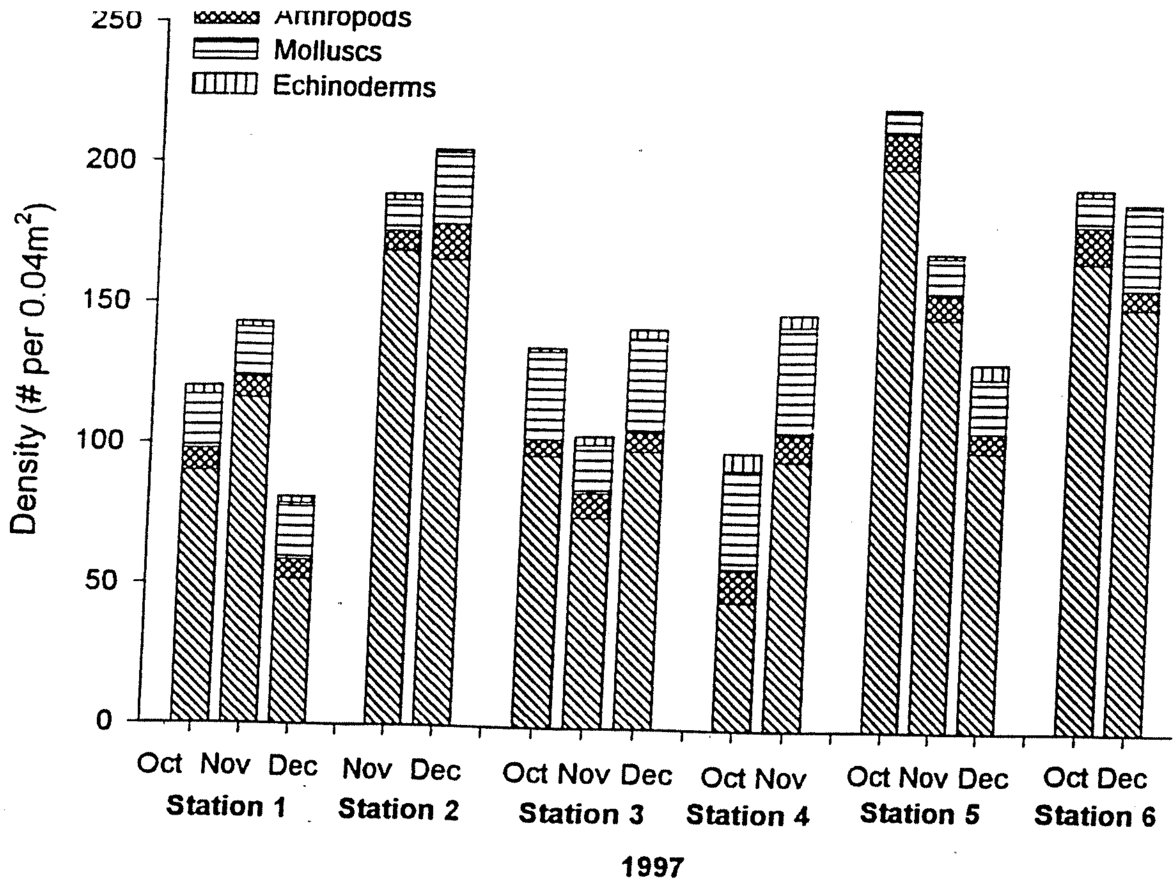
Run: 12–Aug–1998@09:35

Appendix B

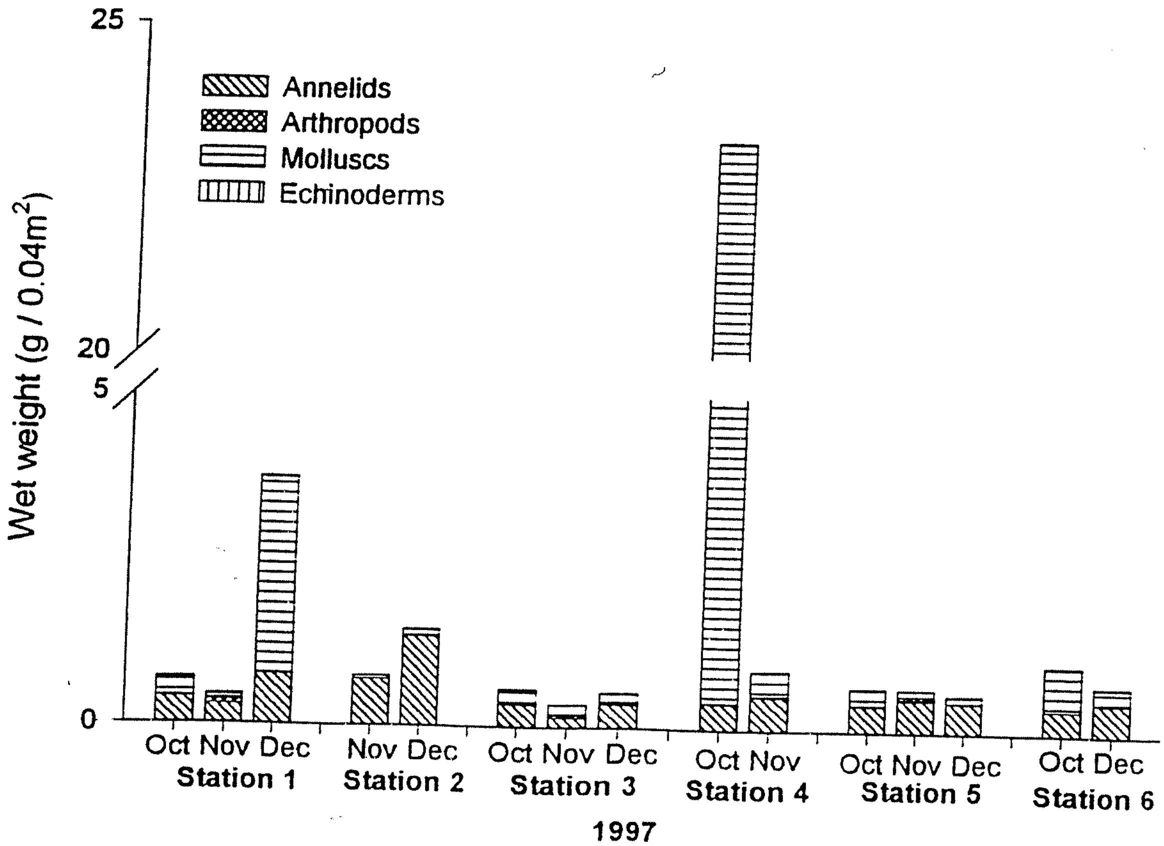
Discrete sample water quality data for the proposed aquaculture site

Appendix C

Infaunal benthic community at the proposed aquaculture site



APPENDIX C- Figure 1. Density of major groups of infaunal benthos



APPENDIX C- Figure 2. Wet weights major groups of infaunal benthos

Appendix D

Fish Species in the vicinity of the Isles of Shoals

Appendix E

Bottom Sediment textural analysis

Sample Collected	Sample Type	Station	Classification G/S/M	S/Z/C	%GSM	%SZC	MEAN	SORT	SKEW	KURT	% Moist	% LOI
4/1/98	Grab	4	muddy-sand (mS)	silty-sand (zS)	0/74/26	74/22/4	4.07	2.09	0.40	2.36	29.7	1.4
4/1/98	Grab	5	muddy-sand (mS)	silty-sand (zS)	0/73/27	73/19/8	4.37	2.18	0.53	2.32	34.0	1.9
5/1/98	Grab	1	muddy-sand (mS)	silty-sand (zS)	0/76/24	76/20/4	3.57	2.21	0.28	1.53	29.4	1.6
5/1/98	Grab	2	muddy-sand (mS)	muddy-sand (mS)	0/70/30	70/15/15	4.39	2.23	0.64	2.42	30.5	1.6
5/1/98	Grab	3	muddy-sand (mS)	muddy-sand (mS)	0/66/34	66/18/16	4.64	2.59	0.62	1.26	34.5	2.0
5/1/98	Grab	4	muddy-sand (mS)	silty-sand (zS)	0/75/25	75/18/7	3.82	2.35	0.37	2.00	33.9	1.8
5/1/98	Grab	5	muddy-sand (mS)	silty-sand (zS)	0/7030	70/22/8	4.18	2.30	0.61	1.18	34.3	1.9
6/26/98	Grab	1	muddy-sand (mS)	silty-sand (zS)	0/78/22	78/19/3	3.54	2.05	0.62	1.94	34.5	2.3
6/26/98	Grab	2	muddy-sand (mS)	silty-sand (zS)	0/78/22	78/18/4	3.87	2.18	0.63	2.22	36.8	2.3
6/26/98	Grab	3	muddy-sand (mS)	silty-sand (zS)	0/83/17	83/13/4	3.00	1.60	0.43	2.64	32.9	1.7
6/26/98	Grab	4	muddy-sand (mS)	silty-sand (zS)	0/81/19	81/14/5	3.37	1.80	0.56	2.47	33.6	1.9
6/26/98	Grab	5	muddy-sand (mS)	silty-sand (zS)	0/78/22	78/18/4	3.77	1.93	0.63	2.28	31.8	2.0
7/22/98	Grab	1	sand (S)	sand (S)	1/89/10	90/9/1	2.50	1.17	0.26	2.77	23.5	1.1
7/22/98	Grab	1a	muddy-sand (mS)	silty-sand (zS)	0/84/16	84/11/5	3.47	1.05	0.45	4.34	29.6	1.3
7/22/98	Grab	2	muddy-sand (mS)	silty-sand (zS)	3/82/15	85/14/1	2.97	1.72	-0.18	2.53	29.7	1.2
7/22/98	Grab	3	sandy-mud (sM)	sandy-silt (sZ)	0/42/58	42/52/6	4.70	2.19	0.02	0.99	73.7	4.8
7/22/98	Grab	4	No Sample Recovered After Two tries									
7/22/98	Grab	5	sandy-mud (sM)	sandy-silt (sZ)	3/47/50	50/46/4	4.47	2.03	0.13	0.77	45.8	3.9
7/22/98	Grab	6	muddy-sand (mS)	silty-sand (zS)	4/76/20	80/18/2	3.73	1.89	0.29	3.05	46.1	2.2
7/22/98	Grab	7	muddy-sand (mS)	silty-sand (zS)	0/78/22	79/19/2	3.80	1.28	0.53	3.10	32.1	1.5
7/22/98	Grab	8	No Sample Recovered After Two tries									

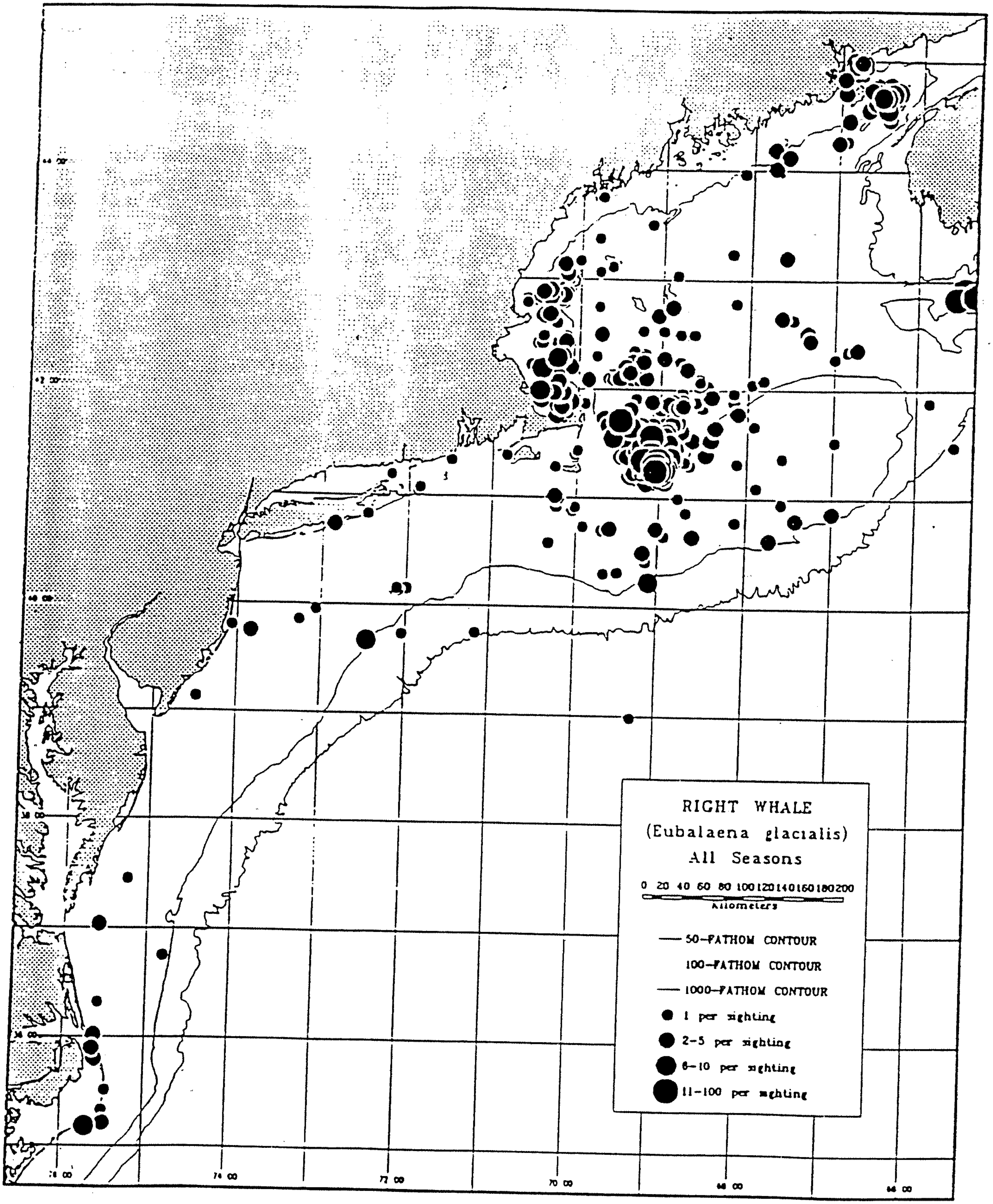


Figure F-1. A map showing the distribution of right whale sightings in the Gulf of Maine based on CeTAP/NMFS database for 1978 through 1985.

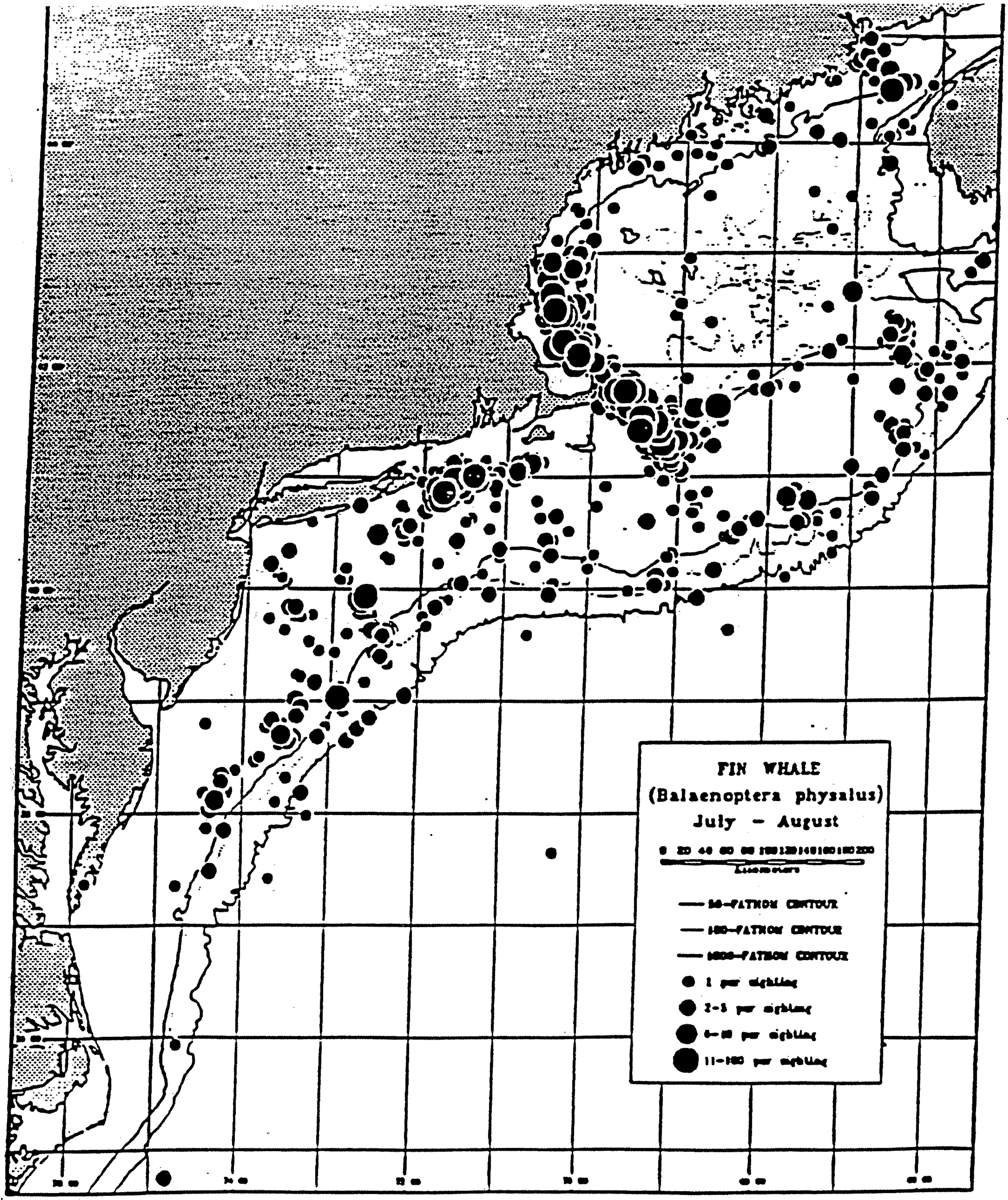


Figure F-3. A map showing the distribution of fin whale sightings during July and August in the Gulf of Maine based on CeTAP/NMFS database for 1978 through 1985.