North Atlantic Right Whale

(*Eubalaena glacialis*)

Source Document

for the Critical Habitat Designation:

A review of information pertaining to the definition of “critical habitat”

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1. Background

The Endangered Species Act (ESA or Act) requires the National Marine Fisheries Service (NMFS) to designate critical habitat for species listed under the Act as endangered or threatened, with limited exceptions. The purpose of this document is to present information documenting each of the specific determinations that we made in our rulemaking to designate new critical habitat for the North Atlantic right whale (*Eubalaena glacialis*).

The ESA defines an endangered species as any species in danger of extinction throughout all or a significant portion of its range, and a threatened species as any species likely to become endangered within the foreseeable future (Section 3). For species listed since 1978, the ESA requires designation of critical habitat unless it is determined that such a designation is not prudent or not determinable. Section 3(5)(A) of the ESA defines critical habitat as: (i) the specific areas within the geographical area occupied by the species, at the time it is listed...on which are found those physical or biological features (I) essential to the conservation of the species and (II) which may require special management considerations or protection; and (ii) specific areas outside the geographical area occupied by the species at the time it is listed…upon a determination by the Secretary that such areas are essential for the conservation of the species. Section 3 of the ESA defines the terms "conserve," "conserving," and "conservation" to mean "to use, and the use of, all methods and procedures which are necessary to bring any endangered species or threatened species to the point at which the measures provided pursuant to this chapter are no longer necessary. Such methods and procedures include, but are not limited to, all activities associated with scientific resources management such as research,

census, law enforcement, habitat acquisition and maintenance, propagation, live trapping, and transplantation, and, in the extraordinary case where population pressures within a given ecosystem cannot be otherwise relieved, may include regulated taking" (16 U.S.C. 1532(3)).

Listing and Critical Habitat Designation History for the North Atlantic Right Whale

In June 1970, all right whales were listed as endangered under the Endangered Species Conservation Act, the precursor to the Endangered Species Act (ESA)(35 FR 8495; codified at 50 CFR 17.11). Subsequently, when the ESA became law in 1973, right whales were included on the list of endangered species under that statute. At that time, there was no requirement in the ESA to designate critical habitat concurrent with the listing of species. Amendments to the Act in 1978 added the mandatory duty to designate critical habitat for species listed beginning in that year, and provided the Services with discretion to designate critical habitat for species listed prior to 1978. NMFS did not designate critical habitat for right whales at that time.

In 1990, NMFS was petitioned by the Right Whale Recovery Team to designate critical habitat for the Northern right whale. At that time, NMFS considered right whales in the North Atlantic and the North Pacific to be one species taxonomically, *Eubalaena glacialis*, with a common name of "Northern right whale." In 1994, NMFS published a final rule (59 FR 28793, June 3, 1994) designating two foraging areas in Cape Cod Bay and the Great South Channel, and one calving area in waters adjacent to the coasts of Georgia and the east coast of Florida as critical habitat for the Northern right whale in the North Atlantic Ocean.

In 2002, NMFS received a petition from the Ocean Conservancy requesting that the agency revise the critical habitat designation for Northern right whales. The petition specifically requested a reevaluation of the Cape Cod Bay and Great South Channel critical habitats. On August 28, 2003, NMFS denied the petition to revise critical habitat (65 FR 51758), although NMFS committed to continue analyzing available information on the physical and biological features essential to the conservation of right whales.

In 2006, NMFS published a comprehensive right whale status review (NMFS 2006) that concluded that recent genetic data provided unequivocal support to distinguish three right whale lineages (including the southern right whale) as separate phylogenetic species, based on the work of Rosenbaum et al. (2000). Rosenbaum et al. (2000) concluded that the right whale should be regarded as the following three separate species:

1. The North Atlantic right whale (*Eubalaena glacialis*) ranging in the North Atlantic Ocean;
2. The North Pacific right whale (*Eubalaena japonica*), ranging in the North Pacific Ocean; and;
3. The southern right whale (*Eubalaena australis*), historically ranging throughout the Southern Hemisphere's oceans.

Based on these findings, NMFS published proposed and final determinations listing right whales in the North Atlantic and North Pacific as separate endangered species under the ESA (71 FR 77704, December 27, 2006; 73 FR 12024, March 6, 2008). With the new listing determination, NMFS evaluated and designated critical habitat for the North

Pacific right whale (73 FR 19000, April 8, 2008). The 1994 designation of critical habitat for the Northern right whale analyzed and included only areas in the North Atlantic Ocean. The population of whales analyzed in the 1994 critical habitat designation was right whales in the North Atlantic Ocean. Since the biological basis and analysis for the 1994 critical habitat designation was based on the North Atlantic population of right whales, we believe that analysis and designation applies to the North Atlantic right whales as they were subsequently listed as a separate species in 2008. We, therefore, considered the 1994 designation legally valid and applicable until replaced by a subsequent designation. This document is part of the effort to replace the 1994 critical habitat with two new areas for the North Atlantic right whale. In the following discussion, NMFS summarizes the best available scientific information regarding the biology, distribution, and essential life history characteristics of North Atlantic right whales to support the new critical habitat designation.

2. Select Physical and Life History Characteristics of the North Atlantic Right Whale

The North Atlantic right whale is a member of the family Balaenidae and is closely related to the right whale species that inhabit the North Pacific Ocean and the Southern Hemisphere. Right whales are large baleen whales that grow to lengths and weights exceeding 15 meters and 70 tons, respectively. Females are typically larger than males. The distinguishing features of right whales include a stocky body, generally black coloration (although some individuals have white patches on their undersides), lack of a dorsal fin, large head (about 1/4 of the body length), strongly bowed margin of the lower lip, and raised callus-like patches of skin on the head region called callosities. Callosities are colonized by amphipod crustaceans (cyamids nicknamed “whale lice”; *Cyamus* sp.)

which give them a white appearance. Two rows of long (up to about eight feet in length) baleen plates hang from the upper jaw with about 225 plates on each side. The tail is broad, deeply notched, and all black with a smooth trailing edge. Right whales attain sexual maturity at an average age of 8–10 years, and females produce a single calf at intervals of 3 to 5 years (Kraus et al. 2001). Their life expectancy is unclear, but individuals have been known to reach 70 years of age (Hamilton et al. 1998a, Kenney 2002).

Historically, right whale species inhabited all the world's oceans from temperate to subpolar latitudes before they were severely depleted by commercial whaling (Perry et al. 1999). Right whales primarily inhabit coastal or shelf waters, although movements over deep waters are known to occur. They are migratory, with at least a portion of the population moving between summer feeding grounds in temperate or high latitudes and winter calving areas in warmer waters, though during winter the whereabouts of a portion of the population remain unknown (Kraus et al. 1986, Clapham et al. 2004).

The International Whaling Commission (IWC) recognizes two right whale populations in the North Atlantic: a western and eastern population (IWC 1986). The current known distribution and migration patterns of North Atlantic right whales are largely limited to the western North Atlantic Ocean (i.e., Florida to Canada). The current abundance, distribution, and migration pattern are unknown for eastern North Atlantic right whales because of a lack of recent sightings. Based on historical whaling records, it appears that the eastern population may have migrated from northern Europe to northwestern Africa. Best et al. (2001) estimated that the eastern North Atlantic population probably numbers only in the low tens of animals at best, and may be functionally extinct. Following

periods of historical whaling in the Bay of Biscay, Cintra Bay, coastal Iceland, and the British Isles, right whales have been sighted only sporadically in eastern North Atlantic coastal waters (NMFS 2005). Between 1935 and 1985 there were only 21 possible sightings in the eastern North Atlantic, totaling 45 individuals (Brown, 1986). Furthermore, Brown (1986) considered only five of these sightings (seven individual whales) to be confirmed.

The western North Atlantic population size is estimated to be at least 465 individuals in 2011, based on a census of individual whales identified using photo-identification techniques (Waring et al. 2015). Due to past depletion from which they have not recovered, the continued anthropogenic threats to the species, and the whale's life history, the North Atlantic right whale is in danger of extinction throughout its range.

Knowlton et al. (1994) reported that the population growth rate of North Atlantic right whales for the period 1986-1992 was 2.5% (CV=0.12), suggesting that the stock was showing signs of slow recovery. Caswell et al. (1999) suggested that crude survival probability declined from about 0.99 in the early 1980s to about 0.94 in the late 1990s. The decline in survival probability was statistically significant (Waring et al. 2009). Additional work conducted in 1999 was reviewed by the IWC workshop on status and trends in this population (Best et al. 2001). The IWC workshop concluded based on several analytical approaches that survival had indeed declined in the 1990s (Best et al. 2001). In September 2002, NMFS convened another workshop that reached similar conclusions regarding the decline in the population (Clapham 2002). Recent mortalities, including those in the first half of 2005, suggest an increase in the annual mortality rate (Kraus et al. 2005, Glass et al. 2009). Calculations based on demographic data through

1999 (Fujiwara and Caswell 2001) indicated that this mortality rate increase would reduce population growth by approximately 10% per year (Kraus et al. 2005). These analyses, however, focused on changes in survival (or mortality) rates but did not directly address changes in population size.

Waring et al. (2013) reported that the minimum number alive population index (calculated from the individual sightings database as it existed on 21 October 2011) for the years 1990-2009 suggested a positive and slowly accelerating trend in population size. These data revealed a significant positive trend in the number of catalogued whales alive during this period (a geometric mean growth rate of 2.6%), but with significant interannual variation due to apparent losses exceeding gains during 1998-1999. Because the right whale is a long-lived species, extinction may not occur in the near future. However, given this population has not recovered from commercial whaling, the existence of anthropogenic threats (i.e., ship strikes, fishing gear entanglement), and the whale's life history, the North Atlantic right whale is in danger of extinction throughout its range (NMFS 2006).

3. Conservation of North Atlantic Right Whales

The ESA definition of critical habitat focuses in part on those physical or biological features within the geographical area occupied by a species that are essential to the conservation of the species. In addition, areas outside of the occupied geographical area may be designated as critical habitat if those areas are determined to be essential to the conservation of the species. The purpose of this section is to explain what the conservation of North Atlantic right whales means, in order to support subsequent

findings regarding whether habitat features and unoccupied areas are essential to the conservation of the species.

For right whales, conservation is the use of all methods and procedures necessary to bring right whales to the point at which factors related to population ecology and vital rates indicate that the population, first, may be downlisted to threatened, and, ultimately, may be delisted because it is no longer in danger of extinction throughout all or a significant portion of its range. Important factors related to right whale population ecology and vital rates include population size and trend, range, distribution, age structure, sex ratios, age-specific survival, age-specific reproduction, and lifetime reproductive success. The North Atlantic Right Whale Recovery Plan (as revised in 2005) identifies the following criteria that, when met, will indicate the species may be reclassified to threatened:

1) The population ecology (range, distribution, age structure, and sex ratios, etc.) and vital rates (age-specific survival, age-specific reproduction, and lifetime reproductive success) of right whales are indicative of an increasing population;
2) The population has increased for a period of 35 years at an average rate of increase equal to or greater than 2% per year;
3) None of the known threats to North Atlantic right whales (corresponding to the five ESA listing factors) are known to limit the population's growth rate; and
4) Given current and projected threats and environmental conditions, the right whale population has no more than a 1% chance of extinction in 100 years.

The Right Whale Recovery Plan states that it is not possible at this point in time to propose delisting criteria related to these factors that must be met for NMFS to delist the species (NMFS 2005).

The Recovery Plan also identifies five major objectives designed to increase population size and vital rates so that North Atlantic right whales may be reclassified to threatened. These objectives include significantly reducing sources of human-caused death, injury and disturbance; developing demographically-based recovery criteria; identifying, characterizing, protecting, and monitoring important habitats; monitoring the status and trends of abundance and distribution of the North Atlantic population; and coordinating federal, state, local, international, and private efforts to implement the Recovery Plan.

The Recovery Plan states that reducing direct and indirect threats to right whale habitat is integral to recovery (NMFS 2005). The Recovery Plan notes that information is needed on the environmental factors that influence right whale occurrence and distribution. While information gaps need to be filled, significant information already exists regarding features characterizing vital feeding habitats and calving/nursery areas. Furthermore, there is information indicating a correlation between feeding and reproductive success demonstrating that protecting features of foraging habitat is essential to the initial conservation objective of achieving increasing population growth rates and population size.

Right whales feed almost exclusively on copepods, a type of zooplankton. Of the different kinds of copepods, North Atlantic right whales feed especially on late developmental life stages of *Calanus finmarchicus*, a large calanoid copepod

(Baumgartner et al. 2007). Because a right whale's mass is so immensely larger than that of its prey (late stage *C. finmarchicus* is approximately the size of a small grain of rice), right whales are very specialized and restricted in their habitat requirements – they must locate and exploit feeding areas where copepods are concentrated into high-density patches.

Efficient feeding on prey with high nutritional value is essential to the conservation of the North Atlantic right whale. Efficient feeding is not only important to meet the day-to-day caloric needs of individual right whales, but is important to achieve the overall goal of conservation because of the apparent correlation between the abundance and caloric richness of copepods and the calving rates for right whales (Pace and Merrick 2008).

The only known calving area for North Atlantic right whales is off the coast of the southeastern United States (U.S.) (Kraus et al. 1986, Knowlton et al. 1994, Reeves et al. 2001). Recent aerial survey data indicate calving and nursing occurs from the coasts of northeastern Florida and southeastern Georgia to as far north as North Carolina (e.g., Good 2008, Waring et al. 2007). Calving right whales typically arrive in this region during mid to late November and early December after migrating south from feeding grounds in the northeastern U.S. and Canada. Mothers and newborn calves reside within this region through early March, and they generally depart the calving grounds by the end of March and early April (Reeves et al. 2001).

Recovery of North Atlantic right whales depends on an increase in population size, which in turn depends on successful reproduction and the survival of calves to sexual maturity (NMFS 2005). Survival and reproduction rates must occur at levels sufficient to result in

positive population growth while accounting for natural and anthropogenic mortality. Conservation of right whales in the North Atlantic, therefore, includes at minimum identification and protection of habitat features characterizing feeding areas and calving/nursery areas, not only to help ensure right whales meet their individual caloric needs, but also to support reproductive success necessary to increase the population size.

4. Geographical Area Occupied by the Species

Designation of critical habitat first requires identification of the geographical area occupied by the species at the time of its listing. NMFS has long interpreted ''geographical area occupied'' in the definition of critical habitat to mean the range of the species at the time of listing (45 FR 13011; February 27, 1980).

Historically, North Atlantic right whales resided throughout the temperate, subarctic, coastal, and continental shelf waters of the North Atlantic Ocean (Perry et al. 1999).[1] The current known distribution and migration patterns of North Atlantic right whales are largely limited to the western North Atlantic Ocean. In the western North Atlantic, right whales range from calving grounds in coastal waters of the southeastern U.S. to feeding grounds in New England waters and northward to the Bay of Fundy, the Gulf of St. Lawrence, and the Scotian Shelf (Waring et al. 2013).

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[1] The International Whaling Commission (IWC) recognizes two right whale populations in the North Atlantic: a western and eastern population (IWC, 1986). As discussed, the current abundance, distribution and migration patterns are unknown for eastern North Atlantic right whales based on a lack of sighting information. Best et al. (2001) notes that sighting surveys from the eastern Atlantic Ocean suggests that right whales in this region are currently rare and may be functionally extinct.

During winter, North Atlantic right whales occur along the southeastern U.S. coast of northern Florida and Georgia and northward to the Gulf of Maine (Kraus et al. 1986, Knowlton et al. 1994, Reeves et al. 2001). Waters off the southeastern U.S. are the only known calving area for the North Atlantic right whale, and nearly all mothers with calves (i.e., mother-calf pairs) observed in the northern feeding grounds in summer have also been sighted in the southeastern U.S. during the winter. However, not all reproductively active females return to the calving grounds each year (Kraus et al. 1986, Payne 1986).

Aerial surveys conducted off the coast of North Carolina during the winters of 2001 and 2002 sighted 8 calves, suggesting the calving grounds may extend as far north as Cape Fear, NC (33.8N, 78.0W) (Waring et al. 2009). In recent years, surveys flown in the area just north of Brunswick, Georgia (31°53' N latitude), to just south of St. Augustine, Florida (29°78' N latitude) documented a growing number of non-calving right whales using the area for varying amounts of time (e.g., individual adult males are typically observed only a few times by aerial survey teams suggesting these animals do not reside long in the calving area).

New England and Nova Scotian waters are a primary feeding habitat for right whales during the late winter, spring, summer, and fall. Right whales feed primarily on copepods (largely of the genera *Calanus*). Research indicates that right whales must locate and exploit extremely dense patches of zooplankton to feed efficiently (Mayo and Marx 1990). These dense zooplankton patches are a primary characteristic of the spring, summer, and fall right whale habitats (Kenney et al. 1986, 1995). Variation in the abundance and development of suitable food patches appears to modify the general patterns of right whale movement by reducing peak numbers, stay durations and specific

locales (Brown et al. 2001, Kenny et al. 2001). In particular, large changes in the typical pattern of food abundance can dramatically change the general pattern of right whale habitat use (Kenny et al. 2001, Baumgartner 2001).

In New England, peak abundance of feeding right whales occurs in Cape Cod Bay, usually beginning in late winter. In early spring (May), peak right whale abundance occurs in Wilkinson Basin to the Great South Channel (Kenney et al. 1995). In late June and July, right whale distribution gradually shifts to the Northern Edge of Georges Bank. In summer and fall, much of the population is found in the Bay of Fundy and around Roseway Basin (Winn et al. 1986, Kenney et al. 1995, Kenney et al. 2001). In December 2008, NOAA researchers sighted a relatively large number (44) of right whales in the Jordan Basin area during an aerial survey of the region. More recently, in April 2010, NMFS researchers sighted nearly 100 right whales in Rhode Island Sound south of the Gulf of Maine and Georges Bank region.

Right whales are migratory, with at least a portion of the population moving between summer feeding grounds in temperate or high latitudes and winter calving areas in warmer waters, though during winter the location of much of the population is unknown. North Atlantic right whales occur primarily in coastal or shelf waters, although movements over deep waters are known to occur. Telemetry data have shown rather lengthy and somewhat distant excursions, including into deep water off the continental shelf (Mate et al. 1997). Right whales have been observed from the Mid-Atlantic Bight northward through the Gulf of Maine (GoM) during all months of the year.

Knowlton et al. (1992) reported several long-distance movements as far north as Newfoundland, the Labrador Basin, and southeast of Greenland. In addition, recent resightings of photographically identified individuals have been made off Iceland, arctic Norway and in the old Cape Farewell whaling ground east of Greenland. The Norwegian sighting (in September 1999) represents one of only two published sightings this century of a right whale in Norwegian waters, and the first since 1926.

More recently, scientists from NOAA's Pacific Marine Environmental Laboratory, NOAA's National Marine Mammal Laboratory and Oregon State University reported that they had recorded right whale calls in an area 200 to 400 miles off the coast of Greenland. In 2007, this team of scientists deployed five stationary hydrophones to continuously record sounds for a year in the Cape Farewell Ground, an area off the southern tip of Greenland. The hydrophones were collected a year later in July 2008. These researchers identified more than 2,000 right whale calls. All of the calls occurred between July and December, with evidence between July and September of a north-south migration (Mellinger et al. 2011).

In January 2009, a North Atlantic right whale was observed off the Azores by biologists from the University of the Azores Department of Oceanography and Fisheries as well as by a biologist from Whale Watch Azores. This was the first confirmed sighting of a right whale in the Azores since 1888. In September 2009, this same whale was sighted in a surface active group in the Bay of Fundy.

Right whales have also been rarely observed in the Gulf of Mexico. The few published sightings (Moore and Clark 1963, Schmidly and Melcher 1974, Ward Geiger et al. 2011)

represent either geographic anomalies or a more extensive historic range beyond the sole known calving and wintering ground in the waters of the southeastern U.S. (Waring et al. 2009). Therefore, the Gulf of Mexico is not considered part of "the geographical area occupied…at the time it is listed."

In conclusion, the geographical area occupied by the North Atlantic right whale at the time it was listed (i.e., 2008) includes the U.S. waters of the North Atlantic from Florida to the Gulf of Maine, northward to the Bay of Fundy, the Gulf of St. Lawrence and the Scotian shelf, extending to the waters of Greenland and Iceland (and possibly beyond). While right whales have been sighted in the waters off Norway and the Azores, and in the Gulf of Mexico, the reports of animals in these areas are rare and may be related to what was once the historic range of the species. Without additional sightings beyond the few, sporadic recordings of individuals in those areas, we do not consider those areas to be part of the species' range. Therefore, these areas are not considered to be part of the "the geographical area occupied…at the time it is listed."

5. Physical and Biological Features Essential to the Conservation of North Atlantic Right Whales

In the geographical area occupied by the species, critical habitat consists of specific areas on which are found those physical or biological features that are essential to the conservation of a given species ("essential features") and that may require special management considerations or protections (ESA section 3(5)(A)(i)). Such requirements include, but are not limited to the following: (1) space for individual and population growth and for normal behavior; (2) food, water, air, light, minerals, or other nutritional or physiological requirements; (3) cover or shelter; (4) sites for breeding, reproduction,

and rearing of offspring; (5) and habitats that are protected from disturbance or are representative of the historical geographical and ecological distribution of a species (50 CFR 424.12(b)).

NMFS has identified several biological behaviors that are critical to the overarching recovery objectives of increased survival and population growth of the North Atlantic right whale, some of which appear to be linked to highly specific areas within their range. These include: (1) feeding, which occurs in New England waters and north to the Bay of Fundy and the Scotian Shelf; (2) calving, which occurs in the coastal waters of the southeastern U.S.; (3) migration between the calving area in the southeastern U.S. and feeding habitats in the northeastern U.S.; and (4) breeding. We evaluated whether there are physical and biological features of the habitat areas used for these behaviors that are essential to the species' conservation because they facilitate or are intimately tied to the behaviors.

5.1 The Physical and Biological Features of Foraging Habitat that are Essential to the Conservation of the Species

The features characteristic of right whale foraging habitat that are essential to the conservation of the North Atlantic right whale are a combination of both physical and biological oceanographic features:

(1) The physical oceanographic conditions and structures of the Gulf of Maine (GOM) and Georges Bank region that combine to distribute and aggregate *C. finmarchicus* for right whale foraging, namely prevailing currents and

circulation patterns, bathymetric features (basins, banks, and channels), oceanic fronts, density gradients, and temperature regimes;

(2) Low flow velocities in Jordan, Wilkinson, and Georges Basins that allow diapausing *C. finmarchicus* to aggregate passively below the convective layer so that the copepods are retained in the basins;

(3) Late stage *C. finmarchicus* in dense aggregations in the Gulf of Maine and Georges Bank region; and

(4) Diapausing *C. finmarchicus* in aggregations in the Gulf of Maine and Georges Bank region.

Right Whale Energetic Requirements

For much of the year, the right whale's distribution is strongly correlated to the distribution of their prey. Right whales feed primarily on copepods (largely of the genera *Calanus*). Research indicates that right whales must locate and exploit extremely dense patches of zooplankton to feed efficiently (Mayo and Marx 1990). These dense zooplankton patches are a primary characteristic of the spring, summer, and fall right whale habitats (Kenney et al. 1986, 1995). Variation in the abundance and development of suitable food patches appears to modify the general patterns of right whale movement by reducing peak numbers, stay durations, and specific locales (Brown et al. 2001, Kenney et al. 2001). In particular, large changes in the typical pattern of food abundance

can dramatically change the general pattern of right whale habitat use (Kenney et al. 2001, Baumgartner 2001).

Right whale distribution in the Gulf of Maine is largely controlled by zooplankton distribution (Mayo et al. 2004, Singer and Ludwig 2005). Right whales prey primarily on zooplankton, specifically the later juvenile stages (copepodites) of a species of copepod, *C. finmarchicus* (Baumgartner et al. 2007). *C. finmarchicus* is the dominant copepod in the Gulf of Maine. During the copepodite states (C1-5), *C. finmarchicus* develops an oil sac which, by stage C5, has reached its maximum size, comprising up to 50 percent of its body volume (Miller et al. 2000 in Baumgartner et al. 2009).

The right whale's life history and reproductive strategies create very high energetic demands. The combination of the physical and biological features identified above promote efficient feeding on prey with high nutritional value to support right whale life history and reproductive strategies and, therefore, are essential to the conservation of North Atlantic right whales. If food is not available at the necessary densities or nutritional value, then right whales would be unable to obtain sufficient energy to successfully complete their long migrations, reproduce, and/or (for lactating females) successfully rear their progeny. When compared to other copepods, *C. finmarchicus* has a much larger biomass and higher caloric content (Baumgartner et al. 2007). *C. finmarchicus* populations found near feeding right whales typically have a higher percentage of older stage *C. finmarchicus* (C4 and older) compared to areas where whales are not present (Baumgartner et al. 2003a, Baumgartner and Mate 2005, Watkins and Schevill 1976, Mayo and Marx 1990, Wishner et al. 1995). Wishner et al. (1995) found that while total water column biomass and *C. finmarchicus* abundance did not always

differ between locations near feeding whales and sites without whales, higher proportions of older copepod life stages were found in locations close to feeding right whales.

Late stage *C. finmarchicus*, especially C5, contain high lipid content (i.e., oil sacs) and are therefore the most energetically rich zooplankton prey source available to right whales. If sufficient densities of late stage copepods become unavailable to feeding right whales, it is uncertain if the remaining developmental stages of *C. finmarchicus* and other prey species[2] (independent of abundance) could provide right whales with the required energetic densities to meet their metabolic and reproductive demands (Kenney et al. 1986, Payne et al. 1990). By focusing their foraging efforts on the energetically rich late stage *C. finmarchicus*, right whales are able to maximize their energy intake.

Kenney et al. (1986) estimated the minimum caloric intake required by a right whale, using standard mammalian metabolic models. Not only must right whales meet their basal (i.e., resting) metabolic needs but they must obtain an energy surplus in the long-term (Brodie 1975, Sameoto 1983, Kenney et al. 1986, Kenney and Wishner 1995). Using estimates of mouth opening area, swimming speed, and daily foraging time, Kenney's model suggests an average 40 ton right whale's basal energetic requirements

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[2] Baumgartner et al. (2007) note that right whales cannot efficiently filter feed on the smaller larval stages (i.e., nauplii) and early copepodite stages of *C. finmarchicus*. In addition, right whales do not feed exclusively on *C. finmarchicus.* Researchers have documented right whales foraging on the copepods *Pseudocalanus* and *Centropages typicus* as well as barnacle larvae (Mayo and Marx 1990 in Baumgartner et al. 2007). These observers noted, however that right whales quickly ceased foraging on these zooplankton assemblages indicating that the prey was likely not suitable (Baumgartner et al. 2007).

range from 7.57 to 2,394 kcal/m^3 or a concentration of 4.67 x 10^3 to 1.48 x 10^6 m^{-3} stage C5 *C. finmarchicus* (Kenney et al. 1986).[3]

In order to maximize their caloric intake, right whales must target dense layers containing large, energetically rich prey (Wishner et al. 1995). Baumgartner et al. (2003b) found a correlation between right whale diving depths and depth of maximum stage C5 *C. finmarchicus* abundances in Grand Manan Basin in the lower Bay of Fundy. This provides further evidence that right whales seek out aggregations of late stage C5 *C. finmarchicus* life stages rather than simply the densest aggregations (Wishner et al. 1995).

North Atlantic Right Whale Calving Rates Related to Prey Availability

An examination of right whale calving rates provides additional evidence of the importance of dense aggregations of late stage *C. finmarchicus* to the conservation of the species. Female right whales need adequate nutritional resources to meet the physical demands of gestation and lactation (Kraus et al. 2007). As the principal prey source of

[3] This model's estimation exceeded the densities of copepods found in the Great South Channel among feeding right whales during the Cetacean and Turtle Assessment Program (CETAP) (1982), despite not accounting for increased energetic demands caused by growth, reproduction, lactation, or processing food. These results are not necessarily indicative of a right whale food shortage in the Gulf of Maine. Instead it may be that right whales are able to selectively detect prey patches of significant density and quality in dimensions that plankton sampling methods have been unable to capture. Where many plankton sampling programs, such as Marine Resources Monitoring, Assessment, and Prediction (MARMAP) program and South Channel Ocean Productivity Experiment (SCOPEX), have focused on integrated plankton densities over the entire water column, realistically it is the subtle distributions of *C. finmarchicus* at spatial scales in the tens of centimeters to meters in the vertical and tens to hundreds of meters in the horizontal that are most likely relevant to right whales (Baumgartner and Mate 2003).

right whales, *C. finmarchicus* abundance may play a key role in determining conditions favorable for right whale reproduction (Greene and Pershing 2004).

Kenney et al. (2001) suggested that variability in prey abundance may affect the reproductive success of the species. Research has correlated *C. finmarchicus* abundance to right whale calving rates. Greene et al. (2003) linked right whale calving rates to changes in the North Atlantic Oscillation (NAO) and concurrent changes in the abundance of *C. finmarchichus* (Figure 1). Greene et al. (2003) hypothesized that impacts to right whales due to climate variability is primarily related to changes in *C. finmarchicus* populations. To explore this hypothesis, Greene et al. (2003) examined right whale calving rate patterns since the early 1980s. These researchers found that major multi-year declines in right whale calving rates have tracked major multi-year declines in *C. finmarchicus* abundance since 1982.

Greene et al. (2003) found that calving rates were relatively stable from 1982 to 1992, with a mean rate of 12.4 ± 0.9 (standard error (SE)) calves per year. These researchers note that the stable calving rates were consistent with the relatively high abundance of *C. finmarchicus* observed during the 1980s. From 1993 to 2001, right whale calving rates exhibited two major, multi-year declines, with the mean rate dropping and becoming much more variable at 11.2 ± 2.7 (SE) calves per year. Greene et al. (2003) found that these declines coincided with the two precipitous drops in *C. finmarchicus* abundance observed during the early and late 1990s.

This research demonstrates the importance of adequate food availability to right whale reproductive success and the effect that large scale climatological and oceanographic

factors may have on *C. finmarchicus* abundance in the GoM region. Climate-driven changes in ocean circulation over the past 40 years have had a profound impact on the plankton ecology in the GoM (Greene et al. 2003). It has been hypothesized that a reduction in the abundance of prey due to changes in oceanographic mechanisms responsible for concentrating dense aggregations of copepods and/or competition with planktivorous fish species could affect right whale reproduction (Kraus et al. 2007).

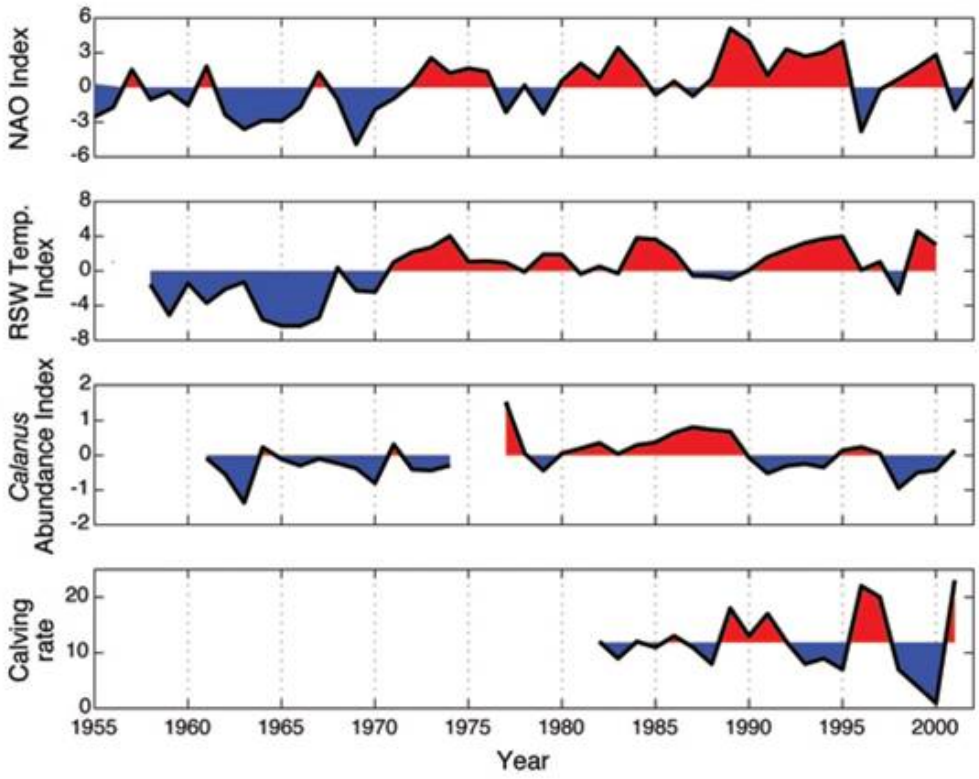

Figure 1 Right whale reproduction, *C. finmarchicus* population and North Atlantic Oscillation (NAO) Index (Source: Greene and Pershing 2004).

Physical Oceanographic features characteristic of right whale foraging habitat

As discussed in detail below, the physical features characteristic of right whale foraging habitat are:

- The physical oceanographic conditions and structures of the Gulf of Maine and Georges Bank region that combine to distribute and aggregate *C. finmarchicus* for right whale foraging, namely prevailing currents and circulation patterns, bathymetric features (basins, banks, and channels), oceanic fronts, density gradients, and temperature regimes; and
- Low flow velocities in Jordan, Wilkinson and Georges Basins that allow diapausing *C. finmarchicus* to aggregate passively below the convective layer so that the copepods are retained within the basins.

The GoM and Western Scotian Shelf region presents right whales with a highly variable feeding environment (Greene et al. 2003). This region lies within an oceanographic transition zone, located between cold subpolar waters influenced by fluctuations in the Labrador Current to the northeast and warm temperate waters influenced by fluctuations in the Gulf Stream to the south (MERCINA, 2001, Greene et al. 2003). Within the GoM, right whale foraging activities are concentrated in areas where physical oceanographic conditions and structures, namely prevailing currents and circulation patterns, bathymetric features (basins, banks, and channels), oceanic fronts, density gradients, and temperature regimes operate to concentrate copepods (Wishner et al. 1988, Mayo and Marx 1990, Murison and Gaskin 1989, Baumgartner et al. 2003b, Jiang et al. 2007, Pace and Merrick 2008).

The GoM is a large semi-enclosed basin along the northeast coast of the U.S. The GoM is bounded by the coasts of Maine and New Hampshire, as well as Massachusetts from Cape Cod northward. To the north, the GoM is bounded by the coastlines of New Brunswick and Nova Scotia, Canada. The GoM includes Massachusetts and Cape Cod Bays, and the Bay of Fundy (Figure 2).

The waters of the GoM are isolated from the Northwest Atlantic Ocean by Georges and Browns Banks and Nantucket Shoals. These banks are relatively shallow with average depth ranges between 20 and 60 m, with some areas as shallow as 5 m. Georges Bank in particular acts to separate the GoM waters from the warmer Gulf Stream waters. The Northeast Channel (NEC) and Great South Channel (GSC) connect the GoM to the waters of the Northwest Atlantic.[4] The bathymetry of the central GoM is dominated by three large, deep basins: Jordan and Georges Basins to the northeast and east respectively and Wilkinson Basin in the southwest. The best available evidence indicates that these deep water basins serve as refugia habitat for diapausing copepods[5], and that these diapausing copepods serve as source populations for the annual recruitment of copepods

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4 The NEC is a 230-m deep channel situated between the eastern edge of Georges Bank and Browns Bank connecting the GoM with the deeper waters of the Atlantic Ocean. The Southeast Channel, a secondary, shallower connection to the Atlantic, is located between Nantucket Shoals and the western edge of Georges Bank and is only about 75 m deep.

5 The life history of *C. finmarchicus* includes a period immediately prior to adulthood called diapause during which copepods cease development and enter a prolonged dormant resting phase (Baumgartner et al. 2007).

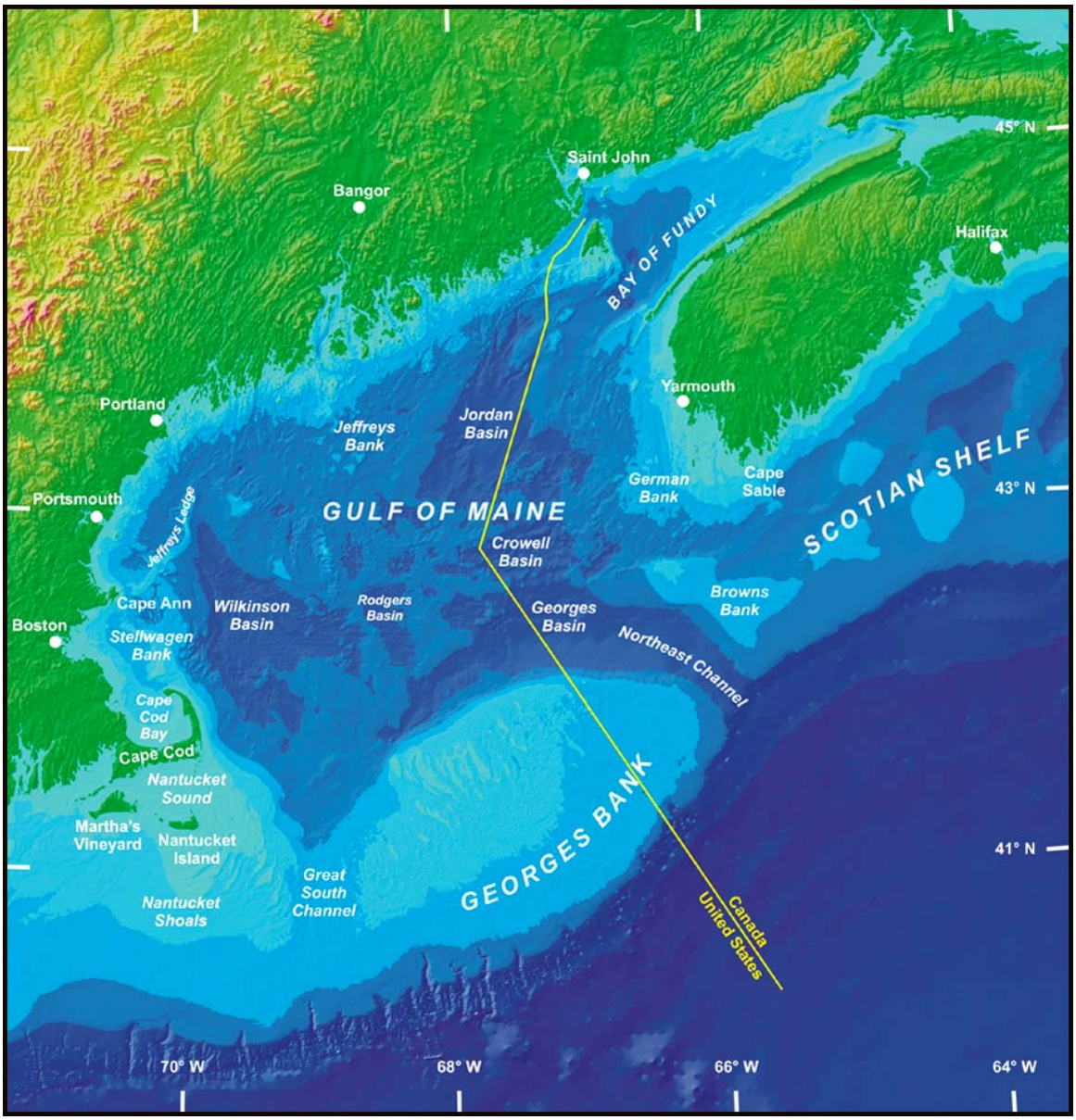

Figure 2: Gulf of Maine and Georges Bank Region (Source: Gulf of Maine Research Institute).

to the GoM population (Davis 1987, Meise and O'Reiley 1996, Lynch et al. 1998, Johnson et al. 2006).

The GoM has a complex and highly variable circulation regime due to varying inflow of Atlantic Ocean water, interactions between the eastern and western Maine coastal currents, freshwater inflow and temperature fluctuation. The oceanographic features of the GoM are very dynamic, with strong currents, sharp frontal gradients and high mixing rates. The GoM circulation is strongly influenced by its topography, with counterclockwise flow over Georges, Jordan and Wilkinson Basins and clockwise circulation over Georges and Brown Banks and Nantucket Shoals (Smith 1989, Brown and Irish 1992, Bisgani and Pettigrew 1994). These physical features have a large effect on the distribution, abundance and population dynamics of zooplankton populations within the GoM (Durbin 1997).

Major oceanographic features in the Gulf of Maine and Georges Bank include the Maine Coastal Current (MCC), Georges Bank anti-cyclonic frontal circulation system, the basin-scale cyclonic gyres (Jordan, Georges and Wilkinson), the deep inflow through the NEC, the shallow outflow via the Great South Channel and the shelf-slope front (SSF) (Gangopadhyay et al. 2003, Pace and Merrick 2008). These features create the conditions that disperse, concentrate and retain copepods within the GoM. The prevailing oceanographic structures and conditions also create low energy environments within several of the deep ocean basins located within the GoM.

Water from the Northwest Atlantic Ocean enters the GoM over the Scotian Shelf and through the deep NEC where it forms a general counterclockwise circulation pattern. These slope waters entering the GoM from the Scotian Shelf are believed to transport considerable numbers of developing copepodites originating from both the Gulf of St.

Lawrence and the Scotian Shelf (Plourde and Runge 1993, Greene and Pershing 2000, Conversi et al. 2001, Pace and Merrick 2008). Within the GoM several smaller scale circulation patterns form over oceanographic features including some of the deep water basins. Some of this water exits the GoM through the Great South Channel, while some continues to the northwest where it flows onto Georges Bank in a clockwise circulation gyre (Chen et al. 1995, Durbin 1997) (Figure 3).

Due to the strong influence of the Labrador Current, the water of the GoM is significantly colder and more nutrient-rich than waters to the south. This relatively fresh, cold water flows to the northeast around the southern end of Nova Scotia, across the mouth of the Bay of Fundy and then flows southward. This water helps drive the MCC (Brooks 1985, Durbin 1997). The cold water inflow from the Nova Scotian Shelf and the Northeast Channel helps drive the primarily counterclockwise circulation of the Gulf, propelling the MCC in a southwesterly direction (Brooks 1985, Durbin 1997). The MCC has two major components, the Eastern Maine Coastal Current (EMCC) off Maine's east coast and the Western Maine Coastal Current (WMCC) off the coasts of western Maine, New Hampshire and Massachusetts. These currents are influenced by fluctuations in river outflow, often enhanced during spring runoff. Lower salinity surface water from spring runoff carried into this region by the MCC can cause strong stratification and increase the rate of horizontal transport, therefore having an impact on the abundance, distribution and population dynamics of the GoM's *C. finmarchicus* (Durbin 1997).

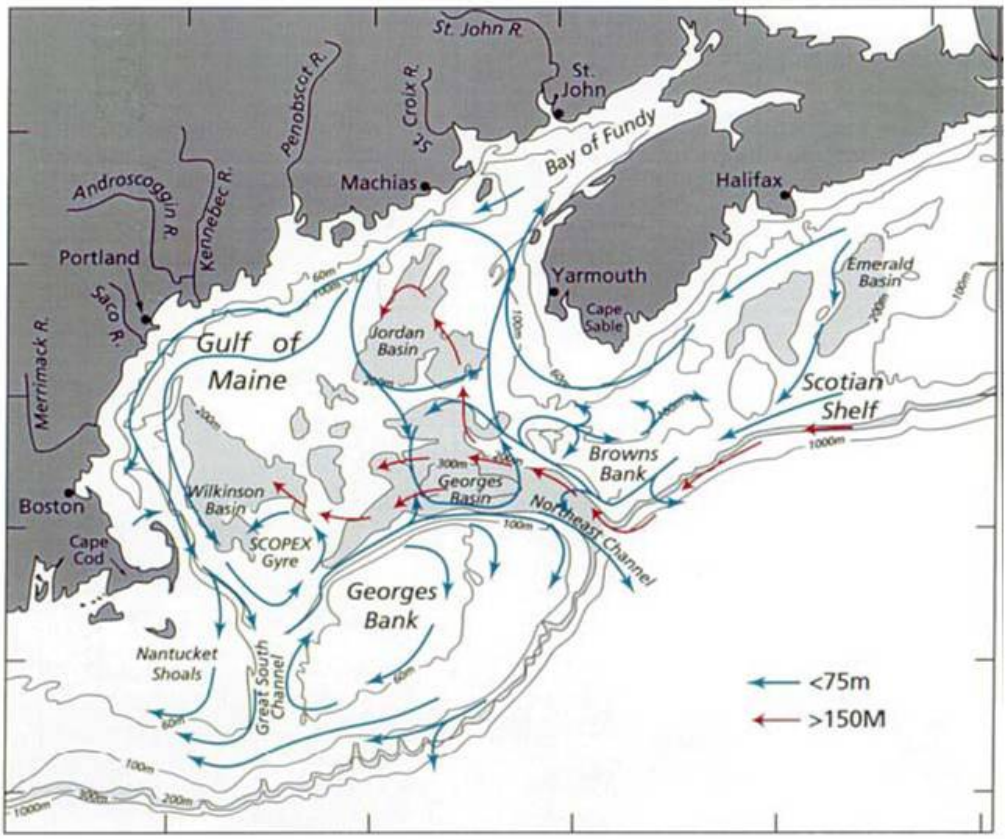

Figure 3 Major oceanographic features and circulation patterns in the Gulf of Maine and Georges Bank (Source: Miller et al. 1998).

The EMCC is a band of cold, tidally-mixed water originating on the southwest Nova Scotian Shelf. The EMCC crosses the mouth of the Bay of Fundy and continues southward along the coast of eastern Maine to the mouth of Penobscot Bay (Pettigrew et al. 1998). The EMCC is relatively fast moving and somewhat colder than the western portion (i.e., WMCC) of the MCC current. As the EMCC flows southwest along the coast its waters become increasingly vertically stratified and nutrient depleted with a

concurrent increase in both phytoplankton biomass and developmental stages of copepods. The EMCC and the WMCC converge at the mouth of Penobscot Bay. Here the faster moving EMCC is diverted away from the coastline and out over the central GoM (Pettigrew et al. 1998). As the EMCC moves offshore, a portion of the cold water plume becomes entrained in the prevailing cyclonic gyre over Jordan and Georges Basins. The remaining portion is brought back towards Maine's coast where it continues as part of the WMCC (Pettigrew et al. 1998).

The GoM's circulation pattern is principally density driven due in large part to seasonal temperature changes and salinity gradients. During spring and summer months, water within the Gulf warms, resulting in buoyant, less dense water that expands, setting up a westerly flowing coastal current which helps to draw water into the GoM. The seasonal warming pattern of waters within the GoM also results in enhanced stratification of the water column. Warmer, less dense surface water is separated from the colder, more saline dense waters that persist at greater depth throughout the year. The currents in the GoM are also strongly influenced by density gradients between high-salinity slope water entering from the Atlantic and fresher waters, which form in the GoM or enter from the Scotian Shelf (Brooks 1985).

The physical oceanographic features of the Gulf of Maine Georges Bank region are influenced by variety of conditions including several outside of the Gulf of Maine. For example, the North Atlantic Oscillation (NAO) (a climatic phenomenon in the North Atlantic Ocean of fluctuations in the difference of atmospheric pressure at sea-level between the Icelandic low and the Azores high) influences the relative location within the Atlantic Ocean of warm Gulf Stream waters that approach the Gulf of Maine from the

south, and the colder Labrador Current waters that flow toward the area from the north. Small-scale changes in the North Atlantic can produce large-scale changes in the Gulf of Maine. There are large-scale coastal circulation patterns that influence the Gulf of Maine that originate from the Labrador Sea. The circulation and water properties within the Gulf of Maine therefore may depend as much on influences originating over 1,000 km away as on local processes (Thompson 2010)

In addition there are other local environmental processes that influence the physical oceanographic conditions inside the Gulf of Maine include such factors as wind, tidal mixing, the periodic cooler and more fresh inflow from the Scotian Shelf, winter cooling, summer heating, the deep warmer and more saline inflow of the slope water, and river runoff including freshwater inflow from numerous rivers (e.g., the St. John, Penobscot, Kennebec, Androscoggin, and Merrimac Rivers) (Brooks 1985, Xue et al. 2000).

There is a distinct seasonal pattern associated with prevailing circulation patterns within the GoM. During spring and summer, the surface circulation pattern in the GoM is characterized by a predominantly cyclonic (i.e., counterclockwise) circulation pattern with cyclonic and anti-cyclonic (clockwise) gyres over the three main basins and banks. As surface water cools during the fall months, it becomes denser and sinks, mixing with stratified water below breaking down the stratification of the water column. As the stratification weakens, the counterclockwise circulation pattern within the GoM slows until, by late winter, it is no longer evident (Xue et al. 2000).

In Cape Cod Bay, the general water flow is counter-clockwise, running from the GoM south into the western half of Cape Cod Bay, over to eastern Cape Cod Bay, and back

into the GoM through the channel between the north end of Cape Cod and the southeast end of Stellwagen Bank, a submarine bank that lies just north of Cape Cod. Flow within Cape Cod Bay is influenced by several environmental factors including tidal currents, the influence of the MCC, a predominantly westerly wind, and runoff events. (Franks and Anderson 1992a, 1992b, Geyer et al. 1992). Thermal stratification occurs in the bay during the summer months. Surface water temperatures typically range from 0 to 19° C throughout the year. The circulation pattern in Cape Cod Bay allows for the entrainment of *C. finmarchicus* produced elsewhere.

The Great South Channel becomes thermally stratified during the spring and summer months. Surface waters typically range from 3 to 17° C between winter and summer. Salinity is stable throughout the year at approximately 32-33 parts per thousand (Hopkins and Garfield 1979). In late-winter/early spring, mixing of warmer shelf waters with the cold GoM water funneled through the channel causes a dramatic increase in faunal productivity in the GSC. Copepods are concentrated north of the 100 m isobath at the northern end of the Great South Channel (Wishner et al. 1995, Durbin et al. 1997, Kenney 2001).

Baumgartner et al. (2007) note that several studies have suggested ocean fronts, areas that demarcate the convergence of different water masses, as a possible mechanism for concentrating copepods at densities suitable to support right whale foraging requirements. However, the available information is somewhat contradictory, with some studies finding associations between right whale foraging and oceanic fronts and others finding no evidence of associations (Wishner et al. 1995, Beardsley et al. 1996, Epstein and Beardsley 2001, Baumgartner el al. 2007). Given the evidence that in some cases

oceanic fronts are contributing factors to concentrating copepods and their role is uncertain in other cases, we are identifying it as one of the combination of physical oceanographic features that are essential. In combination, these features and mechanisms have been linked to increased copepod densities (Baumgartner et al. 2007).

The combination of prevailing physical oceanographic features present within the GoM and Georges Bank region--namely, currents and circulation patterns; bathymetric features (basins, banks, and channels); oceanic fronts; density gradients; and temperature regimes--interact to distribute, aggregate and retain *C. finmarchicus* in concentrations necessary to support right whale foraging and energetic requirements.

As noted, Jordan, Wilkinson and Georges Basins (deep ocean basins within the overall GoM basin) (see Figure 3) provide refugia for diapausing populations of *C. finmarchicus* which serve as source populations for the annual recruitment of copepods into the GoM population (Davis 1987, Meise and O'Reiley 1996, Lynch et al. 1998, Johnson et al. 2006). The hydrographic conditions of the deep ocean basins where diapausing copepods aggregate are conducive to low flow velocities. The high lipid content of late stage copepods helps keep these animals neutrally buoyant such that, in their resting state, they remain below the convective mixed layer (Visser and Jónasdóttir 1999). Within the low velocity environments of the deep ocean basins, the neutrally buoyant copepods passively aggregate below the convective mixed layer (Lynch et al. 1998, Visser and Jónasdóttir 1999, Baumgartner et al. 2003b, Pace and Merrick 2008). Johnson et al. (2006)

concluded that copepods that can stay below basin sill depths are retained within the deep ocean basins.[6]

Researchers have developed models that predict that the deep basins in the GoM are sources of copepods for other areas within the GoM (Lynch et al. 1998, Johnson et al. 2006). These modeling results support the existence of deep resting *C. finmarchicus* populations present in these basins and help to explain their age distribution and abundance in the rest of the GoM (Lynch et al. 1998, Johnson et al. 2006). Johnson et al. (2006) concluded that "surface waters of the Gulf of Maine both supply the deep GoM with *C. finmarchicus* and in turn are supplied with *C. finmarchicus* from deep water" (see Figure 4 and Figure 5). Modeling has suggested that endogenous *C. finmarchicus* (i.e. offspring of copepods that emerged locally) can re-stock Wilkinson Basin in the western GoM, while self-stocking is minimal in Jordan and Georges Basins (Miller et al. 1998). Jordan and Georges Basins are restocked by external sources of copepods entering in surface Scotian Shelf and continental slope waters or in the 230-m deep Northeast Channel (Johnson et al. 2006). These copepods subsequently enter dormancy in these deep water basins (Lynch et al. 1998, Johnson 2006).

Johnson et al. (2006) also examined the influence of environmental forcing and copepod behavior on transport and retention of dormant *C. finmarchicus* in the deep GoM. Based on model simulations, they concluded that both transport and retention of *C. finmarchicus* within the GoM was high. The copepod transport and retention simulations demonstrate

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[6] Sill depth is the maximum depth at which there is horizontal exchange between an ocean basin and the waters of the open ocean. The restricted exchange of waters between the open ocean and waters below the sill depth in deep ocean basins contributes to the retention of *C. finmarchicus* in these areas.

transport of copepods from the eastern GoM into the western GoM, as well as the recruitment of copepods from slope and Scotian Shelf waters into the eastern GoM (Johnson et al. 2006). The researchers concluded that while a high proportion of dormant copepods are retained in the GoM as a whole, transport within the GoM was significant during the summer and fall, and loss from individual basin regions can be high (Johnson et al. 2006). Simulation results suggest the Wilkinson Basin region is the most retentive of the three major basins and receives copepods transported from Jordan and Georges Basins. As noted earlier, Jordan and Georges Basins are themselves recipients of copepods from upstream sources in the Northeast Channel, continental slope water, and Scotian Shelf (Johnson et al. 2006).

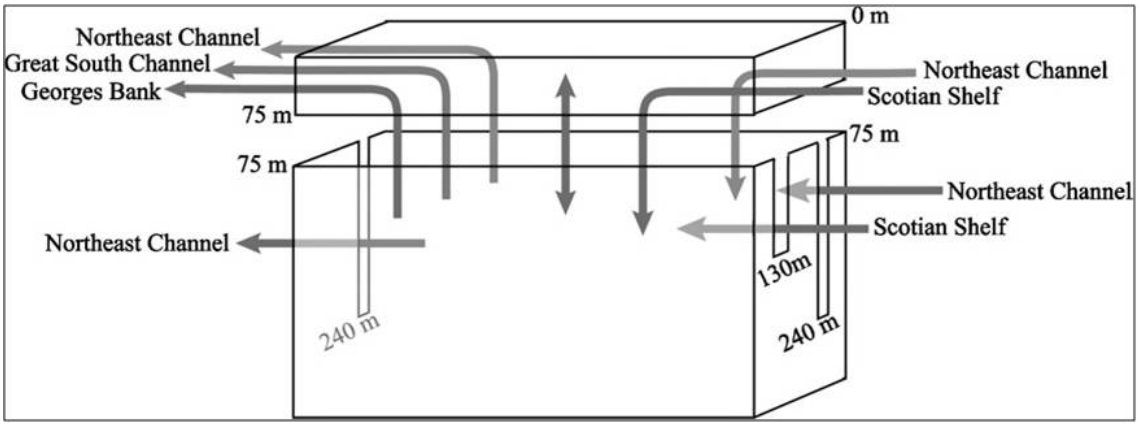

Figure 4 Conceptual model of dormant copepod transport into and out of the deep Gulf of Maine (Source: Johnson et al. 2006).

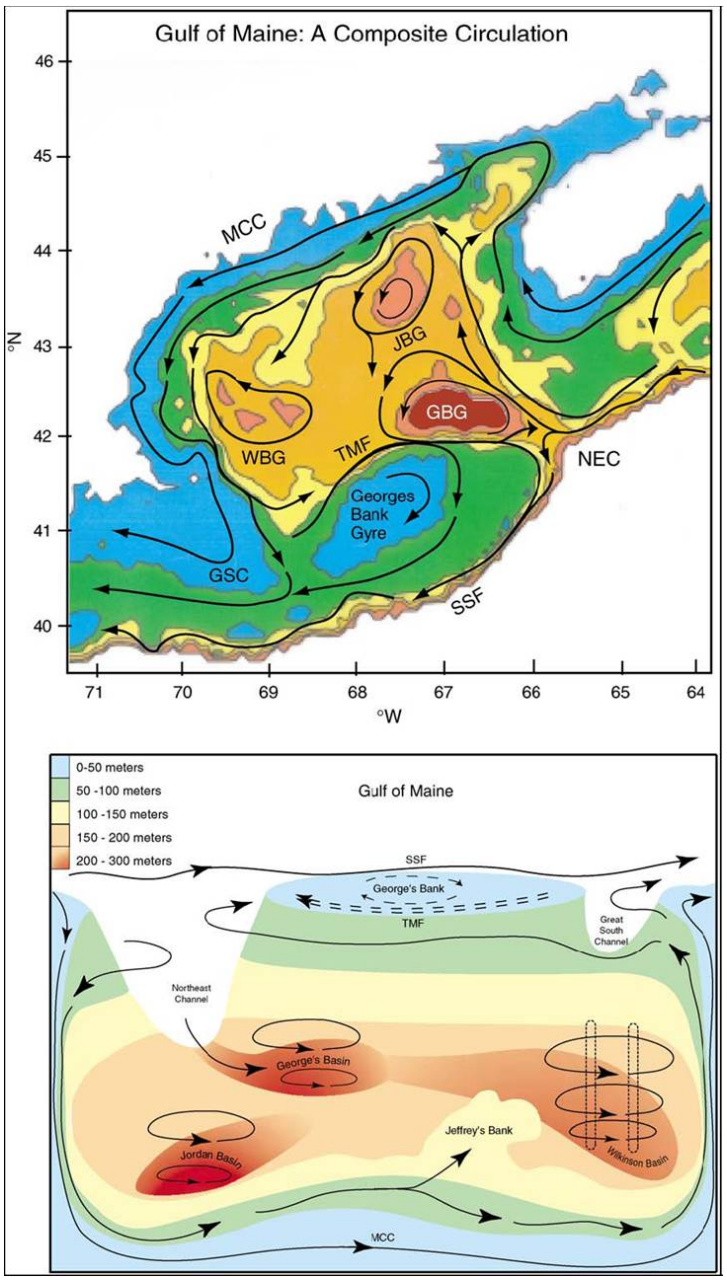

Figure 5 Schematic of Gulf of Maine and Georges Bank circulation system (Source: Warns-Varnas et al. 2005).

Johnson et al. (2006) suggest these transport patterns indicate that, in the late fall and winter (late dormant period), the western deep GoM is stocked primarily with copepods that entered dormancy in either the western or eastern GoM, while dormant copepods in the eastern deep GoM are stocked primarily from copepods that entered dormancy in the eastern GoM or were transported from upstream waters of the western Scotian Shelf and Slope.

The ability for copepods within the deep basins in the GoM to repopulate the GoM is dependent on how well they are retained within the basins during this period of dormancy. Johnson et al. (2006) predicted retention rates to be generally high, greater than 40%, though transport within the Gulf was high "resulting in shifts of eastern copepods into western Gulf and upstream copepods, from slope and Scotian Shelf waters, into the eastern Gulf" (Johnson et al. 2006). The retention of active *C. finmarchicus* in the eastern GoM may be higher for copepods that stay below the surface Ekman layer (Hannah et al. 1998).

Such distinct sources of dormant copepods in different GoM regions may contribute to observed regional differences in abundance of *C. finmarchicus* (Johnson et al. 2006). In late fall and early winter, *C. finmarchicus* is more abundant in the western GoM than in the northern and eastern GoM (Fish 1936, Meise and O'Reilly 1996). Dormant copepods in slope water are found at depths greater than the Northeast Channel sill depth (232 m), both south of Georges Bank and southeast of the Scotian Shelf (Miller et al. 1991, E.J.H. Head, unpublished data, cited in Johnson et al. 2006). Transport simulations indicate that circulation of slope water low in *C. finmarchicus* concentrations flush the Georges Basin region above the Northeast Channel sill depth (232 m), while dormant *C. finmarchicus*

deep in Georges Basin would be retained (Johnson et al. 2006). Support for this interpretation is found in the generally deeper mean depths of dormant copepods in Georges Basin compared to those in Wilkinson and Jordan Basins (Wiebe et al., unpublished results, Johnson et al. 2006). Johnson et al. (2006) note that the available data, while limited, suggest that inflow of deep water from upstream sources, in addition to transport loss to the western GoM, could contribute to lower abundance of dormant *C. finmarchicus* in the eastern GoM in the fall and winter.

The GoM acts as a source of *C. finmarchicus* for Georges Bank in late winter and spring (Bigelow 1926, Gentleman 1999, Hannah et al. 1998, Lynch et al. 1998). Simulations of population dynamics of *C. finmarchicus* in the GoM indicate that the deep basins of the GoM (i.e., Wilkinson, Jordan and Georges Basins) are capable of providing copepods to Georges Bank at the onset of the growing season (Lynch et al. 1998). Lynch et al. (1998) conclude that Jordan and Wilkinson Basins clearly support resting stocks of *C. finmarchicus* and that Georges Basin may also serve this function.

Miller et al. (1998) provide an individual-based population model of *C. finmarchicus* for the Georges Bank region demonstrating the importance of Georges Basin, as well as Wilkinson and Jordan Basins, as sources of *C. finmarchicus* to Georges Bank. As for specific zones within the GoM, Miller et al. (1998) point to the MARMAP samples that support Jordan and Wilkinson Basins as sources, and suggest that Georges Basin may also be a contributor. The role of Georges Basin has been debated due to the considerable water movement and relative openness of Georges Basin to the shelf edge (Lynch et al. 1998, Pace and Merrick 2008). Recent simulation models combining plankton sampling results of the last two decades and earlier, robust circulation models of

the GoM, and life history dynamics of *C. finmarchicus* corroborate earlier conclusions about the importance of these basins, in addition to the Scotian shelf and its sources, as a copepod source for the GoM ecosystem. As discussed, models by Lynch et al. (1998) support all three deep basins (Jordan, Wilkinson and Georges) as contributors of *C. finmarchicus* to Georges Bank and the Great South Channel (GSC).

Li et al. (2006) suggest that copepod sources within the GoM are sufficient to account for the early *C. finmarchicus* population of Georges Bank, with an increased importance of advected sources later in the year. The simulation models of Johnson et al. (2006) also support the prominence of Jordan and Wilkinson Basins in the *C. finmarchicus* dynamics in the GoM.

Biological Features Characteristic of Right Whale Foraging Habitat

The biological features of foraging habitat essential to the conservation of the North Atlantic right whale are:

- Late stage *C. finmarchicus* in dense aggregations in the Gulf of Maine and Georges Bank region;
- Diapausing *C. finmarchicus* in aggregations in Jordan, Wilkinson, and Georges Basins.

As explained above, late-stage *C. finmarchicus* in dense aggregations in the Gulf of Maine and Georges Bank regions are essential for the conservation of the species because they, in combination with the other identified features, provide for efficient feeding on

prey with high nutritional value to support right whale life history and reproductive strategies. Though the means by which right whales locate and exploit these food resources is not well understood, the presence of foraging right whales is a reasonable proxy for determining where these critical food densities are located (Kenney et al. 1995, Baumgartner et al. 2003a). Right whales are filter feeders whose prey consists exclusively of zooplankton, notably the copepod *C. finmarchicus*. For much of the year, the right whale's distribution is strongly correlated with the distribution of their prey. Right whales forage by filtering large volumes of seawater through open mouths, trapping zooplanktonic organisms on the dense filamentous mat fringing the inner surface of their baleen (Mayo and Marx 1990). Foraging takes place at the surface or at depth depending on the habitat type and where in the water column the prey source aggregates (Mayo and Marx 1990, Baumgartner et al. 2003b).

Zooplankton are found throughout the ocean, but frequently at concentrations far too low to meet right whales' energetic requirements (Baumgartner et al. 2007). Within the GoM –Georges Bank region, oceanographic processes and structures aggregate copepods, particularly *C. finmarchicus,* at densities suitable to support the energetic demands of right whales. The late developmental life stages (stages C4-C5) of the copepod, *C. finmarchicus,* are generally recognized as the North Atlantic right whale's primary prey (Watkins and Schevill 1976, 1979, Kenney et al. 1986, 1995, Wishner et al. 1988, 1995, Murison and Gaskin 1989, Mayo and Marx 1990, Beardsley et al. 1996, Kenney et al. 2001, Baumgartner 2003b) (Figure 6). While right whales have also been observed preying on other similarly sized copepods and juvenile euphausiids, the density threshold for *C. finmarchicus* to trigger right whale feeding appears to be lower than for other

calanoid copepods (Kenney et al. 1986, Mayo and Marx 1990, CCS 2004, Singer and Ludwig 2005).

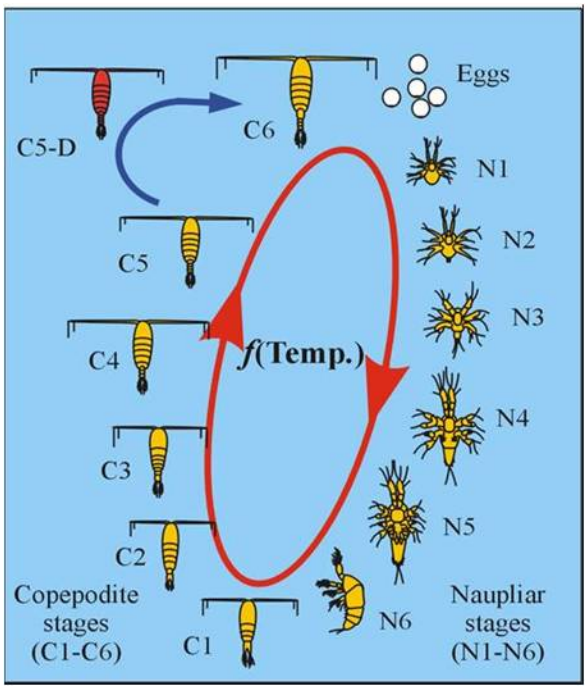

Figure 6 *C. finmarchicus* life cycle
(Source: http://pulse.unh.edu/Root%20Pages/Biology.htm).

Available research has documented right whales feeding on varying densities of *C. finmarchicus*. Due to energetic conservation, a threshold density of prey likely exists under which right whales are unlikely to exhibit foraging behavior (Wishner et al.1996). Several studies have attempted to quantify this threshold density. Murison and Gaskin (1989) in the Bay of Fundy and Mayo and Marx (1990) in Cape Cod Bay have both suggested a threshold density of approximately 800-1,000 organisms per m^3 (Wishner et al. 1995). Other studies have determined threshold values to range as high as 3,750-

4,000 organisms/m^3 (CCS 2003, 2004, 2005, 2006, 2008, Mayo and Goldman in Hain, ed. 1992), which are similar to the values calculated by Kenney et al. (1986).

Life History of Calanus finmarchichus

C. finmarchicus is the dominant copepod in the GoM in terms of biomass (Bigelow 1926, Fish and Johnson 1937, Durbin 1996). In the spring, *C. finmarchicus* is co-dominant with the copepod *Pseudocalanus spp.*[7] and constitutes the bulk of total zooplankton biomass on Georges Bank (Davis 1987, Howarth 1987). *C. finmarchicus* occupies an important place in the trophic web as the primary prey of many groundfish and larger pelagic planktivores including the North Atlantic right whale. While this species is most dominant within 200 m from the ocean surface, it has been reported from near-surface waters down to 4000 m.

The annual life cycle of the copepod *C. finmarchicus* includes a relatively complex series of interconnected life stages. In late winter, diapausing *C. finmarchicus* emerge from their dormant state[8] and molt to the adult stage, migrating to the phytoplankton rich

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[7] As noted, researchers have documented right whales foraging on the copepods *Pseudocalnus* and *Centropages typicus* as well as barnacle larvae (Mayo and Marx 1990 in Baumgartner et al. 2007). These observers noted that right whales quickly ceased foraging on these zooplankton assemblages indicating that the prey was likely not suitable (Baumgartner et al. 2007).

[8] Emergence from dormancy begins in the winter, though there appear to be spatial differences in the timing of emergence (Durbin 1996). There are several theories on what triggers copepod emergence from dormancy including "photic cues" or an internal timer based on reduced development time (Østvedts, 1955, Grigg and Bardwell 1982, Hirche 1989, Miller et al. 1991, Hirche, 1996). Results from Saumweber and Durbin (2006) support the theory that emergence may be triggered by energetic limitations. Emergence from dormancy increases copepods exposure to advection by the prevailing currents within the GoM, which distribute the emerging copepods within the GoM. Lynch et al. (1998) predict that surface layer aggregates move

surface layer (Marshall and Orr 1955, Davis 1987, Baumgartner et al 2007).[9] As *C. finmarchicus* migrate towards the surface, they are transported to other areas within the GoM by prevailing circulation patterns (Lynch et al 1998, Johnson et al. 2006) (see Figure 3). Mating occurs as the copepods migrate to surface waters, where females lay eggs. Within about 24-72 hours after spawning, nauplii larvae emerge.[10] Naupliar development consists of six consecutive molting stages (N1-N6), resulting in progressively larger and morphologically more complex larvae. This is followed by a metamorphosis of N6 to a first copepodite stage (C1), with five subsequent molts culminating in a (C6) mature animal. Development is synchronized with the diatom spring bloom, representing the major food source for *C. finmarchicus*.

In the GoM the relatively prolonged phytoplankton production due to vertical mixing and stratification processes allows *C. finmarchicus* to produce more than one generation (Baumgartner et al. 2007). The first generation to develop after dormancy (G1) enters dormancy and migrates to deep water of the GoM starting in late spring and early summer (May and June) (Durbin et al. 2000, Baumgartner et al. 2007). A second

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approximately twice the speed as those with no depth preference and were advected onto Georges Bank more readily via circulation patterns.

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10 The early naupliar stages (N1-2) do not feed. The later naupliar stages (N3-6), all copepodite stages (C1-5) and adults feed primarily on phytoplankton (Baumgartner et al. 2007).

generation (G2) develops during the summer months, and a small fraction of the population may continue development and enter dormancy in the fall (Johnson et al. 2006) while other G2 stage copepods remain at the surface to spawn a third generation (G3) (Baumgartner and Mate 2005). It is believed that as each generation of copepodites reach the C5 stage some migrate to deep water while some remain in surface waters molting into adults to continue production (Baumgartner et al. 2007).

Beginning in late spring and early summer (May and June), as seasonal water temperature increases and phytoplankton levels decrease, *C. finmarchicus* C5 undergo a vertical migration to deep waters where they enter a state of dormancy (Bigelow 1927, Davis 1987, Durbin et al.1995). Most of the *C. finmarchicus* population can be found in diapause in deep water in the summer and fall (Durbin et al. 2000, Baumgartner et al. 2003). These dormant, diapausing pre-adult C5 copepodites form dense layers near the bottom of deep basins and continental slope waters. Diapausing *C. finmarchicus* are characterized by their stage of development, deep distribution, and large oil sacs on which they rely for energy and low activity rates (Baumgartner et al. 2003b). This behavior may be an adaptive measure for surviving periods of low food availability and/or for reducing predation rates (Davis 1987, Kaartvdet 1996, Dale et al 1999, Baumgartner et al. 2003b). These diapausing copepods serve as one of the primary source populations for the copepods that later form the dense aggregations upon which North Atlantic right whales feed.

Diapausing C. finmarchicus

Diapausing *C. finmarchicus* in aggregations in the deep ocean basins within the GoM (i.e., Jordan, Wilkinson and Georges Basins) are essential to the conservation of the North Atlantic right whale, because they are the sources of copepods that form the highly nutritional prey base for right whales when they return to forage in the GoM in the late winter and early spring. Beginning in late spring and early summer, as seasonal water temperature increases and phytoplankton levels decrease, *C. finmarchicus* C5 undergo a vertical migration to deep waters where they enter a state of dormancy (Bigelow 1927, Davis 1987, Durbin et al. 1995). These diapausing copepods serve as one of the primary source populations for annual recruitment of copepods to the waters of the GoM and Georges Bank region. As discussed, the hydrographic conditions of the deep basins where aggregations of diapausing copepods are found are conducive to low flow velocities. These low velocity environments allow the neutrally buoyant, high lipid content copepods to passively aggregate below the convective mixed layer and be retained for a period of time (Lynch et al. 1998, Visser and Jónasdóttir 1999, Baumgartner et al. 2003b, Pace and Merrick 2008). Diapausing populations have been documented in several other northwest Atlantic basins such as the Roseway and Manan Basins in Canadian waters (Baumgartner and Mate 2005).

Modeling results support the existence of deep resting copepod populations present in GoM basins, which help to explain *C. finmarchicus* age distribution and abundance in the rest of the GoM (Lynch et al. 1998, Johnson et al. 2006). The GoM acts as a source of *C. finmarchicus* for Georges Bank in late winter and spring (Bigelow 1926, Gentleman 1999, Hannah et al. 1998, Lynch et al. 1998). Simulations of population dynamics of *C. finmarchicus* in the GoM indicate that the deep basins of the GoM (i.e., Wilkinson,

Jordan and Georges Basins) are capable of providing copepods to Georges Bank at the onset of the growing season (Lynch et al. 1998).

Lynch et al. (1998) conclude that Jordan and Wilkinson Basins clearly support resting stocks of *C. finmarchicus* and that Georges Basin may also serve this function. Johnson et al. (2006) examined the influence of environmental forcing and copepod behavior on transport and retention of dormant *C. finmarchicus* in the deep GoM. Based on model simulations, these researchers concluded that both transport and retention of *C. finmarchicus* within the GoM was high. The results of these model simulations of copepod transport and retention within the GoM demonstrate transport of copepods from the eastern GoM into the western Gulf as well as the recruitment of copepods from slope and Scotian Shelf waters, into the eastern GoM (Johnson et al. 2006).

Research suggests that locally derived copepods, (i.e., offspring of copepods that emerged from dormancy locally), are capable of restocking Wilkinson Basin (Johnson et al. 2006). Conversely, self-stocking is thought to be minimal at the two other major GoM basins, Jordan Basin and Georges Basin (Miller et al., 1998, Johnson et al. 2006). Jordan and Georges Basins are restocked by external sources of copepods, either *C. finmarchicus* entering the GoM in surface Scotian Shelf and Scotian Slope waters or entering the deep GoM primarily through the 230-m deep Northeast Channel (Johnson et al. 2006). These copepods subsequently enter dormancy in these deep water basins (Lynch et al., 1998, Johnson 2006).

Johnson et al. (2006) note that while a high proportion of dormant copepods are retained in the GoM as a whole, transport within the GoM was significant during the summer and

fall, and loss from individual basin regions can be high. Simulation results suggest that the Wilkinson Basin region is the most retentive of the three major basins and also receives copepods transported from Jordan and Georges Basins. In addition, Jordan and Georges Basins are themselves recipients of copepods from upstream sources in the Northeast Channel, slope water, and Scotian Shelf (Johnson et al. 2006).

Johnson et al. (2006) suggest that these transport patterns indicate that in the late part of the dormant period, late fall and winter, the deep western GoM is stocked primarily with copepods that entered dormancy in both the western and eastern GoM, while dormant copepods in the deep eastern GoM are a mixture of individuals that entered dormancy in the eastern GoM and individuals transported from upstream waters of the western Scotian Shelf and Slope.

Johnson et al. (2006) suggests that such distinct sources of dormant copepods in different GoM regions may contribute to observed regional differences in abundance of *C. finmarchicus*. *C. finmarchicus* are more abundant in the western GoM than in the northern and eastern GoM in late fall and early winter (Fish, 1936, Meise and O'Reilly, 1996). Dormant copepods in slope water are found at depths greater than the Northeast Channel sill depth (232 m) both south of Georges Bank and southeast of the Scotian Shelf (Miller et al. 1991, E.J.H. Head, unpublished data, cited in Johnson et al. 2006). Transport simulations indicate that circulation of slope water low in *C. finmarchicus* concentrations flush the Georges Basin region above the Northeast Channel sill depth (232 m), while dormant *C. finmarchicus* deep in Georges Basin would be retained (Johnson et al. 2006). Support for this interpretation is found in the generally deeper mean depths of dormant copepods in Georges Basin compared to those in Wilkinson and

Jordan Basins (Wiebe et al., unpublished results, Johnson et al., 2006). Johnson et al. (2006) note that the available data, while limited, suggest that inflow of deep water from upstream sources, in addition to transport loss to the western GoM, could contribute to lower abundance of dormant *C. finmarchicus* in the eastern GoM in the fall and winter.

5.2 The Physical and Biological Features of Calving Habitat that are Essential to the Conservation of the Species

Like most large whales, North Atlantic right whales tend to calve in warm subtropical waters during winter, and migrate to feed in the highly productive cold temperate and subpolar waters in spring and summer (Green and Pershing 2004). The only known calving habitat for North Atlantic right whales occurs along the southeastern U.S. coast (Kraus et al. 1986, Knowlton et al. 1994, Reeves et al. 2001). Recent aerial survey data indicate calving and nursing occur from northeastern Florida and southeastern Georgia as far north as North Carolina (e.g., Good 2008, McClellan et al. 2004). Primarily reproductive females, calves, and juveniles are sighted in the calving ground off the coast of Florida and Georgia (Fujiwara and Caswell 2001, Garrison 2007, Hamilton et al. 2007). Calving right whales, the most valuable segment of this species' population[11], typically arrive in this region during mid to late November and early December after migrating south from feeding grounds in the northeastern U.S. and Canada. Mothers and newborn calves reside within this region through early March, and they generally depart the calving grounds by the end of March and early April (Reeves et al. 2001). Given that the area off the southeastern U.S. is the only known calving ground for North Atlantic

[11] Fujiwara and Caswell (2001) concluded that the death of female whales, particularly reproductive females, appears to pose the greatest demographic risk of extinction. The mortality of mature, reproductive females results in declines in population growth rate, life expectancy and the mean lifetime number of reproductive events (Fujiwara and Caswell 2001).

right whales, and that the most valuable portion of the species' population is utilizing this habitat, we conclude that facilitating successful calving by protecting the species' calving area is a key conservation objective that could be supported by designation of critical habitat for the species. Thus, to identify specific areas that may meet the definition of critical habitat we focused first on specifically defining what constitutes a "calving" area for North Atlantic right whales – i.e., what functions does this area provide that lead to successful calving and rearing? We then identified those physical or biological features that are essential to the conservation of the species because they provide calving area functions to the species in these areas.

Physical features common to lower latitude calving areas for large whales include: warmer water temperatures, lower average wind speeds, less frequent storms, and lower wave heights compared to higher latitudes during winter months (Garrison 2007). Calving southern right whales (Payne 1986, Patenaude and Baker 2001, Rowntree et al. 2001, Elwen and Best 2004), gray whales (*Eschrichtius robustus*) (Swartz 1986), and humpback whales (*Megaptera novaeangliae*) (Whitehead and Moore 1982, Smultea 1994, Erstes and Rosenbaum 2003) all appear to prefer shallow, calm waters that provide some degree of protection from open ocean wind and swell. Wintering humpback whales in the western North Atlantic Ocean appear to prefer shallow water within the temperature range of 24 to 28°C (Whitehead and Moore 1982, Whitehead 1987).

These common calving habitat characteristics for large whales likely provide an energy benefit to both lactating mothers and calves. Female baleen whales do not typically feed during the migration to, or residence period in, the calving area, and therefore endure a significant energetic cost (Garrison 2007). Mother whales fast during part of or

throughout lactation, and maternal reserves are heavily exploited for milk production (Oftedal 1997, 2000). Fasting in warm water during early and peak lactation may be more energetically efficient than feeding, let alone fasting, in colder water, and may aid conversion of maternal body fat to high-fat milk, hence contributing to rapid calf growth (Oftedal 2000, Whitehead and Mann 2000). Calmer, shallower waters allow female right whales to use less energy for surfacing, and focus energy reserves on calving and nursing. Additionally, newborns may have increased survival, and/or lower energy expenditure in warmer, calmer, or less predator-infested waters (Brodie 1975, Lockyer 1987, as cited in Whitehead and Mann 2000, Corkeron and Connor 1999). Calves have been reported to have difficulty surfacing to breathe in extremely rough waters (Thomas and Taber 1984). Further, calves are relatively weak swimmers (Thomas and Taber 1984) and are likely to be easily separated from their mothers during storm events and in areas with high winds and waves; separation from the mother for even a short time is likely fatal for newborn calves (Garrison 2007).

While "there are few or no direct data about thermal tolerances in right whales" (Kenney 2007), warmer water temperatures likely provide a thermoregulatory benefit to calving right whales. As homoeothermic (warm-blooded) animals, right whales expend additional energy for thermoregulation when temperatures are either too cold or too hot compared to some thermal optimum. North Atlantic right whales have a mean blubber thickness of 12.2 cm (range 8 to 22 cm; 3 to 8.6 inches), and the blubber of new mothers is thicker than that of females in late lactation or nulliparious females (Angell 2006). The thick blubber of parturient females may pose a thermal constraint, and it is expected that new mothers will be more sensitive than females in late lactation or nulliparious females to warm temperatures (e.g., Atlantic Ocean Gulf Stream water) than colder temperatures

(Good 2008). Calves are unlikely to face such constraints (Good 2008) because calves do not have a thick blubber layer; blubber from newborn southern right whale calves in South Africa averaged 5 cm (2 inches) in thickness (Reeb et al. 2007). Therefore, newborn calves without the thick blubber layer of adults do not have the same thermal tolerance as adult whales (Garrison 2007). Because of the differences in the thermoregulatory needs of mothers (i.e., preferring waters that are not too warm so as to avoid heat stress) and newborns and calves (i.e., preferring waters that are not too cold so as to avoid cold stress), it is likely that these pairs of new mothers (i.e. blubber rich) and newborns or calves (i.e. blubber poor) on a calving ground have relatively narrow combined thermal tolerances (Garrison 2007).

Calving Areas in the South Atlantic Bight

North Atlantic right whales are observed calving off the southeastern U.S. coast, in an area known as the South Atlantic Bight (SAB), which generally provides the calving habitat characteristics described above for other large whales. The SAB extends roughly from Cape Hatteras, North Carolina, to West Palm Beach, Florida. The SAB continental shelf varies from 40 to 140 km wide, with a shallow bathymetric slope. The inner shelf of the SAB, bounded by the 20 m isobath, is characterized mainly by a coastal low-salinity frontal zone resulting from the interaction between freshwater discharges, tidal mixing, and wind forcing (Chen 2000). Tidal motion accounts for about 80 to 90 percent of cross shelf, and about 20 to 40 percent of along shelf, current variation and kinetic energy in the inner shelf of the SAB (Tebeau and Lee 1979, Lee and Brook 1979, Pietrafesa et al. 1985, as cited by Chen 2000). Tidal current is strongest in the widest part of the shelf between Savannah and Charleston and weakest at the northern and southern

ends (Chen 2000). The wind varies seasonally, blowing northwestward or northeastward in spring and summer and southeastward or southwestward in winter (Chen 2000).

In the inner shelf, where the water depth is shallow and friction is strong, the current responds almost instantaneously to local wind stress; as a result, water moves in the same direction as the wind (Chen 2000). In the middle and outer shelves, where the water is deep and friction is weak, the wind-driven current flows perpendicular to the wind direction (i.e., Ekman spiral pattern). Fifteen years of data from two weather stations (SAUF1 and FBIS1) within 100 m (328 feet) of the coast registered average winter wind speeds between 8.1 and 9.6 knots (NOAA's National Data Buoy Center). Average winter wind speeds in the region increase when moving farther offshore. Two additional buoy stations, one (41008) 29 km and another (41009) 35 km offshore registered average winter wind speeds between 10.1 and 11.2 knots and between 12.4 and 13.1 knots, respectively (Good 2008). A fifth buoy (41004), 60 km offshore, registered average winter speeds between 13.2 and 14.7 knots (Good 2008). On the Beaufort scale, wind speeds between 7 and 10 knots indicate a gentle breeze, which results in large wavelets where crests begin to break and in scattered whitecaps. Moving farther offshore, average winter wind speeds in the region begin increasing with a corresponding deterioration in sea state conditions. Wave size increases and the sea surface becomes more turbulent.

Winter sea surface temperatures across the SAB range from 8°C to 25°C (Good 2008). Gulf Stream waters typically have temperatures greater than 20°C during winter, and water closer to shore is cooler ranging between 8 and 17°C in the southeastern U.S. during winter months (Garrison 2007). Pulses of warm water frequently move shoreward as the result of Gulf Stream meanders, but a steady tongue of colder water persists

directly adjacent to shore and out to the continental shelf break in winter (Stegmann and Yoder 1996, Keller et al. 2006). These waters also are warmer than the waters of the northern feeding grounds during winter, yet cooler than the waters located farther offshore the southeastern U.S. and closer to the warm water influence of the Gulf Stream.

Aerial surveys for calving right whales have been conducted in the southeastern U.S. each winter (December-March) since 1992. Survey effort has varied throughout the area with the core calving area being surveyed most consistently (Keller et al 2006). Figure 7 illustrates the heterogeneous nature of survey effort for surveys conducted since 2003. The bias created by this uneven survey effort can be reduced to best assess the distribution of mother/calf right whales. Reducing the sampling bias can be accomplished by dividing mother/calf sightings by level of survey effort on a spatial scale (i.e. effort-corrected sightings or sightings per unit of effort).

Figure 8 shows effort-corrected locations of mother/calf right whale pair observations during annual calving seasons from 2003/2004 to 2014/2015. Despite the sightings in Figure 8 being effort corrected, caution is still needed when interpreting the data as the level of effort in the central part of the survey zone is over an order of magnitude greater than in the northern part of the zone and there are relatively low numbers of sightings. In other words, even one sighting of a mother/calf pair in the northern part of the survey zone may have a substantial effect on the results of sightings corrected by effort.

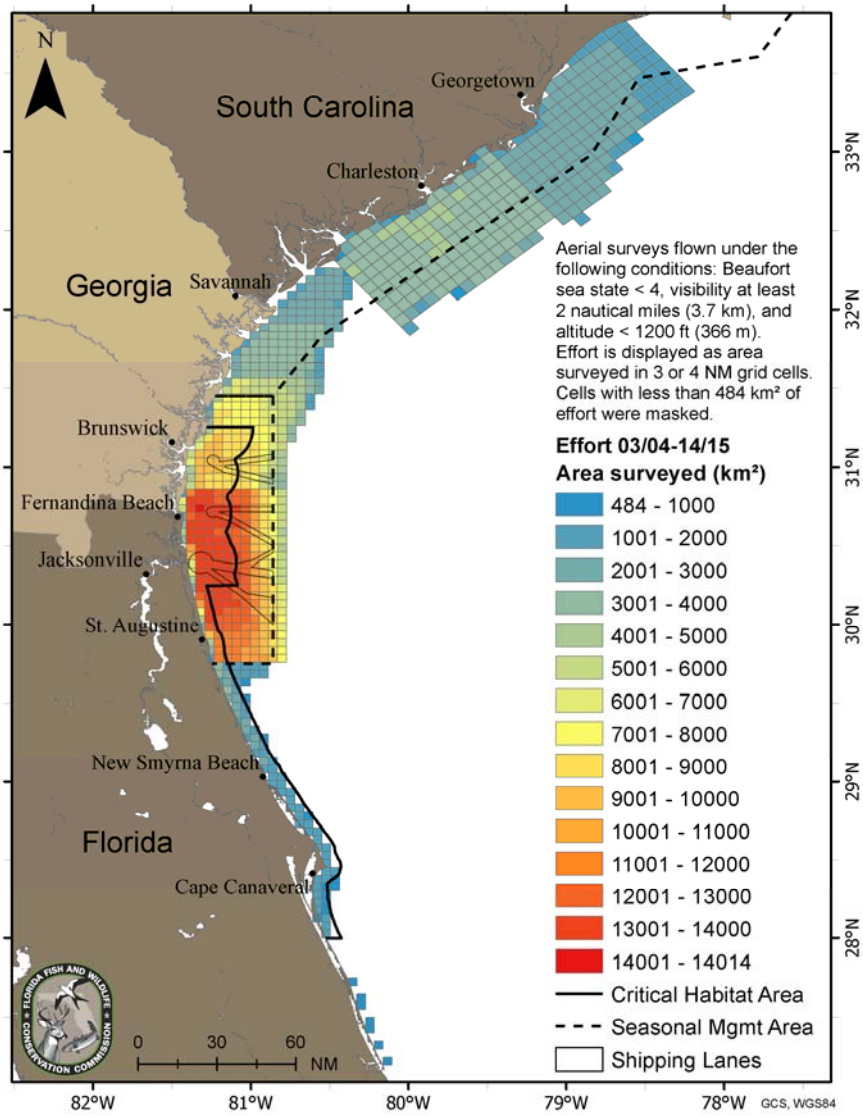

Figure 7 Total survey effort in the Southeast U.S. for November 2003 – March 2015 (excluding survey effort associated with known whale locations). The Critical Habitat Area refers to the boundaries of the 1994 designation.

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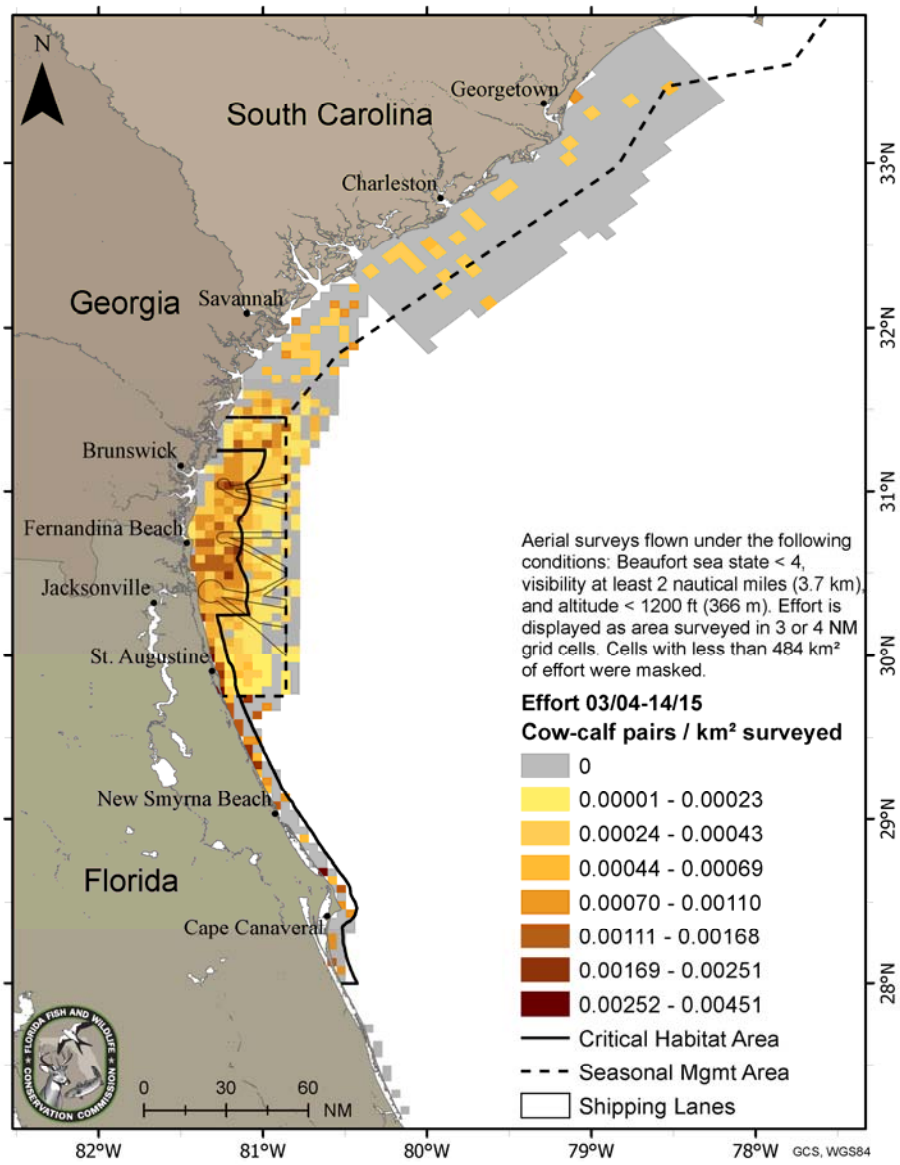

Figure 8 Right Whale Mother/Calf Pair Sightings per Unit Effort (SPUE), November 2003 – March 2015. Note: light gray illustrates maximum extent of area surveyed (Florida Fish and Wildlife Conservation Commission 2015). The Critical Habitat Area refers to the boundaries of the 1994 designation.

Based on Figure 8, the densest distribution of observed North Atlantic right whale mother-calf pairs is generally between St. Augustine, Florida, and just south of Savannah, Georgia, in waters of the inner shelf of the SAB, which correlates with the preferred calving habitat characteristics observed in other large whale species – e.g., relatively calm, temperate, and shallow waters. Three recent predictive habitat models based on sightings data for North Atlantic right whales (Garrison 2007, Good 2008, Keller et al. 2012) confirm these habitat selection preferences and predict areas of suitable calving habitat within the SAB. The following paragraphs discuss these habitat modeling studies at length to determine the specific aspects of the features of sea state, water temperature, and water depth that make these features, and potentially other features, essential to the conservation of North Atlantic right whales.

Calving Habitat Models

Garrison (2007) and Keller et al. (2012) assessed habitat correlations and spatial patterns in the distribution of right whale mother-calf pairs using sightings data, satellite derived sea surface temperature, bathymetry, modeled average wind data, and several other spatial variables. Right whale mother-calf pair sightings data were derived from annual aerial surveys (1992-2001) flown from Savannah, Georgia, to Ormond Beach, Florida, during December 1 through March 31. Advanced Very High Resolution Radiometer (AVHRR) imagery, which has a spatial resolution of just over 1 km^2, for the southeast U.S. was used to derive sea surface temperature data. Bathymetry data for the continental shelf were obtained from digital elevation grids available from the National Geophysical Data Center (NGDC) Coastal Relief Model (~ 60 m) resolution bathymetry grids for the U.S. continental shelf (http://www.ngdc.noaa.gov/mgg/coastal). Wind

intensity data for the study area were derived from a regional climate/weather model covering North America and the adjacent ocean waters developed by the National Center for Environmental Prediction (NCEP). Output from the NCEP model on predicted winds (meters/second) at 10 m above ground were used to calculate spatial grids of monthly average wind speeds for December through March each season (1992/1993 through 2000/2001). The sample size for the analysis consisted of 16 km^2 grid cells (4 km x 4 km). The model results indicated that sea surface temperature and water depth were significant predictors of calving right whale spatial distribution. Wind intensity did not explain the spatial distribution of calving right whales in this model (Garrison 2007, Keller et al. 2012).

Using the significant predictor variables of sea surface temperature and water depth, the model showed that peak predicted right whale mother-calf pair sighting rates (95th percentile) occur at water temperatures from 13 to 15°C and water depths from 10 to 20 m. The 95th percentile of predicted rates of right whale mother-calf pair sightings accounts for only 43.5 percent of all observed right whale mother-calf pair sightings.[12] The 75th percentile of predicted sighting rates, however, accounts for 91 percent of all observed right whale mother-calf pair sightings and occurs at water temperatures from 7 to 17°C and water depths from 6 to 28 m. Predicted sighting rates decline dramatically at water temperatures greater than 17°C. As calving season progresses from December

[12] Garrison's (2007) model was unable to capture 100 percent of all observed right whale sightings because of the following reasons. First, the model was more effective at predicting sightings in the year with the higher abundance of whales. Second, the model also tended to predict higher than observed sightings during the 2000/2001 calving season. During the 2000/2001 season, the spatial patterns in observed sightings were similar to those predicted by the habitat model. Last, the inability of the model to predict 100 percent of all observed sightings was a typical feature of habitat models as the available habitat area is typically larger than that occupied by the organisms, particularly for a relatively low abundance animal like the right whale.

through February, the model shows the predicted number of right whale sightings extending farther south, following the seasonal latitudinal progression of favorable water temperatures and the seasonal change in the distribution of observed right whale sightings. In the southern portion of the predicted optimal habitat area, the predicted number of right whale sightings were relatively close to shore, confined by both the narrow shelf in this area and the incursion of warm water temperatures influenced by the Gulf stream close to shore (Garrison 2007).

These results are corroborated by Good's (2008) predictive model of optimal right whale calving habitat, which assesses topological and physical conditions associated with the presence of North Atlantic right whale calves in the SAB. The model was used to evaluate the importance of water depth, sea surface temperature, and sea surface roughness in relation to the distribution of right whale mother-calf pairs over a period of six years (2000-2005). Similar to Garrison (2007), Good (2008) utilized right whale mother-calf pair sightings data derived from aerial surveys conducted between Savannah, Georgia and Cape Canaveral, Florida during December 1 through March 31. Sea surface temperature data were obtained from an earlier version (Version 5) of NOAA's AVHRR imagery, which has a spatial resolution of 4.6 km. Bathymetric data for the model's study area were derived from S2004 one-arc-minute global bathymetry (unpublished data, W. Smith, as cited by Good 2008). Sea surface roughness data were derived from enhanced resolution backscatter images from NASA Jet Propulsion Laboratory's SeaWinds Scatterometer aboard the QuikScat satellite (Long and Hicks 2005). Normalized radar backscatter (sigma-0) is a measure of wind-driven surface roughness over the ocean. A 5 km x 5 km sampling unit was utilized for the analyses due to satellite data resolution constraints. The model showed that sightings of right whale mother-calf

pairs occurred within a narrow range of physical parameters. Over the course of the winter season (December through March), Good's (2008) model showed that the distribution of female right whales and their calves along the SAB was correlated with water depth, sea surface temperature, and surface roughness, with the importance of each variable differing from month to month. Sightings of mothers and calves occurred within a mean depth range of 13.8 m to 15.5 m where mean sea surface temperature varied from 14.2 to 17.7°C and mean surface roughness varied from -24.8 dB to -23.3 dB. Higher backscatter values (e.g., -25 dB) reflect a calmer surface, while lower values (e.g. -20 dB) indicate rougher, choppier conditions (Good 2008). Sea surface roughness had the strongest correlation with right whale mother-calf pair distribution early in the calving season (December). In December and January, most mother-calf pairs were located in waters calmer than the rest of the study area, but the range of preferred values widened as the calving season progressed (February/March); whales occupied rougher surface waters, especially in March. Further, the habitat used by non-calving whales differed from that used by mother-calf pairs with respect to surface roughness and sea surface temperatures. The highest rates (70 to 76 percent) of right whale mother-calf pair sightings occurred in areas predicted as habitat in both 3 and 4 months out of the calving season, which accounts for approximately 86 percent of all observed right whale mother-calf pair sightings. Good's (2008) modeling results were similar to those produced by Garrison (2007) respecting bathymetry and sea surface temperature importance to right whale mother-calf pair distribution on the calving ground, and the results show that sea surface roughness was a significant predictor of right whale mother-calf pair distribution in the SAB.

Together, the sightings data and predictive modeling results showed that mother-calf pairs of North Atlantic right whales were observed and are likely to be observed in relatively calm (> 23.3 dB), shallow waters (≤ 30 m), within a narrow range of water temperatures (7 to 17°C) in close proximity to shore (within 60 km of the coast). The ranges reported in parentheses above represent the 75th percentile of right whale mother-calf pair sightings predicted by Garrison (2007) and Keller et al. (2012), which also capture the mean ranges of sea surface temperature, sea surface roughness, and water depth associated with right whale mother-calf pair sightings reported by Good (2008). Garrison's (2007) and Keller et al.'s (2012) 75th percentile of predicted sighting rates for calving right whales accounts for the greatest portion of all observed calving right whales (91 percent) and captures the means reported by Good (2008). Additionally, Good's (2008) rates of right whale mother-calf pair sightings in predicted habitat included the most temporally consistent habitat and accounted for 86 percent or more of all observed right whale mother-calf pair sightings. Therefore, Garrison's (2007) and Keller et al.'s (2012) 75th percentile and Good's (2008) habitat selected in 3 and 4 months are the most appropriate basis for determining the ranges for the essential features of right whale calving habitat in the southeastern U.S.

Calving right whales can be observed in waters exhibiting the features described above within the specified ranges; the value of each feature selected by whales varies depending on factors such as the weather (e.g., storms, prevailing winds) and age of the calf (e.g., neonate versus more mature calf). For example, early in the calving season mother-calf pair distribution is most strongly correlated with sea surface roughness (Good 2008). Most mother-calf pairs are located in calm waters at this time, consistent with reports that calves have difficulty surfacing to breathe in extremely rough waters (Thomas and Taber

1984), and separation from the mother for even a short time is likely fatal for newborn calves (Garrison 2007). Therefore, mother-calf pairs are likely to select locations with the calmest sea surface conditions to facilitate the needs of the neonate, which is a weak swimmer and needs to remain close to the mother to feed, and the needs of the mother who is fasting and lactating. If weather conditions are persistently poor (e.g., windy and/or stormy conditions), then it is likely the mother may search for and locate conditions more conducive to the needs of a weak-swimming neonate.

Sea surface roughness has the strongest correlation to mother-calf pair distribution early in the calving season. As sea surface temperatures and water depths are relatively less important for calf survival than calm water early in the calving season, areas in which mother-calf pairs are located are more likely to contain sea surface temperatures and water depths at the extremities of the preferred ranges (e.g., 17°C or upper range of values for sea surface temperatures, and 10 m or lower range of values for water depths). Early in the season, these shallow waters have not cooled to the seasonal maximum, yet still provide the necessary thermal balance for both a fasting, lactating, blubber-rich mother and a hungry, weak, blubber-poor neonate. As the calving season progresses and young calves mature and become stronger swimmers, however, calm waters become relatively less important to calf survival. Mother-calf pairs begin occupying rougher surface waters and the distribution of mother-calf pairs begins correlating more strongly with the preferred ranges of sea surface temperatures and water depths.

It is evident from the distribution patterns of mother-calf pairs throughout the calving season (see Garrison 2007, Keller et al. (2012), and Good 2008) that calving North Atlantic right whales are moving throughout the SAB to select optimal combinations of

sea surface roughness, sea surface temperatures, and water depths depending on factors such as the weather and the age of the calves. Younger, weaker calves are present earlier in the calving season and Good's (2008) model shows that this is when sea surface roughness had the strongest correlation with right whale mother-calf pair distribution. Therefore, calmer waters are an essential feature for the conservation of the species because they facilitate right whale calf survival. Additionally, the distribution of mother-calf right whale pairs correlates with (1) a narrow sea surface temperature range (7°C to 17°C), which provides for the thermal balance needs of both a fasting, lactating, blubber-rich mother and a hungry, weak, blubber-poor neonate; and with (2) a range of water depths (6 to 28 m) that provide for protection from open ocean swell, which increases the likelihood of calf survival. Therefore, waters within these sea surface temperature and depth ranges are essential features for the conservation of the species because they facilitate successful calving, which is a key conservation objective for endangered right whales.

Further illustrated by the modeling results of Garrison (2007), Keller et al. (2012), and Good (2008) is that the features of sea surface roughness, sea surface temperatures, and water depth are present in the SAB during calving season over large, contiguous areas. As such, mother-calf-pairs can move throughout the SAB to select dynamic, optimal combinations of some or all of these features depending on factors such as the weather and the age of the calves. The ability of mother-calf pairs to move throughout the SAB to use these features also contributes to growth and fitness of young calves. At the end of the calving season, the months-old calves must be strong enough to complete the lengthy northerly migration back to the feeding grounds. It is believed that the swimming abilities of young calves are strengthened by mother-calf pairs looping many miles up

and down the coast in the calving area (S. Kraus, New England Aquarium, pers. comm. to S. Heberling, NMFS, June 25, 2010). Such transit of mother-calf pairs is evidenced by one tracking study in which a tagged right whale with a young calf covered as much as 30 NM in one 24-hour period (Slay et al. 2002) and by annual tracking data of mother-calf pairs (Right Whale Consortium (2010). Therefore, the presence of the features over large, contiguous areas of the SAB such that mother-calf pairs can move throughout the SAB to select dynamic, optimal combinations of some or all of these features depending on factors such as the weather and the age of the calves facilitates calf survival.

Conclusions

These common calving habitat characteristics for large whales likely provide an energy benefit to both lactating mothers and calves. Female baleen whales do not typically feed during the migration to, or residence period in, the calving area, and therefore endure a significant energetic cost (Garrison 2007). Mother whales fast during part of or throughout lactation, and maternal reserves are heavily exploited for milk production (Oftedal 1997, 2000). Fasting in warm water during early and peak lactation may be more energetically efficient than feeding, let alone fasting, in colder water, and may aid conversion of maternal body fat to high-fat milk, hence contributing to rapid calf growth (Oftedal 2000, Whitehead and Mann 2000). Calmer, shallower waters allow female right whales to use less energy for surfacing, and focus energy reserves on calving and nursing. Additionally, newborns may have increased survival, and/or lower energy expenditure in warmer, calmer, or less predator-infested waters (Brodie 1975, Lockyer 1987, as cited in Whitehead and Mann 2000, Corkeron and Connor 1999). Calves have been reported to have difficulty surfacing to breathe in extremely rough waters (Thomas and Taber 1984).

Further, calves are relatively weak swimmers (Thomas and Taber 1984) and are likely to be easily separated from their mothers during storm events and in areas with high winds and waves; separation from the mother for even a short time is likely fatal for newborn calves (Garrison 2007).

While "there are few or no direct data about thermal tolerances in right whales" (Kenney 2007), warmer water temperatures likely provide a thermoregulatory benefit to calving right whales. As homoeothermic (warm-blooded) animals, right whales expend additional energy for thermoregulation when temperatures are either too cold or too hot compared to some thermal optimum. North Atlantic right whales have a mean blubber thickness of 12.2 cm (range 8 to 22 cm) (3 to 8.6 inches), and the blubber of new mothers is thicker than that of females in late lactation or nulliparious females (Angell 2006). The thick blubber of parturient females may pose a thermal constraint, and it is expected that new mothers will be more sensitive than females in late lactation or nulliparious females to warm temperatures (e.g., Atlantic Ocean Gulf Stream water) than colder temperatures (Good 2008). Calves are unlikely to face such constraints (Good 2008) because calves do not have a thick blubber layer; blubber from newborn southern right whale calves in South Africa averaged 5 cm (2 inches) in thickness (Reeb et al. 2007). Therefore, newborn calves without the thick blubber layer of adults do not have the same thermal tolerance as adult whales (Garrison 2007). Because of the differences in the thermoregulatory needs of mothers (i.e., preferring waters that are not too warm so as to avoid heat stress) and newborns and calves (i.e., preferring waters that are not too cold so as to avoid cold stress), it is likely that these pairs have relatively narrow combined thermal tolerances (Garrison 2007).

Based on the natural history of the species, its habitat needs, and the key conservation objective of facilitating successful calving, the identified physical and biological features are essential to the conservation of the North Atlantic right whale because they provide calving area functions. The essential physical features for North Atlantic right whales on their calving grounds are:

- Calm sea surface conditions of Force 4 or less on the Beaufort Wind Scale,
- Sea surface temperatures from a minimum of 7°C, and never more than 17°C, and
- Water depths of 6 to 28 meters.

These features are present over contiguous areas of at least 231 nmi^2 of ocean waters between November and April each year. The features are available to and selected by right whale mothers and calves in dynamic combinations that are suitable for calving, nursing, and rearing, and which vary depending on factors such as weather and age of the calves.

5.3 Migration

In the western North Atlantic, right whales migrate along the North American coast from Nova Scotia to Florida (Perry et al. 1999), ranging from wintering and calving grounds in coastal waters of the southeastern United States to summer feeding grounds in New England waters and northward to the Bay of Fundy and the Scotian Shelf (Waring et al 2013). Peak migration periods are in winter (November/December) and spring

(March/April) when right whales move south and north, respectively, between calving and feeding areas. Large-scale migratory movements between feeding habitat in the northeast and calving habitat in the southeast are a necessary component in the life-history of the North Atlantic right whale. A proportion of the population potentially makes this round trip migration annually, and the most valuable life-history stage (calving females) must make this migration for successful reproduction.

The subset of the North Atlantic right whale population that has been observed migrating between the northern feeding grounds and southern calving grounds is comprised disproportionately of reproductively mature females, pregnant females, juveniles, and young calves (Fujiwara and Caswell 2001; Kraus et al. 1986, as cited by Firestone et al. 2008). Pregnant female North Atlantic right whales, and right whale mothers and calves represent an important component of this species' population and their protection and survival is required for the recovery of North Atlantic right whales. The space used by right whales along their migration remains almost entirely unknown (Schick et al. 2009). During migratory periods it can be more difficult to locate and sample marine mammals systematically[13] or to observe them opportunistically to the extent that they surface less frequently and cover large distances in any given day during migration (Hiby and Hammond 1989; Morreale et al. 1996; Mate et al. 1997; Knowlton et al. 2002, as cited by Firestone et al. 2008).

In the absence of direct evidence and observation of physical or biological features that are essential to migration, and therefore essential to the conservation of the species, we

[13] For example, recent marine mammal abundance surveys conducted by the Riverhead Foundation for Research and Preservation (RFMRP) in the New York Bight and Mid-Atlantic region between November 2004 and December 2005 included over 150 hours of aerial surveys in these two areas, documenting 1,536 marine mammals. Of the marine mammals sighted, 99 percent were cetaceans. Only one was a North Atlantic right whale observed swimming south of Block Island in March 2005.

considered whether observations of migrating whales could be used to identify where migration occurs. To aid in determining potential habitat characteristics that may be important for migrating North Atlantic right whales, we looked at several analyses of North Atlantic right whale sightings and telemetry data:

- Sighting data used to develop/to support the rule to implement speed restrictions to reduce the threat of ship collisions with North Atlantic right whales hereinafter the ship strike rule (73 FR 60173).
- Sighting data from Knowlton et al. (2002) and Firestone et al. (2008), and
- Telemetry data from Schick et al. (2009).

To develop the ship strike rule (73 FR 60173, October 10, 2008), NMFS analyzed right whale sightings data from 1972 through 2000 from the South Carolina/Georgia border to Connecticut (n = 290). This analysis indicated that approximately 83 percent of all observed right whale sightings occurred within 20 nm (37 km) of the coast, and approximately 90 percent of all right whale sightings occurred within 30 nm (55.6 km) of the coast (73 FR 60173). Sightings of right whales have occurred up to 100 nm offshore in the mid-Atlantic region; however, sightings declined as one moved offshore. For the purposes of the ship strike rule analysis, the nearshore area was of greatest interest for determining risk in the vicinity of ports.

In addition to the ship strike analysis, there are three primary papers available to attempt to identify physical or biological features that define migratory habitat of North Atlantic Right Whales off the U.S. east coast: Knowlton et al. (2002), Firestone et al. (2008) and

Schick et al. (2009). Knowlton et al. (2002) and Firestone et al. (2008) deal primarily with sightings data. Schick et al. (2009) analyzes/relies upon/uses telemetry data.

Knowlton et al. (2002) and Firestone et al. (2008) used relatively simple analyses that do not account for spatial autocorrelation in the sighting data. Given this, caution should be exercised in relying on these analyses (see, for example, Segurado et al (2006), Dormann et al. (2007) or Bivand et al. (2008)). Knowlton et al. (2002) also included a small telemetry data set in the migration analysis. Schick et al. (2009) used sophisticated models for the telemetry data that were analyzed. For this reason, where Schick et al. (2009) comes to different conclusions from Knowlton et al. (2002) and Firestone et al. (2008), especially with regard to the likely width of the area utilized by migrating North Atlantic right whales, greater emphasis should be placed on the results from Schick et al. (2009)(NEFSC 2009). The most reliable data and analysis for migrating North Atlantic right whales currently available comes from two females, one of which was accompanied by a calf of the year (NEFSC 2009). Extrapolating these results from one female, one mother-calf pair, and no males to the entire population or a subset of the population was not scientifically supportable.

Knowlton et al. (2002) combined the survey and sightings effort data from a variety of systemic and non-systemic surveys on a month-by-month basis for the years 1974-2002 and analyzed sightings frequencies in terms of distance from shore and water depth. The combined dataset included 489 right whale sightings over a 28-year period. The authors defined the mid-Atlantic region to extend from 31°15’ N (central Georgia) northward to 69°45’ W (western edge of the Great South Channel). The majority of sightings were documented in the southern extent of the range between St. Simons Island, Georgia, and

Georgetown, South Carolina, where survey effort has been more extensive. In terms of distance from shore, Knowlton et al. (2002) reported that 94.1 percent of the sightings were within 30 nm of the coast, and 63.8 percent were within 10 nm of the coast. Of the satellite tag sightings (n = 52), over half were within 20 nm of the coast (Schick et al. 2009). It should be noted that most of the sighting effort through 2002 in the mid-Atlantic region was concentrated within approximately 30 nm of the coast; therefore, sighting data were positively biased towards shore. In terms of water depth, Knowlton et al. (2002) found that a majority of the sightings were within 5 to 10 fathoms of water, with the second highest number of sightings in 0 to 5 fathoms of water. The analysis indicated that 93 percent of sightings are in water depths of 25 fathoms or less, and 80.5 percent are in water depths of 15 fathoms or less. As noted above, in so far as the sightings were positively biased towards shore, it would also be expected that the water depth analysis would be positively biased towards shallow water.

Recognizing the gap in temporal data on migration behavior of North Atlantic right whales, Firestone et al. (2008) employed regression analysis to model northerly movements of right whales in the coastal mid-Atlantic. The goal of this analysis was to predict the spatial and temporal windows during which right whales are most likely to migrate through the mid-Atlantic region. Firestone et al. (2008) analyzed opportunistic data for the mid-Atlantic from 1762 to 2004. Similar to the discussion above, Firestone et al. (2008) also noted that because most of the sightings in the mid-Atlantic were obtained opportunistically rather than as a result of survey effort, the observations were likely biased toward near shore and shallow water where opportunistic effort is likely higher. Looking at 10-day windows, Firestone et al. (2008) determined that March 2-11 represented the modal period of departure for right whales leaving Jacksonville, Florida,

for the northerly migration. Firestone et al. (2008) concluded that right whales generally did not depart the southern calving grounds before the end of February, and that almost all right whales departed the calving grounds by the end of March. Once departed, right whales had an average travel time of 21-24 days from Jacksonville, Florida, to the tip of Long Island, New York, with a mean migration/displacement rate of 1.5-1.7 knots.

The analyses conducted by Knowlton et al. (2002) and Firestone et al. (2008) both utilized opportunistic sightings data. The available information identifies some areas used for migration but is not a comprehensive description. These data verify only that North Atlantic right whales were observed migrating in the area surveyed. Because we acknowledge that the survey data is biased near shore, we must ask whether there is any information to indicate whether areas not surveyed are used for migration.

Data from two tagged female right whales provided a less biased view of where North Atlantic right whales migrate. Schick et al. (2009) created a movement model for a migratory path and to estimate habitat suitability along the Mid-Atlantic coast for these whales: a reproductively active female, at least 20 years old, tagged in 1996 when she was accompanied by her calf, and a reproductively active female tagged in 2000. The analysis indicated a range of peak habitat suitability for migration as a function of distance from shore. For one animal, peak habitat suitability occurred in the range of 17 to 108 nm from shore (a mother calf-pair), and for the other, peak suitability occurred in the range of 8 to 40 nm from shore. Schick et al. (2009) concluded that habitat suitability for migrating right whales extended farther offshore than previously thought (i.e., the 30 nm estimate provided by Knowlton et al. (2002)). In comparison to the analyses based on opportunistic and systematic sighting data (Knowlton et al. 2002, Firestone et al.

2008), the analysis of Schick et al. (2009) showed that migrating North Atlantic right whales were not necessarily concentrated in a 30 nm from shore band but were using a much more variable and wider range of pathways between the north and the south.

The available data showed that a portion of the North Atlantic right whale population was found in waters off the Mid-Atlantic coast during the migration period. As discussed, the data were limited in scope, and do not provide a complete description of migratory habitat (i.e., survey data were biased near shore, and not all right whales migrated within 30 nm of shore). Since the vast majority of the survey effort was focused close to shore, the fact that the majority of migrating whales were observed close to shore does not necessarily indicate that distance from shore and shallow habitat contain or comprise essential features for migration. The one study that did not have a survey bias was based on two tagged whales and the movements of those whales were much broader and variable.

We do not have sufficient information to identify the physical or biological features of migratory habitat. As explained above, we explored the possibility of using sightings of migrating North Atlantic right whales to identify the specific areas used for migration. However, given the limitations in how the data were collected, we cannot be confident that the areas where we have observed migrating right whales are the specific areas where they do migrate. There could be many other unobserved areas that are also used by migrating right whales but which have very different physical and biological characteristics. Therefore, NMFS concludes that it is not possible to identify any specific physical or biological features associated with right whale migratory habitat at this time.

5.4. Breeding

Large groups of physically interacting right whales are called Surface Active Groups (SAGs). While indicative of courtship and reproductive behavior, not all SAGs are reproductive in nature. Therefore, SAGs likely serve multiple functions, including possibly mate selection, socialization, play, and mating practice (Kraus et al. 2007). SAGs, typically comprised of a focal female and multiple males, included 3 to 40 right whales (Kraus et al. 2007). In the North Atlantic Ocean, SAGs have been observed year-round, throughout the right whales' range (Kraus et al. 2007). Based on the fact that calves are born during the winter, and on the estimated right whale gestation period of twelve months, it is believed that mating takes place in the winter months (Kraus et al. 2007).

SAGs occur both in the northeast feeding areas as well as in the southeast calving grounds. For example, in December 2008, NOAA researchers conducting aerial surveys sighted relatively large numbers of right whales in the Jordan Basin area in the GoM, leading to speculation that this area might be an overwintering ground and/or a potential breeding area for right whales. Because SAGs may occur at any time and in any region, evaluating the particular physical or biological features that facilitate or are necessary for breeding and reproduction is not possible based on the currently available data. Therefore, it is not possible to identify any physical or biological features related to breeding and reproduction that are essential to the conservation of the species at this time.

6. Specific Areas on Which are Found the Physical and Biological Features Essential to the Conservation of the North Atlantic Right Whale

The definition of critical habitat in section 3 of the ESA instructs NMFS to identify specific areas on which are found the physical or biological features essential to the species' conservation. NMFS' regulations state that critical habitat will be defined by specific limits using reference points and lines on standard topographic maps of the area, and referencing each area by the State, county, or other local governmental unit in which it is located (50 CFR 424.12(c)). NMFS' regulations also state that when several habitats, each satisfying requirements for designation as critical habitat, are located in proximity to one another, an inclusive area may be designated as critical habitat (50 CFR 424.12(d)).

6.1 Specific Area on which are found the Features of Foraging Habitat that are Essential to the Conservation of North Atlantic Right Whales

The waters extending from the U.S. coast out to the seaward boundary of the U.S. Exclusive Economic Zone were considered in determining the specific area or areas on which are found the essential features of foraging habitat. [14]

An analysis of right whale sightings data along the east coast indicates that these endangered large whales rarely venture into bays, harbors, or inlets (70 FR 35849, June 25, 2005, NMFS 2007, 72 FR 57104, October 5, 2007). Based on this analysis, NMFS

[14] As noted, regulations at 50 CFR 424.12(h) state that "Critical habitat shall not be designated within foreign countries or in other areas outside of United States jurisdiction."

(2007) concluded that it is unlikely that right whales spend substantial amounts of time in the coastal waters of Maine, particularly inshore areas such as bays, harbors, or inlets (70 FR 35849, June 25, 2005, NMFS 2007, 72 FR 57104, October 5, 2007). Similarly, right whales are seldom reported in the small bays and harbors along the inside edge of Cape Cod, with the exception of Provincetown Harbor. As discussed, foraging right whales are indicative of the presence of dense aggregations of late stage *C. finmarchicus*. Due to the absence or rarity of foraging right whales in many of the inshore areas, bays, harbors and inlets, NMFS concludes that these essential biological features are not found in these areas shoreward of the boundaries delineated in the bullet points below. Furthermore, inshore areas, bays, harbors, and inlets create their own oceanographic conditions that, while influenced by the prevailing oceanographic conditions and processes in the greater Gulf of Maine-Georges Bank region, are distinct enough from the Gulf of Maine-Georges Bank system for us to conclude that the essential physical features that serve to aggregate and distribute copepods are not present in inshore areas, bays, harbors, and inlets.

Within the geographical area occupied by the species, the specific area on which are found the combination of physical and biological features of foraging habitat that are essential to the conservation of North Atlantic right whales encompasses a large area within the Gulf of Maine-Georges Bank region, including the large embayments of Cape Cod Bay and Massachusetts Bay and deep underwater basins. This area incorporates state waters from Maine through Massachusetts, as well as federal waters. The specific area on which are found the physical and biological features essential to the conservation of the North Atlantic right whale include all waters seaward of the boundary delineated by the line connecting the geographic coordinates and landmarks identified below (see Figure 9):

- The southern tip of Nauset Beach (Cape Cod)(41º 38.39' N/69º 57.32' W)
- From this point, southwesterly to 41º 37.19' N/69º 59.11' W
- From this point, southward along the eastern shore of South Monomoy Island to 41º 32.76' N/69º 59.73' W
- From this point, southeasterly to 40º 50' N/69º 12' W
- From this point, east to 40º 50' N 68º 50' W
- From this point, , north to 42º 00' N 67º 55' W
- From this point, west to 42º 00' N 67º 30' W
- From this point, northeast to the intersection of the Exclusive Economic Zone (EEZ) and 42º 10' N
- From this point, following the EEZ north to the intersection of 44º 49.724' N/66 57.833' W

From this point, moving southwest along the coast of Maine, the specific areas are located seaward of the line connecting the following points:

Latitude	**Longitude**
44º 49.67' N	66º 57.77' W
44º 48.64' N	66º 56.43' W
44º 47.36' N	66º 59.25' W
44º 45.51' N	67º 2.87' W
44º 37.7' N	67º 9.75' W
44º 27.77' N	67º 32.86' W
44º 25.74' N	67º 38.39' W
44º 21.66' N	67º 51.78' W
44º 19.08' N	68º 2.05' W
44º 13.55' N	68º 10.71' W
44º 8.36' N	68º 14.75' W
43º 59.36' N	68º 37.95' W
43º 59.83' N	68º 50.06' W
43º 56.72' N	69º 4.89' W
43º 50.28' N	69º 18.86' W
43º 48.96' N	69º 31.15' W
43º 43.64' N	69º 37.58' W
43º 41.44' N	69º 45.27' W
43º 36.04' N	70º 3.98' W
43º 31.94' N	70º 8.68' W

43º 27.63' N	70º 17'.48' W
43º 20.23' N	70º 23.64' W
43º 4.06' N	70º 36.70' W
43º 2.93' N	70º 41.47' W

Table 1a: Coordinates for North Atlantic right whale northeastern foraging critical habitat.

From this point (43º 2.93' N /70º 41.47' W) on the coast of New Hampshire south of Portsmouth, the boundary of the specific areas follows the coastline southward along the coast of Massachusetts along Cape Cod to Provincetown southward along the eastern edge of Cape Cod to the southern tip of Nauset Beach (Cape Cod)(41º 38.39' N/69º 57.32' W) with the exception of the areas landward of the lines drawn by connecting the following points:

42°53.691′ N	70°48.516′ W	TO	Hampton Harbor
42°53.516′ N	70°48.748′ W		Hampton Harbor
42°59.986′ N.	70°44.654′ W	TO	Rye Harbor
42°59.956′ N	70°44.737′ W		Rye Harbor
42°49.136′ N	70°48.242′ W	TO	Newburyport Harbor
42°48.964′ N	70°48.282′ W		Newburyport Harbor
42°42.145′ N	70°46.995′ W	TO	Plum Island Sound
42°41.523′ N	70°47.356′ W		Plum Island Sound
42°40.266′ N	70°43.838′ W	TO	Essex Bay
42°39.778′ N	70°43.142′ W		Essex Bay
42°39.645′ N	70°36.715′ W	TO	Rockport Harbor
42°39.613′ N	70°36.60′ W		Rockport Harbor
42º 20.665' N	70º 57.205' W	TO	Boston Harbor
42º 20.009' N	70º 55.803' W		Boston Harbor
42º 19.548' N	70º 55.436' W	TO	Boston Harbor
42º 18.599' N	70º 52.961' W		Boston Harbor
42°15.203′ N	70°46.324′ W	TO	Cohasset Harbor
42°15.214′ N	70°47.352′ W		Cohasset Harbor
42°12.09′ N	70°42.98′ W	TO	Scituate Harbor
42°12.211′ N	70°43.002 W		Scituate Harbor
42°09.724′ N	70°42.378′ W	TO	New Inlet
42°10.085′ N	70°42.875′ W		New Inlet
42°04.64′ N	70°38.587′ W	TO	Green Harbor
42°04.583′ N	70°38.631′ W		Green Harbor
41°59.686′ N	70°37.948′ W	TO	Duxbury Bay/Plymouth Harbor

41°58.75′ N	70°39.052′ W		Duxbury Bay/Plymouth Harbor
41°50.395′ N	70°31.943′ W	TO	Ellisville Harbor
41°50.369′ N	70°32.145′ W′		Ellisville Harbor
41°45.87'N	70°28.62'W	TO	Sandwich Harbor
41°45.75'N	70°28.40'W		Sandwich Harbor
41°44.93'N	70°25.74'W	TO	Scorton Harbor
41°44.90'N	70°25.60'W		Scorton Harbor
41°44.00'N	70°17.50'W	TO	Barnstable Harbor
41°44.00'N	70°13.90'W		Barnstable Harbor
41°45.53′ N	70°09.387′ W	TO	Sesuit Harbor
41°45.523′ N	70°09.307′ W		Sesuit Harbor
41°45.546′ N	70°07.39′ W	TO	Quivett Creek
41°45.551′ N	70°07.32′ W		Quivett Creek
41°47.269′ N	70°01.411′ W	TO	Namskaket Creek
41°47.418′ N	70°01.306′ W		Namskaket Creek
41°47.961′ N	70°0.561′ W	TO	Rock Harbor Creek
41°48.07′ N	70°0.514′ W		Rock Harbor Creek
41°48.932′ N	70°0.286′ W	TO	Boat Meadow River
41°48.483′ N	70°0.216′ W		Boat Meadow River
41°48.777′ N	70°0.317′ W	TO	Herring River
41°48.983′ N	70°0.196′ W		Herring River
41°55.501′ N	70°03.51′ W	TO	Herring River, inside Wellfleet Harbor
41°55.322′ N	70°03.191′ W		Herring River, inside Wellfleet Harbor
41°53.922′ N	70°01.333′ W	TO	Blackfish Creek/Loagy Bay
41°54.497′ N	70°01.182′ W		Blackfish Creek/Loagy Bay
41°55.503′ N	70°02.07′ W	TO	Duck Creek
41°55.753′ N	70°02.281′ W		Duck Creek
41°59.481′ N	70°04.779′ W	TO	Pamet River
41°59.563′ N	70°04.718′ W		Pamet River
42°03.601′ N	70°14.269′ W	TO	Hatches Harbor
42°03.601′ N	70°14.416′ W		Hatches Harbor
41°48.708′ N	69°56.319′ W	TO	Nauset Harbor
41°48.554′ N	69°56.238′ W		Nauset Harbor
41°40.685′ N	69°56.781′ W	TO	Chatham Harbor
41°40.884′ N	69°56.28′ W		Chatham Harbor

Table 1b: Coordinates for North Atlantic right whale northeastern foraging critical habitat (continued).

In addition, the specific area does not include waters landward of the 72 COLREGS[15] lines (33 CFR 80) described below.[16]

Portland Head, ME to Cape Ann, MA.

- A line drawn from the northernmost extremity of Farm Point to Annisquam Harbor Light.

Cape Ann, MA to Marblehead Neck, MA.

- A line drawn from Gloucester Harbor Breakwater Light to the twin towers charted at latitude 42°35.1' N. longitude 70°41.6' W.
- A line drawn from the westernmost extremity of Gales Point to the easternmost extremity of House Island; thence to Bakers Island Light; thence to Marblehead Light.

Hull, MA to Race Point, MA.

- A line drawn from Canal Breakwater Light 4 south to the shoreline.

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15 International Regulations for Preventing Collisions at Sea, 1972

16 As discussed, an analysis of right whale sightings data along the east coast indicates that endangered large whales rarely venture into bays, harbors, or inlets (70 FR 35849, June 25, 2005, NMFS 2007, 72 FR 57104, October 5, 2007).

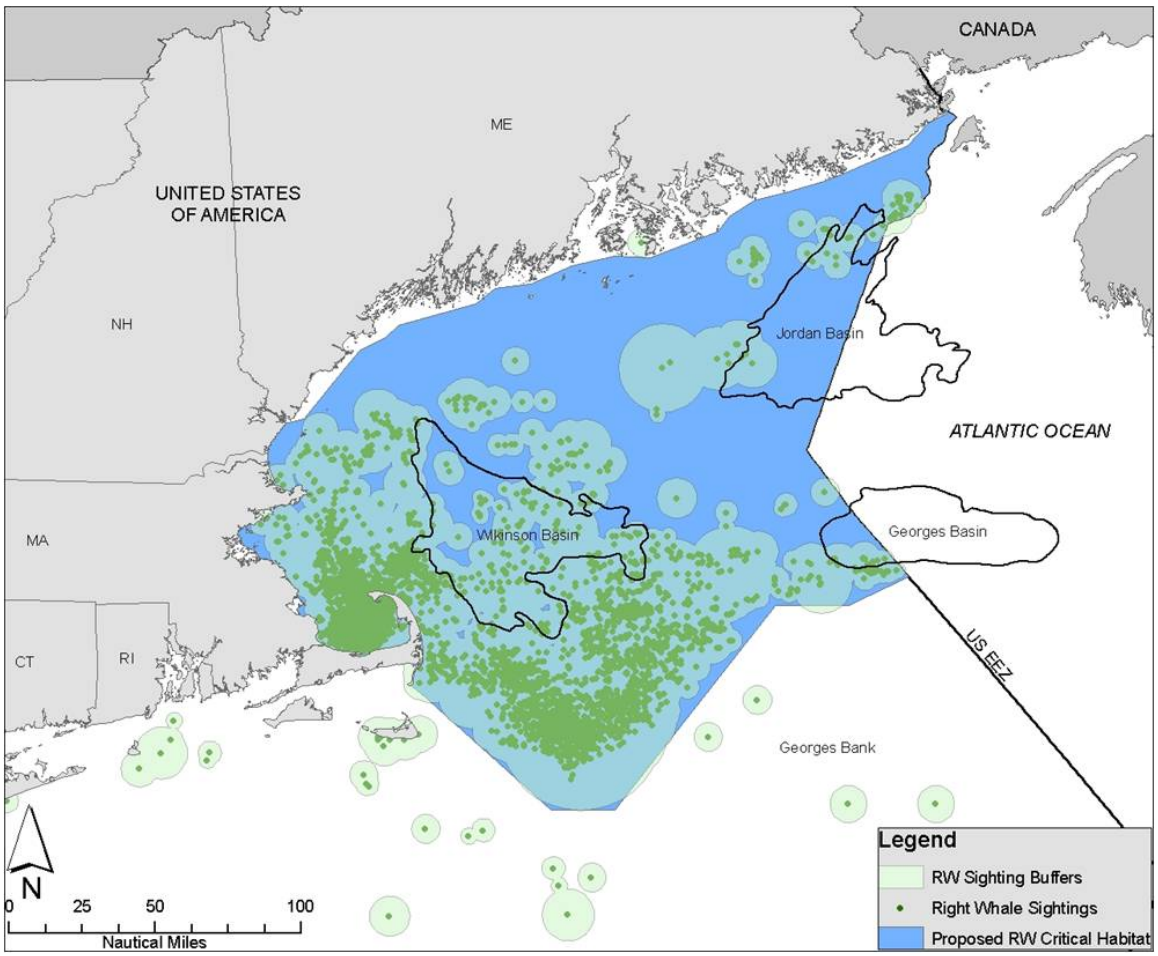

Figure 9 Specific area on which are found the essential features of North Atlantic right whale foraging habitat

All of the identified essential features for foraging right whales are present within the area shown on Figure 9. The physical oceanographic conditions, late stage *C. finmarchicus* aggregations, and aggregations of diapausing *C. finmarchicus* that have been identified as essential features are dynamically distributed throughout this specific area. This specific area represents where the essential features are most likely to be

found consistently from year to year. The basis for defining the specific area as shown in Figure 9 is explained in detail below.

6.1.1 Physical Oceanographic Structures and Conditions That Serve To Distribute and Aggregate Dense Concentrations of Late Stage *Calanus finmarchicus*

The large area depicted in Figure 9 encompasses all of the physical oceanographic conditions and structures of the Gulf of Maine-Georges Bank region, namely prevailing currents and circulation patterns, bathymetric features (basins, banks, and channels), oceanic fronts, density gradients, and temperature regimes that combine to distribute and aggregate *C. finmarchicus* for right whale foraging (see Figure 3).

6.1.2 Late Stage *Calanus Finmarchicus* in Dense Aggregations

While *C. finmarchicus* are found throughout the GoM, some regions within the GoM show more seasonal variation in abundance and age group distribution than others. Based on 10 years of data collected through the Marine Resources Monitoring, Assessment, and Prediction (MARMAP) program, Meise and O'Reilly (1996) found that total *C. finmarchicus* abundance peaked in early spring (March-April) on the Mixed Georges Bank, Tidal Front Georges Bank and Mass Bay, and late summer (July-August) in Northern GoM and Scotian-Coastal GoM (Figure 10 and Figure 11). The remaining areas peaked in copepod abundance May through June. A sharp decrease in overall copepod abundance was found by Meise and O'Reilly (1996) in the months of July through October (Figure 11). During this time period, copepod abundance decreased in all areas except for waters 50-300 m located over Jordan and Wilkinson basins in the GoM and the 200-500 m slope water seaward of Georges Bank. In these areas where

abundance did not decrease, densities of stage C5 *C. finmarchicus* exceeded densities of other life stages. Additionally, overall abundance throughout the entire GoM increased ten-fold from January through April when diapausing *C. finmarchicus* would be expected to migrate towards the surface to molt, spawn, and be advected to the rest of the GoM via depth associated increased flow and transport (see Figure 3)(Meise and O'Reilly 1996).

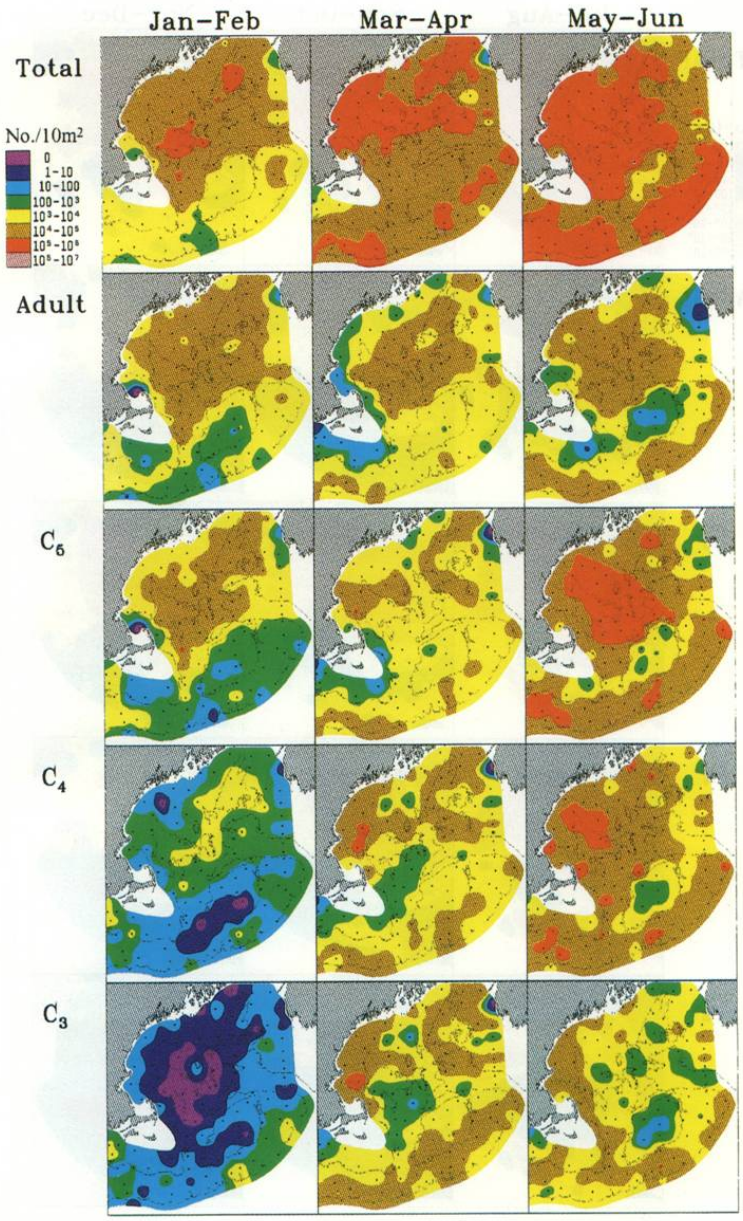

Figure 10 Seasonal distribution of *C. finmarchicus* in the Gulf of Maine-Georges Bank region, January to June (Source: Meise and O'Reilly 1995).

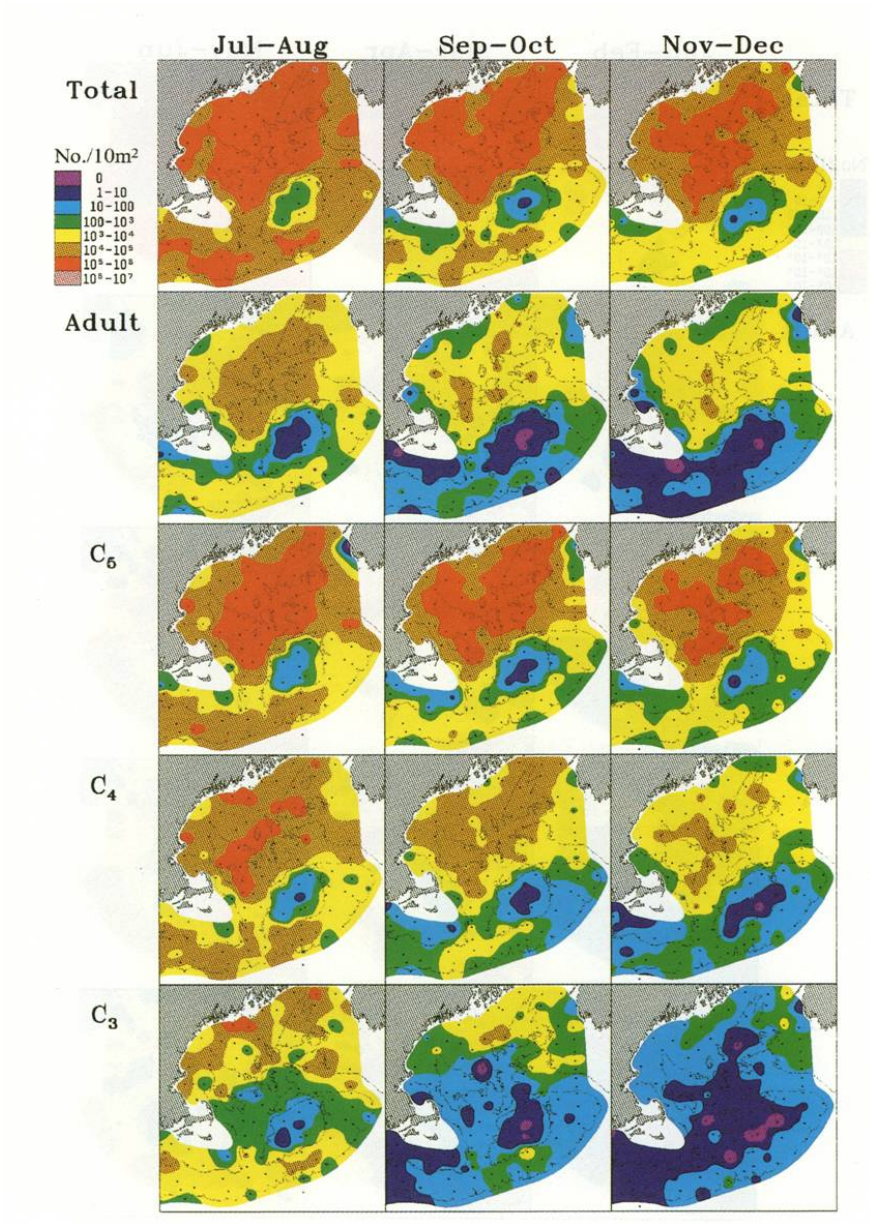

Figure 11 Seasonal distribution of *C. finmarchicus* in the Gulf of Maine-Georges Bank region, July to December (Source: Meise and O'Reilly 1995) (Continued Overleaf).

While the seasonal distributions and general patterns of abundance of *C. finmarchicus* within the Gulf of Maine and Cape Cod Bay have been documented, the geographic scales and depths at which copepods are sampled only rarely match the fine-scale at which right whales forage (Mayo and Marx 1990, Baumgartner and Mate 2003). Basin-scale zooplankton monitoring schemes have proved ineffective in detecting the high concentrations usually present in the vicinity of actively feeding whales. Furthermore, using direct copepod sampling efforts to identify where dense aggregations occur is also confounded by the fact that sufficient data are not available to establish a specific threshold density of *C. finmarchicus* that triggers feeding. For these reasons, the specific area on which are found dense aggregations of late stage *C. finmarchicus* cannot be defined by relying on data from such efforts to sample copepod aggregations directly throughout the vast Gulf of Maine and Georges Bank region.

Instead, an alternative "whale centric" sampling approach, where sampling occurs around foraging right whales, has proven to be the only effective approach for detecting dense prey patches. Given that right whales only forage on dense copepod aggregations, the location of actively foraging right whales provides a proxy for the distribution of dense copepod patches (Marx and Mayo 1990, Wishner et al 1995, Pace and Merrick 2008).

The protocol for determining the whale density and residency indicative of feeding behavior was developed by Clapham and Pace (2001) for the Dynamic Area Management (DAM) program. The DAM protocol identifies a sighting of >2 right whales close enough to each other to produce a density of 0.04 right whales/nm^2 as the minimum number and density of right whales that reliably indicates the presence of foraging

whales. The DAM protocol was used retrospectively using sighting histories from 1970-2005.[17] Pace and Merrick (2008) extracted 7,761 sighting events representing 15,395 whales (see Figure 12, in Pace and Merrick 2008). The DAM protocol was then applied to calculate the circular core sightings area and, as necessary, circular zones joined. This provided 1,292 unique events that met the criteria (definition) for a DAM (i.e., "pseudo-DAM" events) that were subsequently mapped using ARCView GIS software (Figure 13). The analyses of right whale sightings data in U.S. Northwest Atlantic waters indicate that foraging habitat is expansive and that *C. finmarchicus* is ubiquitous in the Gulf of Maine - Georges Bank region.

Seasonal movement patterns of right whales and the available literature on the distribution, abundance, and population dynamics of calanoid copepods, have identified several areas that are seasonally important for right whale foraging in the Gulf of Maine-

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[17] In 2010, we considered the years of sightings data available since the retrospective DAM analysis was conducted by Pace and Merrick (2008), and we concluded that their inclusion in the DAM analysis would not fundamentally change the outcome provided by Pace and Merrick (2008) in light of the 35 years of sightings data already used (Richard Merrick, personal communication May 2010). Since then, we have reviewed more recent NEFSC Aerial Survey Team sightings data from 2010 to present in the area south of Cape Cod off of Nantucket, Martha's Vineyard and in Rhode Island Sound (see Khan, C. et al 2010, 2011, 2012, 2014, Gatzke J. et al 2013,). Right whales have continued to be observed in these areas. In 2011, the Massachusetts Clean Energy Center (MassCEC) and BOEM established an agreement for conducting field surveys of marine life in the Massachusetts Wind Energy Area (MA-WEA) the adjacent Rhode Island Massachusetts Wind Energy Area (RIMA WEA) offshore of Rhode Island. The field surveys of marine life in the MA-WEA and the RIMA have observed right whales in this area south of Cape Cod and in Rhode Island Sound engaged in behaviors that include taking part in surface active groups (a socializing behavior), travelling, breaching, flipper slapping, and what was likely opportunistic feeding. In year 1 of the surveys (October 2011 to September 2012) a total of three right whales were sighted in separate instances engaged in sub-surface feeding, due to potential feeding opportunities (Kraus et al. 2014). In year 2 of the study (October 2012 and February 2014) one right whale was observed skim feeding at the surface in close proximity to a humpback whale (Kraus et al. 2014). There is no information available to indicate what species of zooplankton these whales were feeding on. We will continue to monitor sightings in these areas and will take appropriate action if warranted.

Georges Bank region: Cape Cod Bay (January-April), Great South Channel (April-June), western GoM (April-May and July-October), northern edge of Georges Bank (May-July), Jordan Basin (August-October), and Wilkinson Basin (April-July). The analysis showed each of these areas to be defined by a pattern of repeated DAM events, particularly in the past decade when more observations are available due to increased survey coverage and/or are the source areas that supply the copepod prey to these foraging areas (Pace and Merrick 2008).

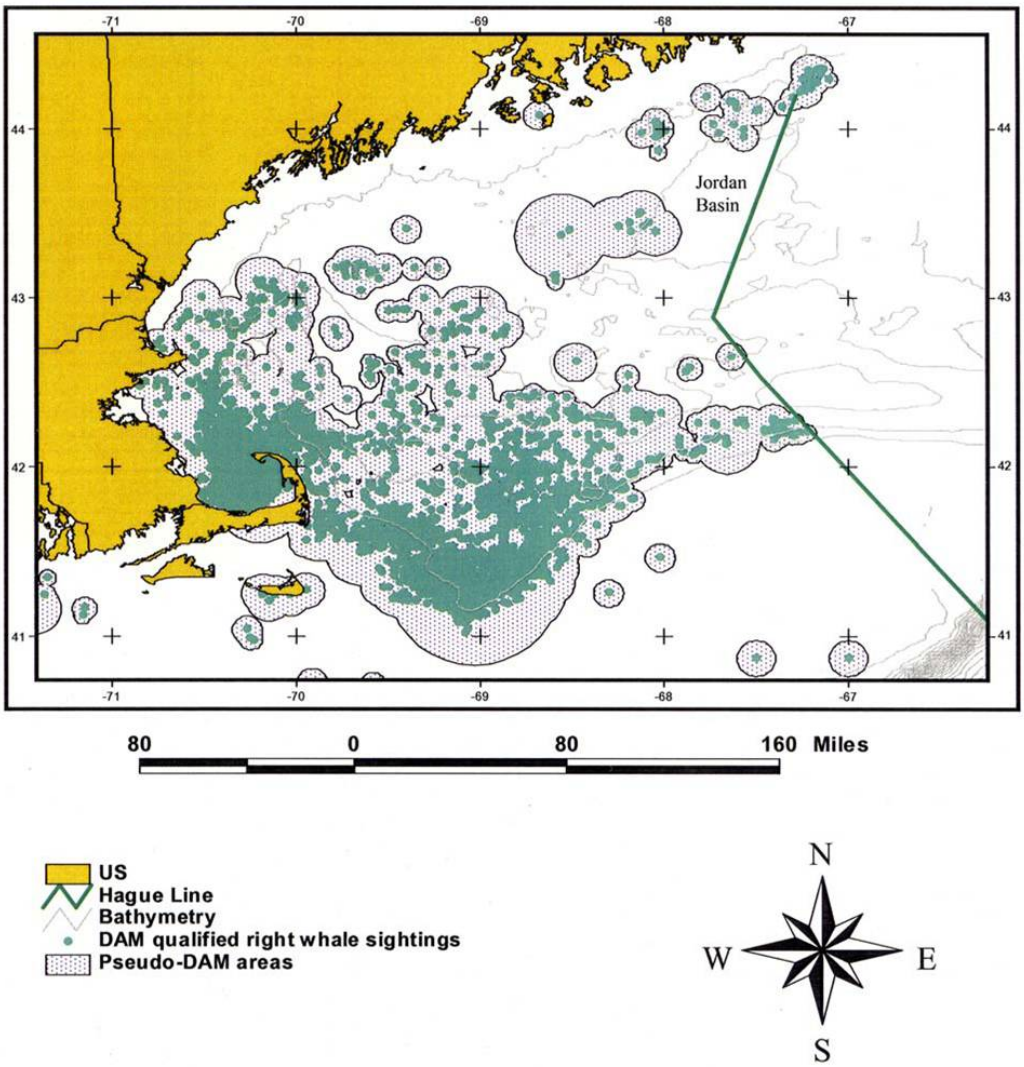


Figure 12 Location of right whale sightings found in the NARWC sightings data base for sightings meeting the DAM criteria during 1970-2005 (Source: Pace and Merrick 2008).

- **Cape Cod Bay** – This area exhibits high densities of copepods during winter, spring, and, possibly, fall as evidenced by the large numbers of feeding right whales. Of the 17,257 right whale sightings in New England during 1970

through 2005, 7,498 were in Cape Cod Bay. A total of 543 pseudo-DAM events occurred in this area, most during January-April.

- **Great South Channel** – This area has high copepod concentrations at depth, especially during March-July, as evidenced by the large numbers of feeding right whales, owing to bathymetric features and water circulation patterns. A total of 5,753 right whales were sighted in the area during 1970-2005; this included 344 pseudo-DAM events. Most right whale sightings occurred during April-June, but also in July in some years. Right whale use of the Great South Channel area is not nearly as uniform as in Cape Cod Bay, but is widespread enough to indicate that the Channel is an essential foraging area in almost every year.

- **Western Gulf of Maine** - The Western Gulf of Maine possesses a complex set of bathymetric features which markedly affect the spatial/temporal concentration of copepods among years, based on the interannual variability in right whale sightings. From 1970 through 2005, 1,749 right whale sightings (including 153 pseudo-DAM events) occurred in this area, mostly during April-May and July-October.

- **Northern Edge of Georges Bank** – This area has high copepod densities at depth, especially during May-July, as evidenced by the large numbers of feeding right whales, emanating from physical features (e.g., currents and upwelling) which concentrate late-stage copepods during spring and summer. Foraging right whales in this area are thought to be following an eastward

progression of dense copepod patch development, which begins in late spring and early summer. A total 32 pseudo-DAMs have occurred in this area. The period of greatest occupancy is during May-July.

- **Jordan and Wilkinson Basins** – Recent surveys have also determined their potential for important feeding areas.[18] Wilkinson Basin serves as a foraging area for right whales in spring. The limited survey sightings effort in Wilkinson Basin during 1970-2005 documented 1,058 individual right whales, including 104 pseudo-DAMs. Surveys have repeatedly found concentrations of right whales in this area during April-July. Right whale surveys conducted in Jordan Basin during the winter of 2004-2005 (perhaps the first winter surveys ever in this Basin) sighted up to 24 foraging right whales at a time (NMFS unpubl. data). The limited survey efforts in the area during 1970-2005 recorded a total 21 pseudo-DAM events. The available data suggest that Jordan Basin is an important right whale foraging area, at least during August–October.

Sightings (and pseudo-DAM events) occur to the south and east of the area described above and depicted in Figure 9. However, a pattern of repeated annual observations is not evident in these areas. Typically, whales were sighted in these areas in one year, but were not seen again for a number of years. As a result, those areas do not appear to have the combination of essential physical and biological features that is evident in the GoM-Georges Bank region. Most likely, these are sightings of whales that fed

[18] As discussed, Jordan and Wilkinson Basins, along with Georges Basin also serve as refugia areas for copepods (Figure 2 and Figure 3), which are then the source for most of the copepod patches on which right whales forage during the following spring and summer.

opportunistically on various zooplankton species while migrating to the GoM (Richard Merrick, personal communication May 2010). As discussed above, researchers have documented right whales foraging on the copepods *Pseudocalanus and Centropages typicus* as well as barnacle larvae (Mayo and Marx 1990 in Baumgartner et al. 2007). These observers noted, however that right whales quickly ceased foraging on these zooplankton assemblages indicating that the prey was likely not suitable (Baumgartner et al. 2007).

In April 2010 a large number of right whales engaged in feeding were sighted in Rhode Island Sound. This unusual sighting off Rhode Island represents the largest group of right whales ever documented in those waters in over 35 years of right whale survey effort. In March of 2010, one month prior to this rare right whale aggregation, New England was impacted by three, unprecedented and historic rainfall events and subsequent record flooding (Thompson 2013). The highest of amounts rainfall occurred from Narragansett Bay, Rhode Island northward along the southern New England coast (Zarriello and Bent 2011). Due to these floods, a very large pulse of nutrient-rich and freshwater was discharged from Narragansett Bay into Rhode Island Sound.

It is believed that the discharge of nutrient-rich, fresh water into Rhode Island Sound resulted in a massive bloom of phytoplankton and zooplankton in Rhode Island Sound. It is highly likely, that this phytoplankton and zooplankton bloom is the underlying explanation for the presence of the large numbers of right whales sighted in this area in April 2010. There was no sampling of zooplankton associated in the area foraging right whales were observed congregating and thus we do not know what species were present or what right whales were feeding on.

We know that the aggregation of right whales sighted in late April had abandoned the area by May. This is consistent with Baumgartner et al (2007) findings that right whales will feed on other species of copepods but quickly cease foraging as the prey is not suitable to meet its energetic requirements. Based on historic sightings data, this event represents an anomaly not likely to be repeated given the rarity of the meteorological conditions that produced the historic New England floods of March 2010.

Zooplankton are found throughout the ocean, but frequently at concentrations far too low to meet right whales' energetic requirements (Baumgartner et al. 2007). No zooplankton sampling was conducted in the vicinity of feeding right whales in Rhode Island Sound, and it is unknown what exactly the rights present were feeding on.

While right whales have also been observed preying on other similarly sized copepods and juvenile *euphausiids*, the late developmental life stages (stages C4-C5) of the copepod, *C. finmarchicus* are generally recognized as the North Atlantic right whale's primary prey (Watkins and Schevill 1976, 1979, Kenney et al. 1986, 1995, Wishner et al. 1988, 1995, Murison and Gaskin 1989, Mayo and Marx 1990, Beardsley et al. 1996, Kenney et al. 2001, Baumgartner 2003b). When compared to other copepods, *C. finmarchicus* has a much larger biomass and higher caloric content (Baumgartner et al. 2007).

6.1.3 Low flow velocities in Jordan, Wilkinson, and Georges Basin and diapausing *Calanus finmarchicus* in aggregations in the Gulf of Maine and Georges Bank region.

Low flow velocity environments that allow the neutrally buoyant, high lipid content copepods to passively aggregate below the convective mixed layer and be retained for a period of time are in the three deep basins--Wilkinson, Jordan and Georges Basins--

within the GoM, with boundaries approximated by the 200 m isopleths. These basins with low flow velocity environments provide refugia habitat for diapausing *C. finmarchicus* source populations that are essential to the conservation of the North Atlantic right whale.

6.2 Specific Area for Calving Habitat Essential Features

The essential features of right whale calving habitat are dynamic in their distributions throughout the SAB in that they vary over both time and space, and their variations do not necessarily correlate with each other. For example, as the winter season approaches sea surface temperatures in the SAB region begin to cool from their summer maximums. Cooling is not instantaneous nor does it occur evenly across the region. As already discussed, right whale mother-calf pairs occupy a discrete temperature range (7 to 17°C). As the winter season progresses, the spatial distribution of this preferred temperature range is likely to shift in response to both the prevailing air temperatures and winds. Sea surface temperatures vary not only seasonally, but annually as well (Keller et al. 2012). Additionally, right whale mother-calf pairs tend to occupy the calmest waters early in the calving season when most (if not all) calves are in their first weeks of life (Good 2008). Later in the calving season, right whale mother-calf pairs tend to occupy rougher waters when there are a higher number of more mature calves (Good 2008). Neonates also are weaker swimmers that have a difficult time surfacing in rougher waters. Calving right whales, therefore, likely select areas containing varying combinations of the preferred ranges of the essential features, as identified above, available within the SAB depending on factors such as the weather (e.g., storms, prevailing winds) and the age of the calves (e.g., neonate or more mature calf). In order to identify specific areas that may contain

the essential features, we used the predictive habitat models of Garrison (2007), Good (2008) and Keller et al. (2012). These models help identify areas within the SAB where the essential features are likely to be present contiguously and consistently throughout the calving season.

In Garrison's (2007) and Keller et al.'s (2012) models, the spatial extent of potential calving habitat is based upon the average environmental conditions for each 4 km x 4 km sampling unit and the resulting use of these areas by calving right whales. The model also reflects the processes observed in the Florida-Georgia region only. Based upon the mean water temperatures between December and March, the model predicts calving habitat for right whales in waters typically between 10 and 50 km from shore and extending from New Smyrna Beach, Florida, north to Cape Fear, North Carolina. The optimal temperature range within the 75th percentile of predicted sighting rates for calving right whales occurs throughout much of the spatial range. Over the course of the entire calving season (December through March), the preferred water depth (6 to 28 m) and sea surface temperature (7 to 17°C) ranges for calving right whales correspond with predicted sighting rates of calving right whales in the 75th percentile, which accounts for 91 percent of all observed calving right whales. The area containing the 75th percentile of predicted sighting rates for calving right whales extends from approximately Daytona Beach, Florida, north to just beyond the Georgia/South Carolina state border (see Figure 13).[19] The area covered by the 75th percentile of predicted sighting rates allows for

[19] While the model predicts calving habitat for right whales in waters extending from New Smyrna Beach, Florida, north to Cape Fear, North Carolina, Garrison (2007) calculated the area for the 75th percentile only to the Georgia/South Carolina border. Garrison (2007) stated that data available at the time were insufficient to evaluate whether or not regions north of this border are also optimal calving habitats. The model reflects processes observed in the Florida-Georgia region only, which may not reflect processes offshore of South Carolina and North Carolina.

seasonal and annual variability of the distribution of the essential features, particularly sea surface temperatures as evaluated by Garrison (2007) and Keller et al. (2012), and allows for the greatest potential availability of contiguous areas of dynamic combinations of the essential features for selection by calving right whales.

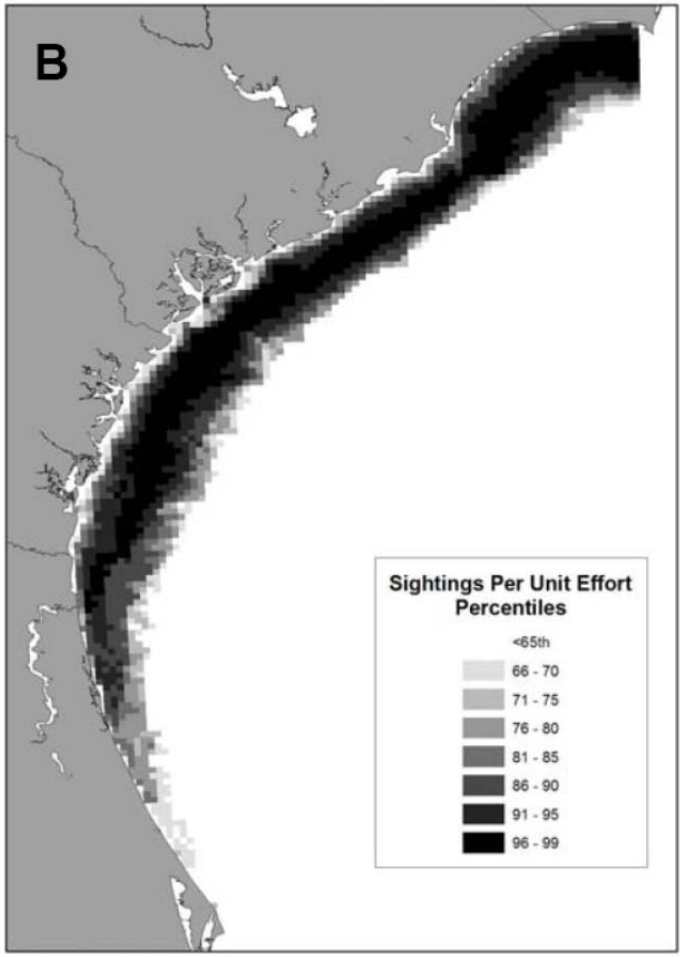


Figure 13 Calving right whale sightings per unit effort (SPUE) percentiles along the mid-Atlantic coast based upon average sea surface temperatures during December through March (Garrison 2007).

Because the model selection processes used by Garrison (2007) and Keller et al. (2012) selected annual effects, sea surface temperature and water depth but not sea state (roughness) or wind conditions and right whale mother-calf distribution, we also looked at where Good's (2008) model predicted potential right whale calving habitat to be, based on this variable as well as sea surface temperature and water depth. Good (2008) calculated the relative density of calf sightings over each 5 km x 5 km sampling unit and

measured the habitat conditions where right whale mother-calf pairs were sighted. These calculated habitat values (sea surface temperature, sea surface roughness, and water depth) then were used to derive a "likelihood surface" of calving habitat for the model. The model was run to predict potential habitat for each month of the calving season and for all four months of the calving season combined. This combined model provided a measure of temporal continuity by delineating the number of months (December through March) a given area was selected as potential calving habitat. The combined model is the best representation of potential calving habitat both in time and space (Good 2008)

Overall, the model predicted the presence of potential right whale calving extending within 40 to 50 km of shore from Cape Lookout, North Carolina, south to approximately New Smyrna, Florida. Areas predicted by the model to be potential right whale calving habitat in three or more months accounted for 85 percent or more of all observed right whale mother-calf sightings. Figure 14 shows the extent of predicted potential right whale calving habitat in the southeastern U.S. This figure was generated using higher resolution sea surface temperature data (1.47 km) with the predictive habitat model developed by Good (2008).

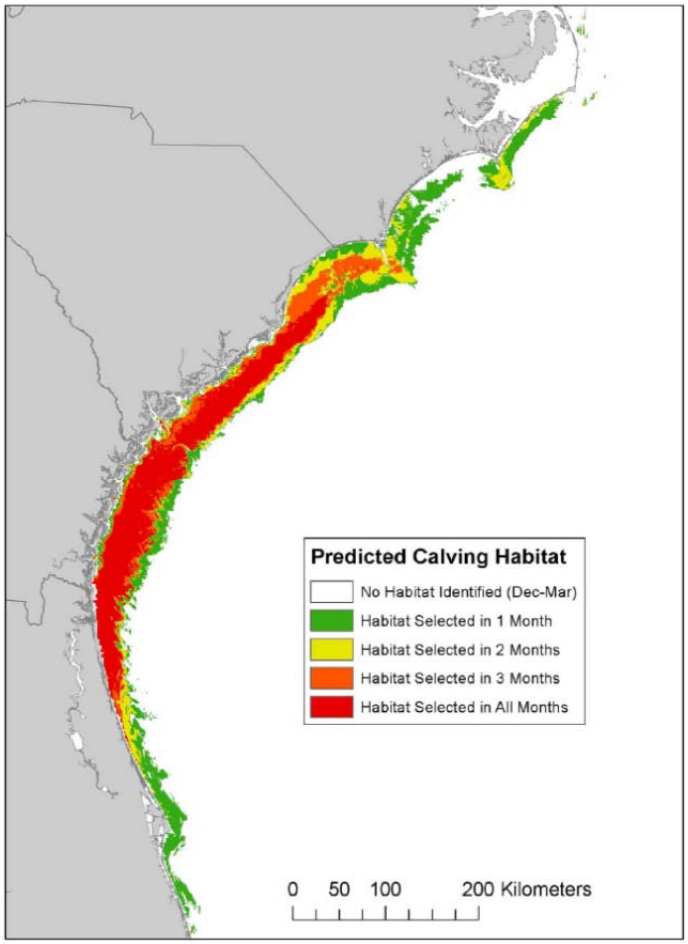


Figure 14 Predicted right whale calving habitat in the southeastern U.S. for each month and all months of the winter calving season (C. Good, Pew Trust, pers. comm., 1/15/2010).

On February 20, 2015, NMFS published a proposed rule to revise critical habitat (80 FR 9314) and received a number of comments in support of retaining the southern portion of the 1994-designated right whale calving area critical habitat. Commenters supported a more southerly boundary because: (1) sightings of mother/calf pairs (available at http://www.nefsc.noaa.gov/psb/surveys/) reported since Good's analysis indicate that

waters south of proposed Unit 2 are used consistently by mother-calf pairs, (2) the agency previously recognized the area as critical to calving right whales, (3) calves are observed in the area so the areas should be protected even though they are not part of the area selected by the habitat models, (4) Good's model (available at: http://dukespace.lib.duke.edu/dspace/handle/10161/588) predicts calving habitat in the area for at least part of the calving season, and (5) right whales utilize the area at above-average densities. The southern portion of the 1994-designated critical habitat wasn't included in the proposed revision because it did not contain the proposed essential calving features in either 3 or 4 months of the calving season in any of the models.

In response to comments concerning the southern boundary, we investigated observations of mother-calf pairs collected subsequent to the data used in the cited models and re-examined Garrison (2007), Good (2008), and Keller et al. (2012).

We reviewed the North Atlantic Right Whale Consortium Database (2015) (available at http://www.narwc.org/index.php?mc=8&p=28), for mother-calf pair sightings south of the proposed Unit 2 and from the 2001/2002 calving season to present. We used this timeframe because Garrison (2007) and Keller et al. (2012) used Consortium data through March 2001. We found 36 mother-calf pair sightings at an annual sighting rate of just under three mother-calf pairs (highest annual number of pair sightings was 10). Of these, January and February sightings were most prevalent and totaled 12 and 19, respectively. While the number of sightings varies among years, sightings of mother-calf pairs within that area are predictable and consistent, as noted by some of the commenters.

Since occupied critical habitat must be based on the presence of features essential to the species' conservation that may require special management considerations or protection, we re-evaluated the predictive habitat model results in terms of temporal distribution of the essential depth, temperature, and sea surface roughness features.

First, we reviewed the models and temporal scales of model outputs. Garrison's (2007) and Keller et al.'s (2012) models at the 4-month (season-level) temporal resolution (as illustrated in Garrison's Figure 19 and Keller et al.'s Figure 7), which were used for the proposed designation, do not predict presence of all the essential features south of the proposed boundary. This is because the 4-month scale obscured the areas containing the essential features for a smaller timeframe (i.e., one month). Garrison's (2007) model output at a finer temporal resolution (monthly scale) does predict presence of the essential features south of the proposed revised critical habitat for at least a portion of the calving season (in January and February) (see Garrison's Figure 22). Good's (2008) model outputs are similar. The presence of all the essential features is not predicted to simultaneously co-occur south of the proposed unit boundary for the coarser temporal scale of 3 or 4 months, but the essential features are expected to simultaneously co-occur over a contiguous area in the finer, 1-month temporal scale. Good's model also predicts presence of the essential features south of the proposed revised critical habitat in January and February, and to a lesser degree, in December. Thus, this southern area contains the essential features at times when the majority of the right whale cow-calf pairs have been observed here in the years since the models were published. Mother/calf pairs in the area were most often seen swimming (n=23) but other behaviors were observed, too (diving - 7, breaching-1, and slapping the water with flippers or tails-2) (Right Whale Consortium 2015). The high number of observations of swimming mother/calf pairs in this area is

consistent with our analysis that mother-calf pairs likely loop many miles up and down the coast in the calving area to strengthen calves' swimming abilities. Apparent nursing was also observed in the area (n=4) and mother-calf pairs were also seen in physical contact with each other (n=9).

Therefore, we believe the available data show consistent and predictable presence of right whale cow-calf pairs in this southern area, during the months the habitat models predict presence of all the essential features.

To determine the boundaries of the specific area containing the essential features identified for North Atlantic right whale calving, we used ArcGIS to overlay shape files for:

- the 75th percentile of predicted sighting rates for calving right whales from Garrison (2007) and Keller et al. (2012) (see Figure 13),
- Good's (2008) habitat selected in three and four months off Georgia through North Carolina (see orange and red areas in Figure 14),
- Good's (2008) habitat selected in at least one month (green area in Figure 14) from Daytona Beach to just south of Melbourne, Florida (i.e. the southern portion of 1994-designated calving critical habitat Figure 14).

Given that the 75th percentile from Garrison (2007) and Keller et al. (2012) and Good's (2008) habitat selected in three and four months account for 91 and 85 percent of all observed right whale mother-calf pair sightings, respectively, Good's (2008) combined (four month) model is the best representation of potential optimal seasonal calving habitat both in time and space, and Good's (2008) one month model also predicts suitable habitat south of Cape Canaveral, Florida where right whale mother-calf pairs have been

predictably and consistently observed in recent years; we believe these predicted habitat areas are the best basis for determining where specific areas of right whale calving habitat are in the southeastern U.S. These areas capture the sliver of cooler water (< 20°C) that hugs the Florida coastline during January through March, allow for seasonal and annual variability of the distribution of the essential features, and allow for the greatest potential availability of large, contiguous areas containing the preferred ranges of the essential features that will allow right whale mother-calf pairs to dynamically select optimal combinations of the features throughout the calving season.

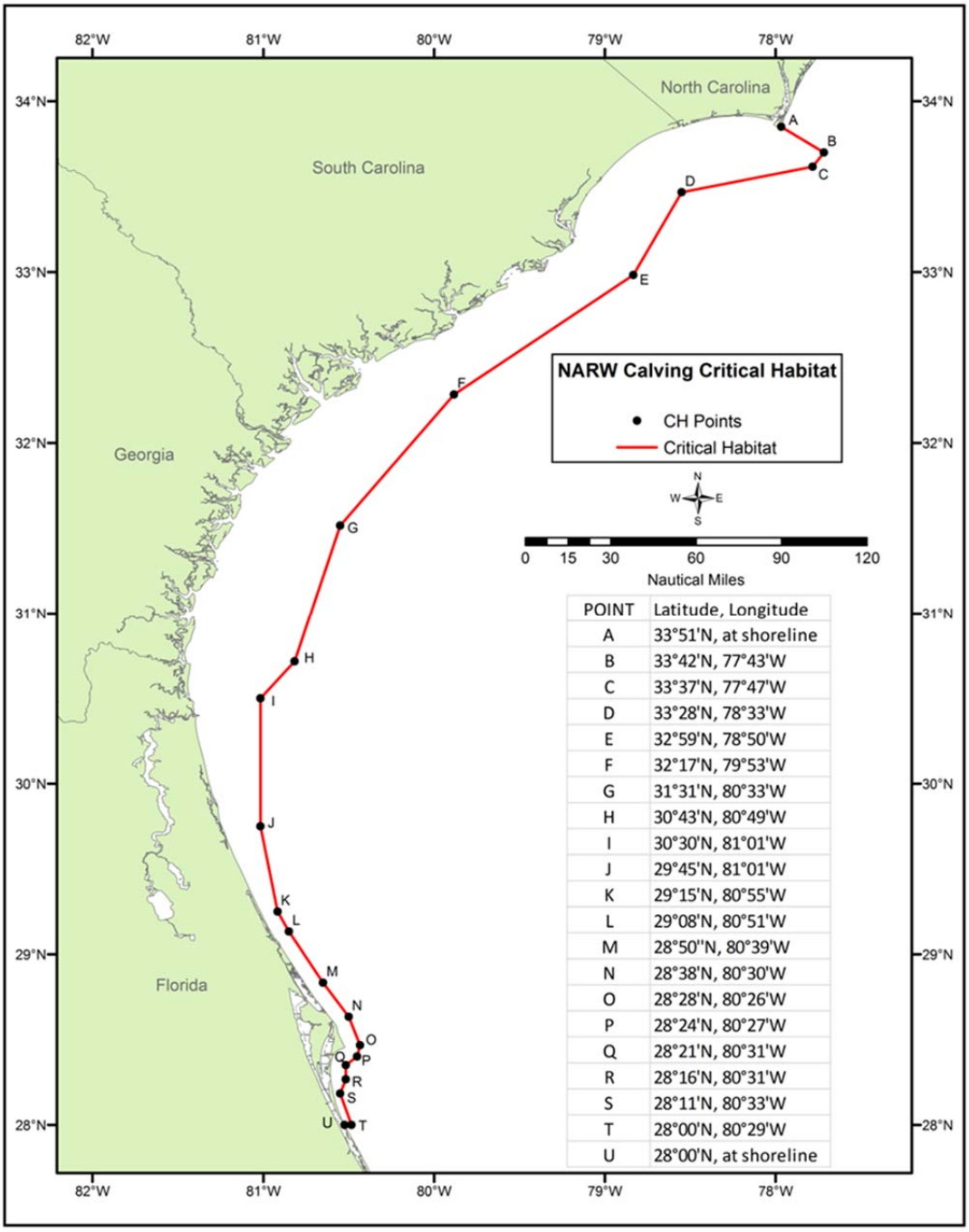
Based on these models and other information described above, which we believe is the best available information, the Southeast Calving Area consists of all waters contained within the area bounded by straight lines connecting the following points in the order stated from north to south in Table 2.

Point	Latitude	Longitude
A	33°51'	at shoreline
B	33°42'	77°43'
C	33°37'	77°47
D	33°28'	78°33
E	32°59'	78°50'
F	32°17'	79°53'
G	31°31'	80°33'
H	30°43'	80°49'
I	30°30'	81°01'
J	29°45'	81°01'
K	29°00'	80°52'
L	29°08'	80°51'
M	28°50'	80°39'
N	28°38'	80°30'
O	28°28'	80°26'
P	28°24'	80°27'
Q	28°21'	80°31'
R	28°16'	80°31'
S	28°11'	80°33'
T	28°00'	80º29’
U	28°00'	At shoreline

Table 2: Coordinates for North Atlantic right whale southeastern calving critical habitat.

Consistent with our regulations (50 CFR 424.12(d)), we identified one “specific area” within the geographical area occupied by the species at the time of listing that contains the essential features for calving right whales in the southeastern U.S (see Figure 15). This area comprises all waters of Brunswick County (North Carolina); Horry, Georgetown, Charleston, Colleton, Beaufort, and Jasper Counties (South Carolina); Chatham, Bryan, Liberty, McIntosh, Glynn, and Camden Counties (Georgia); and all of Nassau, Duval, St. John's, Flagler, and Volusia Counties, and a large portion of Brevard County (Florida). This area is bounded by the coordinates listed in Table 2. Within this specific area, the essential features consist of calm sea surface conditions of Force 4 or

less on the Beaufort Wind Scale, sea surface temperatures from a minimum of 7°C, and never more than 17°C, and water depths of 6 to 28 meters. These features are present over contiguous areas of at least 231 nmi^2 of ocean waters between November and April each year. The features are available to and selected by right whale mothers and calves in dynamic combinations that are suitable for calving, nursing, and rearing, and which vary depending on factors such as weather and age of the calves. The essential features of calm sea surface conditions and sea surface temperatures are dynamically distributed throughout this specific area due to seasonal and annual trends in prevailing wind patterns and air temperatures. This specific area represents where the essential features are most likely to be found consistently and continually throughout the right whale calving season and from year to year. Further, based on data about the historical distribution of this species, right whales are likely to calve anywhere within the boundaries of the specific area. Given this species' reduced abundance, the specific area was identified to include all available potential calving habitat within the SAB to maximize the potential for successful calving, nursing, and rearing of offspring, based on the modeling and mapping of where the essential features are most likely to be present during the calving season.



POINT	Latitude, Longitude
A	33°51'N, at shoreline
B	33°42'N, 77°43'W
C	33°37'N, 77°47'W
D	33°28'N, 78°33'W
E	32°59'N, 78°50'W
F	32°17'N, 79°53'W
G	31°31'N, 80°33'W
H	30°43'N, 80°49'W
I	30°30'N, 81°01'W
J	29°45'N, 81°01'W
K	29°15'N, 80°55'W
L	29°08'N, 80°51'W
M	28°50''N, 80°39'W
N	28°38'N, 80°30'W
O	28°28'N, 80°26'W
P	28°24'N, 80°27'W
Q	28°21'N, 80°31'W
R	28°16'N, 80°31'W
S	28°11'N, 80°33'W
T	28°00'N, 80°29'W
U	28°00'N, at shoreline

Figure 15 Southeastern Calving Critical Habitat for North Atlantic Right Whales.

7. Whether the Essential Physical and Biological Features "May Require Special Management Considerations or Protections"

Specific areas within the geographical area occupied by a species may be designated as critical habitat only if they contain physical or biological features that "may require special management considerations or protection." A few courts have interpreted aspects of this statutory requirement, and the plain language aids in its interpretation. For instance, the language clearly indicates the features, not the specific area containing the features, are the focus of the "may require" provision. Use of the disjunctive "or" also suggests the need to give distinct meaning to the terms "special management considerations" and "protection." Generally speaking, "protection" suggests actions to address a negative impact or threat of a negative impact. "Management" seems plainly broader than protection, and could include active manipulation of a feature or aspects of the environment. Three federal district courts, focusing on the term "may," ruled that features can meet this provision based on either present requirements for special management considerations or protections, or on possible future requirements (see, Center for Biol. Diversity v. Norton, 240 F. Supp. 2d 1090 (D. Ariz. 2003); Cape Hatteras Access Preservation Alliance v. DOI, 344 F. Supp. 108 (D.D.C. 2004); Alaska Oil and Gas Assoc. et al., v. Salazar, 2013 U.S. Dist. LEXIS 10559 (D. AK 2013)). The Arizona district court ruled that the provision cannot be interpreted to mean that features already covered by an existing management plan must be determined to require "additional" special management, because the term "additional" is not in the statute. Rather, the court ruled that the existence of management plans may be evidence that the

features, in fact, require special management (Center for Biol. Diversity v. Norton, 1096–1100). The Alaska district court noted that the "may require" provision is not a high threshold ("The ease with which the special-management-considerations-or-protection requirement can be satisfied almost renders such requirement nonexistent." (2013 U.S. Dist. LEXIS 10559 at 24)). The Alaska district court held further that, "…neither the Service nor the ESA have to be the vehicles by which the procedures or actions involved in the considerations or protection are accomplished. The Service has shown that someday, not necessarily at this time, such considerations or protection *may* be required. In other words, the Service has shown that it is within the realm of possibility that such considerations or protection may be needed now or in the future. Furthermore, the Service does not have to identify the source of such considerations or protection, merely that the considerations or protection may be necessary in the future."(*Id*. at 26-27). NMFS's regulations define "special management considerations or protections" to mean "any methods or procedures useful in protecting physical and biological features of the environment for the conservation of listed species" (50 CFR 424.02(j)).

Based on the discussion above, NMFS evaluated whether the essential features may require special management considerations or protections by evaluating four criteria:
(a) Whether there is presently a need to manage the feature;
(b) Whether there is the possibility of a need to manage the feature;
(c) Whether there is presently a negative impact on the feature; or
(d) Whether there is the possibility of a negative impact on the feature.

In evaluating present or possible future management needs for the essential features, NMFS recognized that the features in their present condition must be the basis for a

finding that these are essential to the North Atlantic right whale's conservation. In addition, the needs for management evaluated in (a) and (b) were limited to managing the essential features for the conservation of the species. In evaluating whether the essential features meet either criterion (c) or (d), we evaluated direct and indirect negative impacts from any source (e.g., human or natural). However, NMFS only considered the criteria to be met if impacts affect or have the potential to affect the aspect of the feature that makes it essential to the conservation of the species. We also evaluated whether the essential features for calving met the "may require" provision separately from the essential features for feeding.

7.1 Special Management Considerations or Protections May be Required for the Essential Physical and Biological Features of Foraging Habitat

Essential features of right whale foraging habitat may require special management considerations or protections because of possible negative impacts from the following activities and events: (1) zooplankton fisheries, (2) effluent discharge from municipal outfalls, (3) discharges and spills of petroleum products to the marine environment as a result of oil and gas exploration, development and transportation; and (4) climate change. The impacts to the four essential features may negatively impact the extent to which these features provide for efficient foraging on an abundance of high energy, dense *C. finmarchicus* aggregations, which are necessary to support right whale energetic and reproductive needs.

7.1.1. Zooplankton Fisheries

The essential foraging habitat features that may be affected by zooplankton fisheries are the late stage *C. finmarchicus* copepods in dense aggregations and diapausing *C. finmarchicus* aggregations in Jordan, Wilkinson, and Georges Basins in the Gulf of Maine and Georges Bank region. Currently the largest zooplankton fishery is the krill fishery, with harvests taking place in Antarctic, Japanese, Australian and Canadian waters (Northeast Pacific and Northwest Atlantic) with the most significant harvests taking place in Antarctica (targeting *Euphasia superba*) and in the Pacific (targeting *Euphasia pacifica*). However, given zooplankton are pervasive throughout the Gulf of Maine and Georges Bank region, and the region's oceanographic conditions and structures combine to aggregate zooplankton, thereby making harvest more efficient, it is possible that the Gulf of Maine and Georges Bank region may support a zooplankton fishery in the future. Even if the fisheries target krill, it is possible that in doing so they will adversely affect late stage *C. finmarchicus* either in dense aggregations upon which right whales feed or the diapausing copepods aggregating in the three deep basins.

While directed zooplankton fisheries have primarily focused efforts on the larger krill species, copepod fisheries have also been attempted. To date, copepod fisheries in Canada and Norway have been limited in scope; however, given the development of new economic demands and more efficient harvesting technology, the copepod fishery has the potential to become a viable fishery in the future.

In 1991, the Canadian Department of Fisheries and Oceans (DFO) issued a scientific permit to harvest zooplankton (both krill and copepods) in the Gulf of St. Lawrence. In November 1993, an exploratory fishery for copepods and krill was initiated in the St.

Lawrence Estuary off Ste-Anne-des-Monts and continued for at least two more years (Runge and Joly 1995).

In addition to this effort in Canadian waters, research concerning the harvest of *C. finmarchicus* in the North Atlantic has continued in the Northeast Atlantic. In 2007, Norwegian researchers filed a patent for a new Calanus®-derived product to counteract infection of sea-lice in farmed salmon and trout. Sea lice infestations are a concern in Maine and Canada, where wild populations and several large-scale salmon aquaculture sites exist.

In January 2008, the Norwegian Directorate of Fisheries awarded a Norwegian Company, Calanus AS renewed and expanded license to harvest *C. finmarchicus* in the Norwegian Economic Zone (Calanus® 2008a). The company intends to expand activities in the years to come and to continue the development of "harvesting technology, including developing more robust equipment which is suitable for larger fishing vessels, harvesting in oceanic water, and more rugged weather conditions." In April 2008, the company entered into a contract with Skretting, the world's largest salmon and trout aquaculture feed production firm, for this product's research and development and subsequent distribution of the Calanus®-derived sea lice deterrent (Calanus® 2008b). In May 2008, Calanus AS submitted a new patent application for a unique trawl that will specialize in the capturing of small crustaceans such as *C. finmarchicus*. The trawl is designed to increase harvesting efficiency and selectivity while reducing towing resistance and increasing net strength (Calanus® 2008c.). This company is also currently engaged in the development of other uses for *C. finmarchicus* in aquarium feed, health and

nutritional products, dietary supplements, flavoring ingredients, bioactive compounds for cosmetics, and pharmaceuticals (Calanus® 2009.).

Nicol and Endo (1997) predict the demand for krill will also increase as future demands increase for pharmaceutical and aquaculture products (Payne et al. 2001, Suontama 2004). As harvesting technology for *C. finmarchicus* becomes more efficient, these increased demands may also increase the demand for *C. finmarchicus* products. These demands may develop to the point where they provide an economic justification for zooplankton fishing or at least may be instrumental in putting these fisheries on a sound economic basis (Nicol and Endo 1997, Suontama 2004, Piasecki et al. 2004).

While there is not currently a directed copepod fishery in the Northwest Atlantic and GoM, one is a real possibility given there is interest in, if not demand for, zooplankton, generally, and *C. finmarchius*, specifically. Since *C. finmarchicus* occupies a large percentage of the GoM's area and biomass, and the physical oceanographic conditions and structures create dense aggregations of copepods in the water column and harbor them in deep basins thereby making harvest more efficient, the essential biological features of foraging habitat in the Gulf of Maine and Georges Bank region may be negatively affected if worldwide demand for *C. finmarchicus* products continues to rise. Therefore, the essential biological features--late stage *C. finmarchicus* copepods in dense aggregations and diapausing *C. finmarchicus* aggregations in Jordan, Wilkinson, and Georges Basins in the Gulf of Maine and Georges Bank region--may require special management considerations or protections. It is possible that the aggregations of diapausing copepods might be significantly dense to make them harvestable should a copepod fishery occur.

7.1.2. Sewage Outfalls

Several municipalities from Maine to Massachusetts have waste discharge facilities that empty into the Gulf of Maine system. Coastal runoff is also a source of nutrient inputs to the ocean. Increased nutrient input from outfall effluent and coastal runoff in the GoM region may change the phytoplankton community structure, enhancing nuisance and/or less desirable forage species that result in decreased productivity and/or changes in the distribution and densities (especially changes to high density patches) of *C. finmarchicus* populations.

While one outfall facility may not have an impact on the entire GoM ecosystem, the cumulative impacts of all sewage input warrant management considerations of monitoring, at least, and possibly restrictions or other types of measures. Monitoring results from the Boston outfall in Massachusetts Bay support this concern. In 2000, the Massachusetts Water Resource Authority (MWRA) implemented a new ocean outfall system 15.2 miles offshore, in Massachusetts Bay, as part of a Boston Harbor Cleanup program. This system upgraded the previously primary sewage treatment to secondary treatment, reduced industrial contaminants, and eliminated sewage sludge discharge into Boston Harbor (Bothner and Butman 2007). Despite improvement to Boston Harbor itself, this project relocated an estimated 350 million gallons of treated effluent per day into the hydrodynamic system of Massachusetts Bay and Cape Cod Bay (PCCS 2005, Bothner and Butman 2007). Concerns have been raised about the affect this discharge may have on water quality and its potential impacts on *C. finmarchicus* and the dense aggregations of the copepod upon which right whales feed (NMFS 1993).

In 1993, NMFS issued a biological opinion on the MWRA project, which analyzed the

impact of increased nutrient input into the Massachusetts Bay and Cape Cod Bay from this new system. It also included monitoring recommendations, and a monitoring plan was developed by the MWRA. Concerns included potential changes to the phytoplankton community structure, including enhancement of nuisance and/or less desirable forage species that result in decreased productivity and/or changes in the distribution of *C. finmarchicus* and densities of its aggregations.

One potential impact on the dense patches of *C. finmarchicus* may be due to eutrophication effects caused by nutrient input. It is hypothesized that inshore copepod species are characteristic of estuarine waters, rather that Massachusetts Bay coastal waters, due to food limitation. If this is the case, with increased nutrient input and increased primary productivity, Massachusetts Bay plankton communities could shift to being dominated by *Acartia* and other inshore copepods, therefore displacing the high concentrations of offshore copepods such as *C. finmarchicus* from these areas during seasons when they are normally present and serve as a food source for right whales (Werme and Hunt 2006).

Increased nutrient input, "particularly nitrogen, could over-stimulate algal blooms, which would be followed by low levels of dissolved oxygen in the bottom waters when the phytoplankton die, sink, and decompose," thereby providing habitat unsuitable for *C. finmarchicus* (Werme and Hunt 2006). Another potential impact of nitrogen input relates to the stimulation of the growth of detrimental algae, such as the dinoflagellate *Alexandrium fundyense*, the diatom *Pseudonitzschia mutiseries,* and the colonial flagellate *Phaeocystis pouchetti*. *Phaeocystis pouchetti,* for example, is not toxic but individual cells can aggregate in gelatinous colonies that provide poor food for

zooplankton (Werme and Hunt 2006).

In 2002, Provincetown Center for Coastal Studies (PCCS) documented a "shift from the predominant winter-spring zooplankton resources, *C. finmarchicus,* to the estuarine copepod *Acartia* spp. in Cape Cod Bay" (PCCS 2003). During this same season, MWRA and PCCS also documented a significant increase in nuisance algae, *Phaeocystis pouchetti* in Cape Cod Bay. Though there was no direct [statistically significant] evidence that these two events were related, or that the events were caused by nutrient influx from this particular sewage outfall, PCCS noted "further work may be required to fully assess cumulative or long-term impacts to plankton and higher trophic levels within this dynamic system" (PCCS 2005).

Results from the MWRA monitoring plan also noted that, compared to baseline data, *Phaeocystis pouchetti* blooms have increased in number and duration. During baseline data collection before the operation of the outfall operation began, "there were spring blooms every three years, in 1992, 1994 (only recorded in the farfield), 1997, and 2000. Since the outfall began operation, the blooms have occurred annually and have increased in duration. In earlier years, *Phaeocystis* blooms occurred primarily in late March and April. Since 2002, they [began] earlier in March and persisted until early May" (MWRA 2006). Also, during the monitoring program in 2005, "a large bloom of toxic dinoflagellates in the genus *Alexandrium* occurred, the largest since 1972. The bloom extended from Maine to south of Cape Cod and Martha's Vineyard. Concentrations of cells were orders-of magnitude higher than in previous years" (Werme and Hunt 2006). Even though with the current data, a direct link cannot be drawn between the outfall operation and these blooms, it does suggest that further long term studies are necessary to

determine the impact of outfall effluent on the phytoplankton communities in the Massachusetts and Cape Cod Bay region.

The MWRA monitoring program also noted that though

> *"the structure of the zooplankton community in 2005 was similar to many earlier years… There was, however, a measurable decrease in total zooplankton abundance during 2001 through 2005 in comparison to the baseline period... Total abundance has been lower during the late spring and early summer and during the fall. Similar decreases have been observed across Massachusetts Bay, including the northern boundary to the Gulf of Maine, the offshore, and coastal stations, but not in the shallower waters of Boston Harbor or Cape Cod Bay"* (Werme and Hunt 2006).

We conclude that in light of the potential changes in phytoplankton and zooplankton assemblages associated with outfall effluents and other sources of nutrients entering the Gulf of Maine and Georges Bank region, which may reduce the number of *C. finmarchius*, the essential features of late stage *C. finmarchicus* in dense aggregations in that region, as well as diapausing *C. finmarchicus* in aggregations in Jordan, Wilkinson, and Georges Basins, may require special management considerations or protection.

7.1.3. Oil and Gas Exploration and Development

The biological effects of oil pollution include both acute and chronic affects.[20] Acute toxicity is the immediate short-term effect of a single exposure to a toxicant. Chronic toxicity includes the effects of long-term and continuous exposure to a toxicant or the long-term sublethal effects of acute exposure (Connell and Miller, 1984). Acute and chronic toxicity of petroleum hydrocarbons to marine organisms is dependent upon a number of factors including:

- concentration of petroleum hydrocarbons and length of exposure,
- persistence and bioavailability of specific hydrocarbons,
- the ability of organisms to accumulate and metabolize various hydrocarbons,
- the fate of metabolized products,
- the interference of specific hydrocarbons (or metabolites) with normal metabolic processes that may alter an organism's chances for survival and reproduction in the environment (Capuzzo, 1987), and
- the specific narcotic effects of hydrocarbons on nerve transmission.

The acute effects may cause immediate or delayed mortality of marine organisms due to chemical or physical properties of the petroleum or its byproducts. Spills are commonly thought of as having short-term effects from high concentrations of petroleum. An example of such an effect is the smothering and asphyxiation of an organism due to a coating of oil (NAS 1975). The acute toxicity of individual hydrocarbons is largely related to their water solubility. The acute toxicity of a specific oil type is the result of

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[20] Not all oil pollution is clearly separable into these two categories. For example, exposure and effects are known to occur for long periods after some spills (Vandermeulen and Gordon, 1976; Sanders et al. 1980; Spies 1987; Teal et al. 1992; Burns et al. 1993) and chronic exposures can be quite high, as is the case near petroleum seeps (Spies et al. 1980; Steurmer et al. 1982).

the additive toxicity of individual compounds, especially aromatic compounds. Narcotic effects of individual petroleum compounds are an important component of acute toxicity and are most closely related to low molecular weight volatile compounds (Donkin et al. 1990).

Chronic effects of oil on marine environments and organisms may also result from continuous or sporadic low level releases of petroleum and its derivatives into the marine environment. Chronic effects include sub-lethal effects that change population characteristics such as productivity and dispersal rates as well as age structure and spatial distribution patterns. Chronic exposure to petroleum can result in changes to ecological communities in the affected area (NRC 1975). Impairment of feeding mechanisms, growth rates, development rates, energetics, reproductive output, recruitment rates and increased susceptibility to disease are some examples of types of sublethal effects due to exposure to petroleum hydrocarbons (Capuzzo 1987, in NRC 2003).

The bioavailability of petroleum to marine organisms is important in understanding the environmental fates and biological effects of petroleum in the marine environment.[21] Accumulation of petroleum hydrocarbons by marine organisms is dependent on the biological availability of hydrocarbons, the length of exposure, and the organism's capacity for metabolic transformations. Generally, chemicals in true solution in water are considered more bioavailable than chemicals in solid or adsorbed forms.

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[21] In aquatic toxicology, bioavailability is usually defined as the extent to which a chemical can be absorbed or adsorbed by a living organism by active (biological) or passive (physical or chemical) processes.

Very low concentrations (from less than 1µg/l to 1 mg/l) of oil and petroleum hydrocarbons have been found to have harmful effects on various marine organisms in laboratory tests (Jacobson and Boylan 1973, Johnson 1977, Steele 1977, Kuhnhold et al. 1978, Howarth 1987). Sublethal effects from hydrocarbon exposure can occur at concentrations several orders of magnitude lower than concentrations that induce acute toxic effects (Vandermeulen and Capuzzo 1983). Early developmental stages of marine organisms, including *C. finmarchicus,* can be especially vulnerable to hydrocarbon exposure, and recruitment failure in chronically contaminated habitats may be related to direct toxic effects of hydrocarbon contaminated sediments (Krebs and Burns 1977, Cabioch et al. 1980, Sanders et al. 1980, Elmgren et al. 1983).

On December 15, 1976, the Liberian tanker Argo Merchant went aground on Fishing Rip (Nantucket Shoals), 29 nautical miles southeast of Nantucket Island, Massachusetts, causing one of the largest oil spills in history. Due to the offshore movement of the spill, initial concerns about potential shoreline impacts shifted to the economically important fishing grounds in the area of Georges Bank. Benthic fish and invertebrate populations and their associated planktonic stages were at risk. Evidence of oil contamination was observed in fish, shellfish, ichthyoplankton and zooplankton collected in the area of the spill. Mortalities of cod and pollock embryos occurred in eggs contaminated with oil, and large numbers of zooplankton were observed to be contaminated with hydrocarbons.

Following the Argo Merchant oil spill, concentrations of oil remained elevated throughout Georges Bank for at least 5 months (Boehm et al. 1978, Howarth 1987). Dissolved hydrocarbons were evenly mixed throughout the water column on Georges Banks during this time and were likely due to storm-wave action, tidal mixing and the

absence of water column stratification causing deep mixing of the oil (Boehm et al. 1978, Vandermuelen 1982, Wiseman et al. 1982, Howarth 1987). The concentrations were high enough that they may have had an adverse effect on phytoplankton, although this was not studied (Howarth 1987). Marchand (1978) found similar near-uniform contamination of the water column following the Amoco Cadiz oil spill, with concentrations of up to 100 µg/L at depths of up to 100 m (Howarth 1987). The more toxic components of oil are lost more slowly from the water column than from surface slicks (Vandermeulen 1982).

Both an acute and chronic exposure due to oil discharge or spills could change the species composition of phytoplankton communities. Any such impacts might affect the forage base on which *C. finmarchicus* copepods feed, thereby resulting in effects to *C. finmarchicus* as well as the abundance and availability of dense aggregations of *C. finmarchicus* necessary to support right whale energetic requirements and reproductive strategies. The phytoplankton communities of Georges Bank are dominated by relatively large diatom species (Howarth 1987), upon which *C. finmarchicus* feed. Some large species of diatoms are sensitive to oil with growth inhibited at concentrations as low as 40 µg/L of fuel oil. Other species of phytoplankton, particularly small celled diatoms and naoflagellates are less adversely affected by exposure to oil (Lee et al. 1977). Parsons et al. (1976) demonstrated that photosynthesis can be stimulated by low concentrations of oil in some species of phytoplankton. These differential sensitivities to low concentrations of oil can result in some species replacing others (Howarth 1987). It is conceivable that species replacing one another due to differential sensitivities to oil exposure could result in shifts in phytoplankton community structure. Such shifts may then negatively affect the abundance and distribution of *C. finmarchicus* and, therefore,

the abundance, availability, and density of aggregations *C. finmarchicus* on which right whales feed, as well as the abundance of diapausing *C. finmarchicus* that serve as source populations, both of which are necessary for right whales to meet their energetic requirements and reproductive strategies.

Oil in the marine environment has the potential to affect dense aggregations of late stage *C. finmarchicus* and diapausing *C. finmarchicus* in aggregations in the Gulf of Maine and Georges Bank region in a number of ways. These include direct mortality of both adult and juvenile and larval life stages due to acute exposure, sublethal affects to both adult and juvenile life-stages due to acute and chronic exposure to oil and indirect impacts to other organisms composing the pelagic ecosystem such as phytoplankton community structure, thereby impacting the forage base of copepods. Acute effects may cause immediate or delayed mortality of marine organisms due to chemical or physical properties of the petroleum or its byproducts. For example, a major oil spill would have the potential to engulf dense concentrations of copepods resulting in direct mortality due to smothering and asphyxiation of the organisms. Also as noted, early life history stages such as eggs and larvae may be particularly susceptible to both acute and chronic effects of oil exposure. The toxicity of many of the individual compounds contained in petroleum is significant, and even small releases can kill or damage organisms from the cellular- to the population-level (NRC 2003).

Prior oil and gas exploration has occurred in the region. In 1974, the Department of the Interior (DOI) first announced plans to lease tracts for oil and gas exploration and development on Georges Bank. Lease Sale 42 was held in late 1979. The Environmental Impact Statements prepared for Lease Sales 42 and 52 estimated that for every billion

barrels (153 million tons) of oil produced there would be 3.23 spills of 10,000 barrels (1,530 tons) of oil or more and 5.92 spills of 1,000 barrels (153 tons) or more (DOI 1982, Howarth 1987).

Ultimately, ten wells were drilled on Georges Bank between 1976 through 1982. The first two wells were Continental Offshore Stratigraphic Test wells, drilled during 1976 and 1977 by energy company consortiums to gain geologic information prior to offshore federal petroleum exploration leasing (see Figure 16). After leases were awarded, eight industry exploration wells were drilled in 1981 and 1982. None of these exploratory wells encountered significant concentrations of oil or natural gas. Records and data from the wells are maintained by the DOI. All of the 1979 Georges Bank leases have now been relinquished or have expired. While all exploratory wells drilled on Georges Bank were deemed to be "dry" wells (i.e., not capable of producing commercial viable quantities of oil and gas at that time) it does not rule out the possibility of future resource development (Ball et al. 1987, Backus 1987).

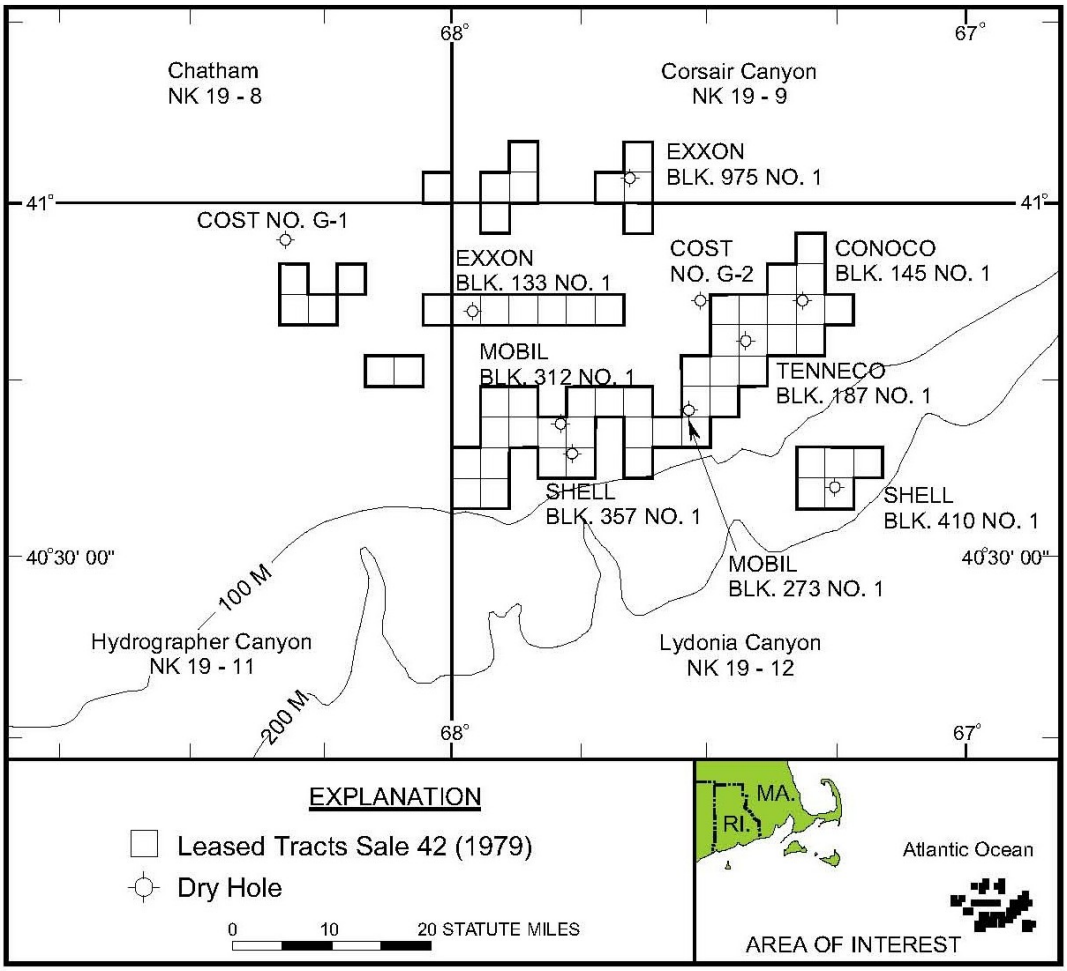

Figure 16 Map of the North Atlantic offshore area showing exploratory well locations (bathymetry in meters) (Source MMS 2000).

The Energy Policy Act of 2005 (P.L. 109-58, Section 357) required the DOI to conduct a comprehensive inventory of OCS oil and natural gas resources. In its report to Congress, the DOI estimated that the North Atlantic Outer Continental Shelf (OCS) Area contained approximately 6 percent of the technically recoverable undiscovered natural gas deposits

and approximately 3 percent of the technically recoverable undiscovered oil deposits on the OCS (MMS 2006).

Ongoing oil and gas development in the Scotian Basin in Canadian waters immediately adjacent to the Gulf of Maine and Georges Bank region provides significant insight into the potential for oil and gas development to occur within the Gulf of Maine-Georges Bank region. Since 1988, a leasing moratorium has also been in effect on the Canadian portion of Georges Bank, which is underlain by the East Georges Bank Basin, to the northeast of the Yarmouth Arch. The Nova Scotian and Canadian governments have extended the moratorium on exploration of eastern Georges Bank through 2015, matching the adjoining U.S. moratorium.

Outside the area under the moratorium, oil and gas exploration and production has proceeded in Canadian waters offshore of Nova Scotia (Figure 17). Since petroleum exploration began offshore of Nova Scotia, one hundred and sixty-seven wells have been drilled (102 exploration, 26 delineation, 38 production, and 1 special relief), and 24 significant petroleum discoveries have been made, mostly natural gas. In recent years companies have made 24 gas condensate[22] discoveries in the Canadian Scotian Basin, to the northeast, and six fields are being developed. A third cycle of exploration activity is underway along the eastern Canadian margin that includes previously unexplored areas. Given the circulation patterns previously described, oil spilled or discharged in Canadian waters may negatively impact *C. finmarchicus* there, which could have negative implications for the abundance or health of the copepods in the U.S. Gulf of Maine-Georges Bank region. Similarly, petroleum products in Canadian waters might be

[22] This term refers to hydrocarbon reservoir(s) in which conditions of temperature and pressure have resulted in the condensation of the heavier hydrocarbon constituents from the reservoir gas.

transported into the U.S. Gulf of Maine-Georges Bank area, where it may negatively impact *C. finmarchicus* in the right whale foraging habitat in U.S. waters.

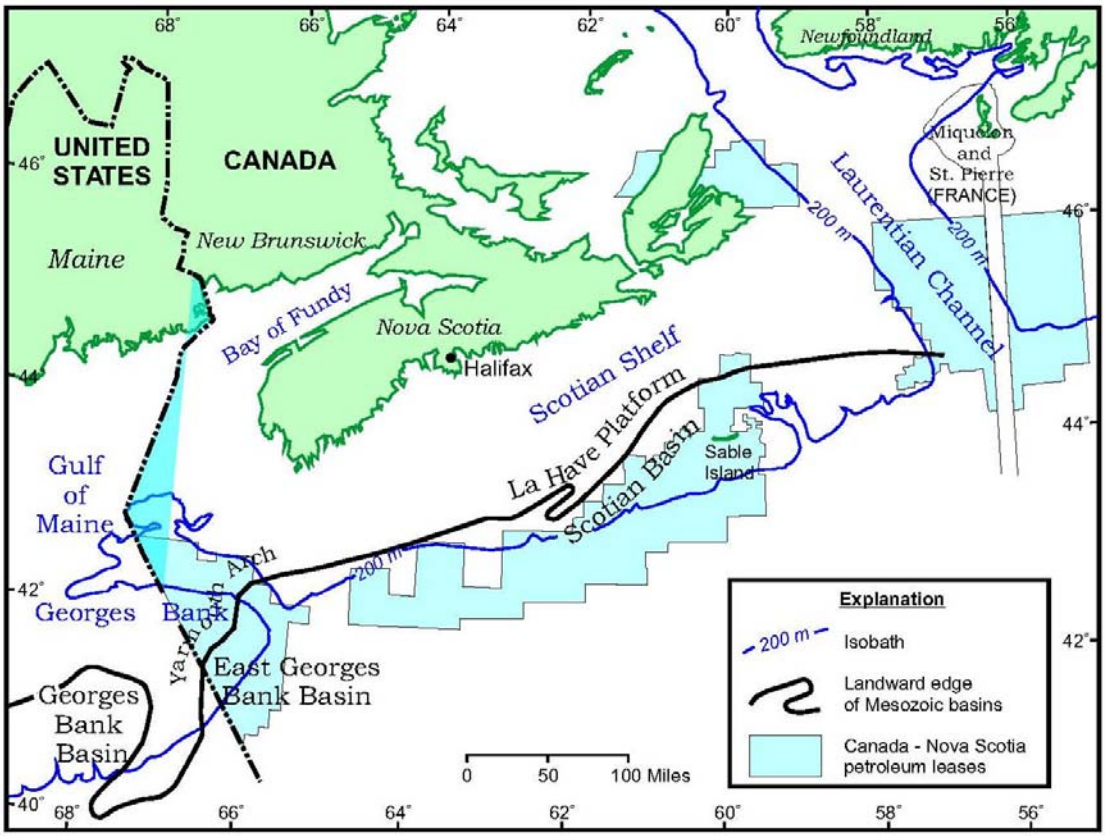

Figure 17 Map of Georges Bank and the Scotian Shelf, showing sedimentary basin locations, areas of Canadian petroleum leases, and 200-meter (shelf-edge) isobath (Source MMS 2000).

Activities associated with the transportation of oil are a potential source of discharge petroleum products into the marine environment. While major oil spills related to tanker accidents are rare, they do occur and may negatively impact dense aggregations of *C. finmarchicus* upon which right whales feed, as well as diapausing populations of *C.*

finmarchicus that serve as source populations for the forage base. The mechanisms by which oil might negatively impact these essential biological features are the same as discussed above for potential spills and discharges related to oil and gas exploration and development. In addition, the application of large volumes of oil dispersants due to an oil spill, whether related to transportation or oil production, could negatively impact dense aggregations of *C. finmarchicus* upon which right whales feed, as well as the diapausing *C. finmarchicus* populations that serve as sources of the forage base.

The Outer Continental Shelf Lands Act (OCSLA) of 1953, as amended, provides for oil and gas leasing of OCS lands. Currently, there is no oil or natural gas exploration or development activity in the Gulf of Maine and Georges Bank area. Until recently, all of the area has been under a moratorium on such natural resource development since 1980. There is reason to believe that oil or natural gas exploration and development may occur in the area at some point in the future. There is economic interest in opening up new domestic sources including OCS lands within the boundaries of the critical habitat for oil and gas exploration and development. In addition, emerging deep water drilling technologies now provides the potential to explore deep water basins and other areas within the Gulf of Maine and Georges Bank region. Therefore, due to the potential for oil and gas exploration, development, transportation and related discharges or spills of petroleum products into the marine environment in or near the U.S. Gulf of Maine-Georges Bank region, the essential biological features of dense aggregations of *C. finmarchicus* upon which right whales feed, as well as the diapausing *C. finmarchicus* populations that serve as sources of the forage base, may require special management considerations or protection to avoid negative impacts of these activities or events on the

ability of dense aggregations of *C. finmarchicus* and diapausing *C. finmarchicus* populations to support right whale energetic requirements and reproductive strategies.

7.1.4. Global Climate Change

The four essential features of right whale foraging habitat may require special management considerations or protection because of future climate change. The projected effects of global climate change include the following ranges of potential impacts based on a variety of scenarios (IPCC 2007):

1. Average global surface air temperatures will increase by 1.8°C (lower-emissions scenario) to 4.0°C (higher-emissions scenario) above 2000 levels. The most drastic warming will occur in northern latitudes in the winter.
2. Sea level is projected to continue to rise another 18-38 cm (lower-emissions scenario) or as high as 26-59 cm (higher-emissions scenario) by 2099.
3. Global precipitation is likely to increase, with more precipitation and more intense storms in the mid to high latitudes in the northern hemisphere.
4. Increasing atmospheric carbon dioxide concentrations may acidify the oceans, reducing pH levels by 0.14 and 0.35 units by 2100, adding to the present decrease of 0.1 units since pre-industrial times.

There are a number of ways in which global climate change may affect the biological and physical features of foraging habitat that are essential to the conservation of the North

Atlantic right whale. The distribution of marine fish and plankton are predominantly determined by climate. The distribution of marine species in U.S. waters is moving northward, and the timing of plankton blooms is shifting (Karl et al. 2009). The potential effects of climate change also include shifts in productivity, biomass, and species composition of zooplankton, including *C. finmarchicus*, which could negatively impact the foraging success of right whales. There is a close linkage between right whale foraging and the physical forcing processes that concentrate their prey in the oceanic environment (Kenney et al. 2001). Inter-annual, decadal, and longer time-scale variability in climate can alter the distribution and biomass of prey available to right whales. For example, decade-scale climatic regime shifts have been related to changes in zooplankton in the North Atlantic (Fromentin and Planque 1996). Decadal trends in the North Atlantic Oscillation (Hurrell 1995) can affect the position of the Gulf Stream (Taylor et al. 1998) and other circulation patterns in the North Atlantic that may influence the oceanographic conditions responsible for distributing, aggregating, and retaining *C. finmarchicus* right whale prey.

The predicted increase in water temperatures, combined with other factors such as increased precipitation and runoff, may negatively impact the essential physical feature of the oceanographic conditions in the Gulf of Maine and Georges Bank region that distribute and aggregate copepods by altering seasonal stratification in the northeast coastal waters. Increased stratification of the water column in the Gulf of Maine region could affect copepod abundance and densities by limiting and/or preventing the exchange of surface and nutrient rich deep water. Increased stratification could affect primary and secondary productivity by altering the composition of phytoplankton and zooplankton (Mountain 2002). This in turn might affect the abundance and distribution of *C.*

finmarchicus patches that support right whale foraging behavior and energetic requirements.

Diapausing *C. finmarchicus* populations could also be affected by predicted climate change-induced changes to the physical oceanographic conditions that create the low-energy environments present within deep ocean basins. The hydrographic conditions of the deep basins where aggregations of diapausing copepods are found are conducive to low flow velocities. These low velocity environments allow the neutrally buoyant, high lipid content copepods to passively aggregate below the convective mixed layer and be retained for a period of time (Lynch et al. 1998, Visser and Jónasdóttir 1999, Baumgartner et al. 2003, Pace and Merrick 2008). Changes to the physical oceanographic features, such as the potential increased stratification of the water column, in the Gulf of Maine region could affect the retention and subsequent emergence and distribution of diapausing copepod source populations in the deep ocean basins. Further, it is possible that climate-related changes to the physical oceanographic features could disrupt the conditions that create the low energy environment that enable retention of copepod populations within deep ocean basins. Therefore, NMFS concludes that the biological and physical features of foraging habitat that are essential to the conservation of North Atlantic right whales may require special management considerations or protections due to climate change. The following discussion of rising temperature, decreased ocean salinity, and enhanced stratification provides reasons why these features characteristic of foraging habitat may require special management considerations or protections because of climate change.

Temperature

Long-term increases in average temperatures, the frequency and intensity of extreme temperature and climatic events, and the timing of seasonal temperature changes can have adverse effects on ecosystem function and health. Combined with extreme precipitation and drought and rising sea levels, these effects have the potential to result in considerable adverse changes to the northeast region's ecosystems.

Sea surface temperatures (SST) of the northeastern U.S. coast have increased more than 0.6°C in the past 100 years, and are projected to increase by another 3.8-4.4°C under the high-emissions scenario and by 2.2-2.8°C under the lower-emissions scenario over the next 100 years (Frumhoff et al. 2007). The IPCC (2007b) concluded there is "high confidence" that observed changes in marine and freshwater biological systems are associated with rising water temperatures, including shifts in ranges and changes in algal, plankton, and fish abundance in high-latitude oceans. Temperature affects nearly every aspect of marine environments, from cellular processes to ecosystem function. The distribution, abundance, metabolism, survival, growth, reproduction, productivity, and diversity of marine organisms, including *C. finmarchicus*, will all be affected by temperature changes (Kennedy et al. 2002, Nedeau 2004). Most marine organisms are able to tolerate a specific temperature range and will become physiologically stressed or die after exposure to temperatures above or below the normal range. At sublethal levels, temperature extremes can affect the growth and metabolism of organisms, as well as behavior and distribution patterns. Reproduction timing and the rates of egg and larval development are dependent upon water temperatures. Such changes would likely affect both the abundance of late stage *C. finmarchicus* as well as diapausing populations of copepods.

In the northeast Atlantic, studies have found shifts in the timing and abundance of plankton populations with increasing ocean temperatures (Edwards and Richardson 2004, Richardson and Schoeman 2004). Edwards and Richardson (2004) found long term trends in the timing of seasonal peaks in plankton populations with increasing sea surface temperatures. Richardson and Schoeman (2004) reported effects of increasing sea surface temperatures on phytoplankton abundances in the North Sea. Phytoplankton production tended to increase as cooler ocean areas warmed, probably because higher water temperatures boost phytoplankton metabolic rates. However, in warmer ocean areas phytoplankton became less abundant as sea surface temperatures increased further, possibly because warm water blocks nutrient-rich deep water from rising to the upper strata where phytoplankton exist (Richardson and Schoeman 2004). Climate change related changes to phytoplankton population abundance and availability, as well as possible shifts in the timing of blooms would affect *C. finmarchicus* because they prey primarily on phytoplankton.

Decreased Ocean Salinity

Some of the projected impacts of global climate change include increased regional precipitation, decreased snow and ice extent and coverage on land, and reductions in sea ice. All of these effects could result in localized changes in ocean salinity and increased sea level rise including the waters of the Gulf of Maine and Georges Bank region. Precipitation patterns and changes in freshwater inflow can influence water residence time, salinity, nutrient delivery, dilution, vertical stratification, and phytoplankton growth and abundance (Scavia et al. 2002). From 1900 to 2005, precipitation increased significantly in eastern parts of North America.

Precipitation across the continental U.S. has increased by about 10% in the past 100 years or so, primarily reflected in the heavy and extreme daily precipitation events (Karl and Knight 1998, USGS 2005). This trend is also evident in the northeastern U.S. region, which has experienced an increase in annual average precipitation by about 5-10% since 1900 (Frumhoff et al. 2007). In addition, increased early spring streamflows have occurred over the past century in New England, possibly a result of earlier melting of winter snowpack caused by increased air temperatures and/or greater rainfall (Hodgkins and Dudley 2005). Climate change models indicate a continued increase in precipitation over the next 100 years (Frumhoff et al. 2007, IPCC 2007b). By the end of the century, the average annual precipitation is expected to increase by about 10%; however, the average winter precipitation is expected to increase 20-30%, and a much greater proportion of the precipitation would be expected to fall as rain rather than snow (Frumhoff et al. 2007, IPCC 2007b).

Satellite data since 1978 show that annual average Arctic sea ice extent has shrunk on average by 2.7% per decade, with larger decreases in summer of 7.4 [5.0 to 9.8]% per decade. Changes in snow, ice, and frozen ground have among other effects, led to changes in some Arctic and Antarctic ecosystems. The increase in continental melting of permafrost, snow, and ice which, combined with increased precipitation, has resulted in greater river discharge into the Arctic Ocean over the past three decades. This is believed to have led to accelerated sea ice melting and reductions in Arctic sea ice resulting in the relative freshening of Artic waters. Changes in snow and ice coverage also may result in localized changes in ocean salinity.

Circulation in the upper layers of the Arctic Ocean changed substantially between the late 1980s and early 1990s (Greene and Pershing 2007). The most significance consequence of these changes was a redirection of the shallow outflow from the Arctic Ocean (Greene and Pershing 2007). Instead of entering the North Atlantic mainly to the east of Greenland via Fram Strait, much of the low salinity outflow began to exit the Canadian Basin and enter the Labrador Sea via the Canadian Archipelago.

Relatively low-salinity waters began to emerge from the Canadian Archipelago during 1989 and started to affect shelf ecosystems downstream from the Labrador Sea to the Mid-Atlantic Bight (Greene and Pershing 2007). Northwest Atlantic shelf ecosystems shifted as they became notably fresher during the 1990s relative to the 1980s. Greene and Pershing (2007) found that the input of relatively freshwater enhanced stratification, resulted in greater phytoplankton production and abundance during the autumn. The increase in phytoplankton abundance coincided with a reorganization of the zooplankton assemblage: the abundance of smaller, shelf-associated copepods increased markedly (Greene and Pershing 2007). Greene and Pershing (2007) found that the early juvenile stages of the larger copepod species *C. finmarchicus* also increased in abundance with these smaller species. However, later juvenile life stages, which right whales forage on, became less abundant (Greene and Pershing 2007).

Enhanced Stratification

The predicted increase in water temperatures, combined with other factors such as increased precipitation and runoff, may alter seasonal stratification in the northeast coastal waters, thereby possibly negatively affecting the essential physical and biological

features of foraging habitat. Increased stratification of the water column in the Gulf of Maine region could affect copepod abundance and densities by limiting and/or preventing the exchange of surface and nutrient rich deep water. Increased stratification could affect primary and secondary productivity by altering the composition of phytoplankton and zooplankton (Mountain 2002). This in turn might affect the abundance and distribution of *C. finmarchicus* patches that support right whale foraging behavior and energetic requirements.

Stratification of ocean waters occurs due to differences in water mass density, due to factors such as temperature and salinity. Stratification of the water column restricts both vertical and horizontal movement of water. Cold, salty water is denser than warmer, lower salinity water and, therefore, will sink. The vertical movement of large volumes of water from the surface to great depths (and vice versa) is possible only where the density of surface water and deeper water is similar. Large differences in temperature and salinity between surface water and deeper water results in greater stratification of the water column, thereby limiting and/or preventing the exchange of surface and deep water. Primary productivity requires the exchange of nutrient rich deep water with the relatively nutrient poor surface water through upwelling.[23] Stratification could affect primary and secondary productivity by altering the composition of phytoplankton and zooplankton (Mountain 2002). Increased vertical stratification of the water column occurs with increasing freshwater inflow and decreasing salinities, resulting from greater precipitation and storm water input and snow melt. Increased freshwater input in the upper layers of

[23] As phytoplankton die and sink out of the surface, photic zone nutrients incorporated in the dead organisms are removed from surface waters. This results in the depletion of nutrients in surface waters that require replacement of these nutrients through upwelling of nutrient rich deeper water for primary productivity to continue.

the ocean could result in increased stratification, which might suppress upwelling of nutrients into the upper regions of the ocean and generally reduces the productivity of phytoplankton (Kennedy et al. 2002). Conversely, increased freshwater flux and stratification could also lead to enhanced biological productivity in some systems by enabling organisms to remain longer in the photic zone (Scavia et al. 2002). In addition, an increased water temperature in the upper strata of the water column also contributes to water column stratification. However, an increase in coastal storm frequency and intensity, as predicted with some climate models, may contribute to some increase in vertical mixing of shallow habitats and reduce the effects of stratification.

While some climate models predict a net decrease in global phytoplankton productivity under doubled atmospheric carbon dioxide conditions caused by increased thermal stratification and reduced nutrient upwelling, simple extrapolation to particular northeast marine waters is difficult (Kennedy et al. 2002).[24] The climatic variability associated with natural, large-scale phenomena such as the North Atlantic Oscillation/Northern Hemisphere Annular Mode effects water column mixing and stratification on regional and global scales and has implications on the productivity of the oceans. These natural phenomena may act in tandem with, or in opposition to, anthropogenic climate change (Kennedy et al. 2002). A number of computer climate models indicate a slowing of the "overturning" process of ocean waters, known as the thermohaline circulation (THC).[25] This phenomenon appears to be driven by a reduction in the amount of cold and salty,

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24 Some phytoplankton populations may respond positively to increases in water temperatures and available carbon dioxide, which most climate models project are likely as a result of global warming (IPCC 2007a). *C. finmarchicus* prey primarily on phytoplankton.

25 Thermohaline circulation is produced by differences in water temperature and/or salinity that results in different density of water.

and hence, more dense water sinking into the depths of the ocean. In fact, surface waters of the North Atlantic Ocean have been warming in recent decades and parts of the North Atlantic Ocean are also becoming less salty (Nedeau 2004). In the North Atlantic, a weakening of the THC is related to wintertime warming and increased freshwater flow into the Arctic Ocean and the North Atlantic Ocean (Nedeau 2004). An increased weakening of the THC could lead to a complete shut down or southward shift of the warm Gulf Stream, as was experienced during the last glacial period (Nedeau 2004). However, the response of the THC to global climate change remains uncertain, and predictions are dependent upon future greenhouse gas emissions and temperature increases (Kennedy et al. 2002). On a regional level, changes in ocean current circulation patterns may alter temperature regimes, vertical mixing, salinity, dissolved oxygen, nutrient cycles, and larval dispersal of marine organisms in the northeast coastal region, including the Gulf of Maine and Georges Bank region, ultimately leading to a net reduction in oceanic productivity (Nedeau 2004).

Changes in vertical mixing, circulation patterns, salinity, temperature regimes, and dissolved oxygen could all affect the physical oceanographic conditions that distribute and aggregate *C. finmarchicus* patches on which right whales forage and that exist within the low energy environments of the deep ocean basins that serve as refugia habitat for diapausing *C. finmarchicus*. Changes in stratification might adversely affect the success of *C. finmarchicus* in carrying out the diapause phase of their life cycle and subsequent phases in which the high-lipid content late stage *C. finmarchicus* are available to right whales as forage.

The hydrographic conditions of the deep basins, where aggregations of diapausing copepods are found, support low flow velocities. Climate related changes to the prevailing stratification patterns could either result in increased or decreased vertical mixing and, as a result affect the low-flow environments and their use by diapausing *C. finmarchicus*. Increased vertical stratification could result in the sequestering of waters and diapausing copepods in the low velocity environments of the deep ocean basins. Under these conditions, the areas of low velocity could be greater than current conditions and transport of diapausing copepods from these areas may not occur preventing them from becoming available for right whale foraging to the same extent or at similar times of the year as at present. Decreased stratification due to increased vertical mixing associated with increases in storm events and their severity could result in greater exchange of water between the convective layers and the non-convective layers found in the deep ocean basins. Under these conditions, the hydrographic condition of the deep ocean basins would support a smaller area of low flow velocity, and *C. finmarchicus* might have difficulty in descending to the low velocity environments and entering diapause.

As noted, the Gulf of Maine and Georges Bank region, as well as the adjacent Western Scotian Shelf (WSS) region, presents right whales with a highly variable feeding environment. The region lies within an oceanographic transition zone, located between cold subpolar waters influenced by fluctuations in the Labrador Current to the northeast and warm temperate waters influenced by fluctuations in the Gulf Stream to the south (MERCINA 2001). The transitions that occur within this zone are not only physical, as reflected by hydrographic changes, but also biological, as reflected by changes in the composition and relative abundance of plankton (Greene and Pershing 2000, MERCINA

2001). The shifting nature of this transition zone makes the GoM/GB/WSS region especially vulnerable to climate-driven changes in North Atlantic circulation patterns. As noted, the Northwest Atlantic shelf waters became fresher during the 1990s relative to the 1980s, because of changes in the atmospheric and oceanic circulation patterns in the Arctic Ocean (Greene and Pershing 2007). Greene and Pershing (2007) reported enhanced ocean stratification in the Gulf of Maine caused by the increased freshwater outflow from the Arctic during the 1990s.

Climate-related variability in ocean circulation observed over the past 40 years has had a profound impact on the plankton ecology in the GoM. Future climate-induced changes in circulation patterns might affect the availability and density of *C. finmarchicus* patches on which right whales prey. The abundance of *C. finmarchicus* is tightly coupled to the modal state of the coupled slope water systems (CSWS) (Greene and Pershing 2003, MERCINA 2001).[26] During the decade of the 1960s, when the NAO Index was predominantly negative and the CSWS was in its minimum modal state, slope water temperatures and *C. finmarchicus* abundance were relatively low. During the 1980s, when the NAO Index was predominantly positive and the CSWS was predominantly in its maximum modal state, slope water temperatures and *C. finmarchicus* abundance were relatively high. During each of the maximum to minimum modal shifts in the CSWS after 1980, *C. finmarchicus* abundance declined in subsequent years. The modal shift

[26] According to Greene et al. (2003), the physical responses of the GoM and Western Scotian Shelf region due to changes in ocean circulation are often mediated by the coupled slope water system (CSWS) of the Northwest Atlantic (see also MERCINA 2001). Two characteristic modes have been identified for the CSWS, a minimum and maximum mode (Greene et al 2003). The minimum mode corresponds to drop in the NAO and the intrusion of relatively cool, fresh Labrador Subartic Slope Water (LSSW) further south along the continental margin of North America (Greene et al. 2003). The LSSW displaces warmer saltier Atlantic Temperate Slope Water (ATSW) offshore and penetrates the deep ocean basins within the Gulf of Maine, replacing the warmer ATSW waters within these areas (Greene et al. 2003).

during 1981–83 preceded a large, single-year decline in abundance during 1983. The modal shift during 1988–91 preceded a large decline in abundance that persisted throughout the early 1990s. Then, after *C. finmarchicus* abundance began building up again during the mid–1990s, the NAO Index underwent its aforementioned drop of the century in 1996. This event triggered the intense modal shift of the CSWS during 1997, which, in turn, led to very low abundances of *C. finmarchicus* during 1998 and early 1999.

Changes in Water Alkalinity/Ocean Acidification

Since industrialization began in the 18th century, surface-ocean acidity has increased by 30% (Orr et al. 2008). By the end of this century, if atmospheric carbon dioxide (CO_2) is not stabilized, the level of ocean acidity could increase to three times the pre-industrial level. Current projections indicate that by the year 2100 surface ocean pH will decrease by 0.4 ± 0.1 pH units relative to pre-industrial conditions (Meehl et al. 2007, Orr et al. 2008). Increased acidity in oceans is expected to affect calcium carbonate availability in seawater, decreasing the ability of many marine organisms to build their shells and skeletal structure (Orr et al. 2008). It is not known with certainty what effect ocean acidification might have on zooplankton species such as *C. finmarchichus*. A recent review of the literature on the potential impacts of increased ocean acidification on various marine organisms revealed that very little research on the impacts on copepods has been conducted to date (Scott Doney, pers comm.). The available studies indicate that copepods may be less susceptible to being adversely affected by increased ocean acidification than other marine organisms, but that under certain conditions and scenarios copepods may be vulnerable. For example, Kurihara et al (2008) studied the effects of

exposure to seawater equilibrated with carbon dioxide enriched air on the copepod *Acartia tsuensis* from eggs to maturity and over two subsequent generations. These researchers found that exposure to high carbon dioxide levels did not significantly affect survival, body size or developmental speed through all life stages of the 1st generation copepods. Similarly, egg production and hatching rates were also not significantly different between the initial generation of females exposed to high carbon dioxide levels and the 1st and 2nd generation females that developed from eggs to maturity under the high carbon dioxide condition (Kurihara et al. 2008). Kurihara et al. (2008) concluded that the copepod studied appeared more tolerant to increased carbon dioxide than other marine organisms previously investigated (i.e., sea urchins and bivalves).

Mayor et al. (2007) studied how exposure of *C. finmarchicus* to seawater containing 8000 ppm of carbon dioxide influenced the growth and reproduction of this keystone copepod. This is the level of carbon dioxide expected to occur as a result of marine carbon dioxide storage/disposal, and is also representative of the predicted 'worst-case' atmospheric carbon dioxide scenario in the year 2300. Mayor et al. (2007) found that growth (egg production and biomass loss) in adult female copepods was not affected by the simulated ocean acidification. In contrast, a maximum of only 4% of the eggs successfully yielded nauplii after 72 h in the experimental treatment (Mayor et al. 2007). These researchers concluded that, in addition to adult mortality, impacts to juvenile life stages must be considered when conducting environmental risk assessments for marine carbon dioxide storage/disposal. Mayor et al. (2007) concluded that the impacts of carbon dioxide disposal on diapausing populations of *C. finmarchicus* should be considered as part of any proposal to dispose of carbon dioxide in the deep sea in areas utilized by diapausing copepod populations.

In summary, the foraging habitat features of *C. finmarchicus* in dense aggregations, diapausing *C. finmarchicus* in aggregations in Jordan, Wilkinson, and Georges Basins, the oceanographic conditions that distribute and aggregate *C. finmarchicus* for right whale foraging in the Gulf of Maine and Georges Bank region, and the low flow velocity environments in Jordan, Wilkinson, and Georges Basin that allow *C. finmarchicus* to aggregate passively below the convective layer so that the copepods are retained in the basins, may require special management considerations or protection in light of climate change-induced changes in water temperatures, precipitation, runoff, snow and ice melt, stratification of marine waters, phytoplankton and zooplankton communities, ocean salinity, and nutrient upwelling. The impacts to the four essential features may negatively impact the extent to which these features provide for efficient foraging on an abundance of high energy, dense *C. finmarchicus* aggregations, which are necessary to support right whale energetic and reproductive needs.

7.2 Special Management Considerations or Protections May be Required for the Essential Physical Features of Calving Habitat

To determine if the essential features of calving habitat may be negatively impacted under the analytical framework discussed above, we looked first at how these features are being used by right whale mother-calf pairs. The essential physical features for North Atlantic right whales on their calving grounds are calm sea surface conditions Force 4 or less on the Beaufort Wind Scale, sea surface temperatures from a minimum of 7°C, and never more than 17°C, and water depths of 6 to 28 meters.

These features are present over contiguous areas of at least 231 nmi^2 of ocean waters between November and April each year. These features are essential because they increase calf survival and support successful calving of right whales, which is a key conservation objective for this species. As stated previously, mother-calf right whale pairs use the specific area for calving, nursing, and rearing. Throughout the specific area, mother-calf right whale pairs are selecting some essential features in dynamic combinations depending on such factors as weather and age of the calves. These features, selected in dynamic combinations, simultaneously provide for the needs of both the right whale mother and calf.

The needs of the fasting mother include sea surface conditions conducive to giving birth and nursing as well as sea surface temperatures conducive to thermoregulation of the warm-blooded, blubber-rich mother. The needs of the weak-swimming calf include sea surface conditions conducive to nursing and breathing as well as sea surface temperatures conducive to thermoregulation of the warm-blooded, blubber-poor calf. Rearing of young right whale calves by mothers includes preparing the calves for the long migration to the northern feeding grounds by swimming many miles within the specific area during the calving season while still providing for the needs of both mother and calf. Therefore, the aspects of the features that make them essential to the conservation of the species (i.e., supporting successful calving) must be maintained.

Now we must evaluate whether there are activities or conditions that may result in negative impacts to the ability of the essential features to support successful calving of North Atlantic right whales. Negative impacts may result from activities or conditions that directly affect the preferred ranges of the essential features. Negative impacts also

may result from activities or conditions that fragment the contiguousness of the essential features or reduce or eliminate the "selectability" of dynamic, optimal combinations of the essential features. Right whales are large animals that use large areas of habitat, therefore, activities or conditions that may negatively impact the essential features include mainly those that occur on a large scale over a long duration. Activities that permanently occur on a large scale (e.g., over tens to hundreds of square miles) are more likely to negatively impact the essential features than small-scale, temporary activities (e.g., over several hundred square feet and less). Large-scale permanent activities are more likely to interrupt contiguous areas of optimal combinations of the essential features such that the essential features are no longer able to support successful calving of right whales. Because of the size and scope of large-scale activities, these activities are also more likely to reduce or eliminate the "selectability" of dynamic, optimal combinations of the essential features such that the essential features are no longer able to support successful calving of right whales. Further, large-scale activities that occur over long durations are more likely to decrease the availability of large, contiguous areas of the features, if not act potentially as permanent "barriers" to the availability of the features over time.

Based on the above, activities most likely to result in negative impacts to the essential features include offshore energy development, large-scale offshore aquaculture operations, and global climate change. These activities and their potential broad scale impacts on the essential features will be discussed below. Impacts were analyzed in two ways for each activity identified: (1) direct impacts on the essential features, and (2) impacts on contiguousness and selectability of the essential features. These activities have the potential to negatively impact not only the preferred ranges of the essential

features, but also the ability of these features to provide calving area functions (i.e., support successful calving). As stated previously, the ability of these features to support successful calving is what makes these features essential to the conservation of the species.

7.2.1 Offshore Energy Development

There is growing interest in diversifying domestic energy sources, including offshore oil and gas exploration and production (including liquid natural gas (LNG) terminals), exploration and development of techniques for mining mineral deposits from the continental shelf, and development and production of offshore alternative or renewable energy sources in the Atlantic (e.g., wind farms, wave energy conversion) (e.g., see DOE 2008, DOE 2009, or http://www.whitehouse.gov/issues/energy-and-environment). Although NMFS does not anticipate oil and gas producing structures to be built within Unit 2,[27] the construction and operation of other energy production technologies within the specific area have the potential to affect the dynamically distributed essential features of calving habitat and their selectability by right whales. Installation and operation of offshore energy development facilities are not likely to negatively impact the preferred ranges of sea surface roughness, sea surface temperatures, or water depths, in that it will not result in lowering or raising the available value ranges for these features; however, installation and operation of these technologies may fragment large, continuous areas where the essential features are present. Additionally, installation and operation of these technologies may limit the availability of the essential features such that right whales are

[27] BOEM presently implements a 50-mile no-leasing buffer from the coastline for oil and gas leasing off Georgia, South Carolina, and North Carolina. That buffer is being proposed for 2017-2022. No oil and gas leases are planned off Florida through 2022.

not able to select dynamic, optimal combinations of the features necessary for successful calving.

Availability of the essential features may be limited by the construction of large arrays or fields of permanent structures that may act as physical barriers and prevent or limit the ability of right whale mothers and calves to select dynamic combinations of the essential features. There are numerous floating, submerged and emergent structures, mooring lines, and transmission cables associated with large ocean energy facilities (DOE 2009). The effective size of offshore energy facilities (e.g. fields of wind turbines or structures associated with oil production, etc.) includes all of the associated structures, lines and cables, and activities and noise.[28] For example, current wind energy farms range in size anywhere from 13.5 square miles (Dong Energy Horns Rev 2 in Denmark: see http://www.dongenergy.com/Hornsrev2/EN/Pages/index.aspx) to 1,300 square miles (planned RWE Anglesey complex in the Irish Sea: see Dafydd 2010). Prototype wave energy buoy arrays currently consist of 0.5 square mile areas; however, proposed build out capacities could result in these arrays covering tens to hundreds of square miles (Boehlert et al. 2008). Larger whales may have difficulty passing through an energy facility with numerous, closely spaced mooring or transmission lines (DOE 2009). If the density of structures, lines, and cables associated with a facility (including, but not limited to wind turbine fields and structures associated with oil production, etc.) is sufficiently great and spacing is close, cables could have a "wall effect" that could force whales around them (Boehlert et al. 2008). The effective size of offshore energy facilities includes all of the associated structures, lines and cables, and activities and noise.

If selectable combinations of the essential features are present in locations where these large permanent facilities operate, and these facilities have the potential to deter whales, then right whale mother-calf pairs are not likely to select the essential features present in these locations. This would effectively reduce the ability of the essential features to support successful calving because there would be fewer locations within the specific area available to mother-calf pairs and provide for this key conservation objective. Additionally, the installation and operation of many offshore energy facilities within the specific area may also result in the fragmentation of contiguous areas of the essential features such that the ability of the features to provide for successful calving (e.g., allowing mother-calf pairs to select features depending on such factors as weather and the age of the calves, preparation of calves for migration). These are negative impacts on what makes these features essential to the conservation of the species.

7.2.2 Large-Scale Offshore Aquaculture Operations

Aquaculture is the fastest growing form of food production in the world (NOAA 2010). Approximately 20 percent of U.S. aquaculture production is marine species (NOAA 2010); however, there is growing interest in expanding aquaculture operations to offset the increasing demand for seafood (NOAA 2007). Recent advances in offshore aquaculture technology have resulted in several commercial finfish and shellfish operations in more exposed, open-ocean locations in state waters in Hawaii, California, and New Hampshire (NOAA 2010). NOAA's 10-year plan (2007) includes establishing new offshore farms in the U.S. Exclusive Economic Zone (EEZ) for finfish, shellfish, and algae.

Offshore aquaculture operations utilize large net-pens (e.g., 3000 m^3 capacity), which may be partially or fully submerged below the sea surface (see examples in Figure 18 and Figure 19). Partially submerged net-pens typically employ a floating collar that is flexible or strong enough to withstand rough sea conditions and from which the containment net is hung (NOAA 2008). Materials employed for both partially and fully submerged net-pens include steel, aluminum, PEH plastic, rubber, and a variety of synthetic materials used in various netting and rope products (NOAA 2008). These structures typically are anchored to the sea floor.

Figure 18 Partially submerged "gravity" net-pen.

Figure 19 The SeaStation, seen here on the surface, is a type of fully submersible net-pen.

Large-scale offshore aquaculture generally involves the placement of large arrays or fields of individual net-pens. Like offshore energy development, the construction and operation of large-scale offshore aquaculture facilities within the specific area have the potential to affect the dynamically distributed essential features of calving habitat and their selectability by right whales. Installation and operation of large-scale offshore aquaculture facilities are not likely to negatively impact the preferred ranges of sea surface roughness, sea surface temperatures, or water depths, in that it will not result in lowering or raising the available value ranges for these features; however, installation and operation of these facilities may fragment large, continuous areas where the essential features are present. Additionally, installation and operation of these technologies may limit the availability of the essential features such that right whales are not able to select dynamic, optimal combinations of the features necessary for successful calving.

Availability of the essential features may be limited by the construction of large arrays or fields of permanent structures that may act as physical barriers and prevent or limit the ability of right whale mothers and calves to use the essential features. Like ocean energy facilities, large-scale aquaculture operations involve numerous floating or submerged structures and mooring lines, and associated activities and noise. Dense aggregations of net-pen sites could force whales to abandon these areas (Young 2001) by acting as a barrier.

If selectable combinations of the essential features are present in locations where such net-pen aggregations are installed and operated, and these facilities have the potential to deter whales, then right whale mother-calf pairs are not likely to select the essential features present in these locations. This would effectively reduce the ability of the

essential features to support successful calving because fewer locations within the specific area would be available to mother-calf pairs and provide for this key conservation objective. Additionally, aggregations of net-pen sites within the specific area may also result in the fragmentation of contiguous areas of the essential features such that the ability of the features to provide for successful calving (e.g., allowing mother-calf pairs to select features depending on such factors as weather and the age of the calves, preparation of calves for migration). These are negative impacts on what makes these features essential to the conservation of the species.

7.2.3 Global Climate Change

As noted, global climate change and its potential effects on the environment is a very complex issue. Several of the projected future effects of global climate change are discussed above in Section 6.1.4.

Global climate change will inevitably be accompanied by regional scale variability (Hurrell et al. 2009). On the time scale of a few years to a few decades ahead, regional and seasonal variations in weather patterns and climate, and their corresponding impacts, will be strongly influenced by natural, internal variability (Hurrell et al. 2009). In the specific area identified as potential right whale calving critical habitat, sea surface temperatures are influenced by the "Atlantic Multi-decadal Oscillation", or AMO. The AMO is an ongoing series of long-duration changes in the sea surface temperature of the North Atlantic Ocean, with cool and warm phases that may last for 20 to 40 years at a time and a difference of about 1°F between extremes (NOAA AOML 2010; see Figure 20). The AMO also influences the frequency of hurricanes that originate in the Atlantic Warm Pool (AWP). During AMO cool phases, there are fewer major hurricanes and

landfall hurricanes are infrequent because the AWP is smaller. During AMO warm phases, the opposite occurs because the AWP is larger.

Right whales have been calving under this cyclical regime of sea surface temperatures and hurricanes. Over the past century (1900 until present), there have been two AMO warm phases in the North Atlantic – the most recent of which began in 1995 and continues today (Enfield and Serrano 2009; see Figure 20). The current warm period (1995 to present) is anywhere from 0.5°C and higher than 10-year averages for North Atlantic sea surface temperatures during the last AMO cold phase (1965-95) (D. Enfield, NOAA, pers. comm. to K. Reece, NMFS, Apr. 11, 2007). Concurrently, there has been a global warming trend in North Atlantic Ocean sea surface temperatures of about 0.35°C since 1900 (Enfield and Serrano 2009). Current climate models cannot definitively separate multi-decadal modulations of global sea surface temperatures (e.g., AMO) from secular increases in sea surface temperatures that are increasingly attributed to anthropogenic global climate change (Enfield and Serrano 2009). Based on studies of paleoclimate proxies, such as tree rings and ice cores, it is believed that the AMO is mostly a natural climate oscillation (NOAA AOML 2010, Enfield and Serrano 2009) with some anthropogenic variability (Enfield and Serrano 2009).

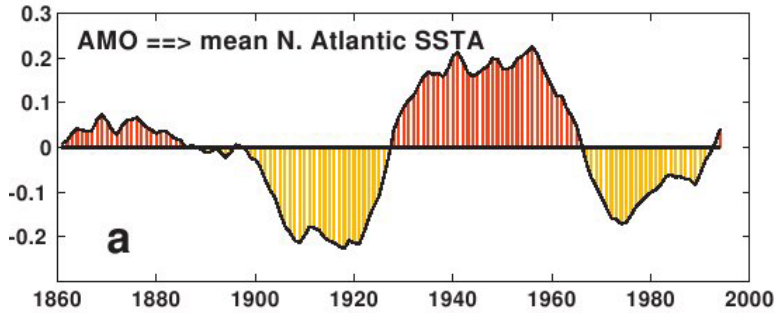

Figure 20 AMO index: the ten-year running mean of detrended Atlantic sea surface temperature anomaly (SSTA, °C) north of the equator (NOAA AOML 2010).

A regime shift from the current AMO warm phase to a cold phase is highly likely (approximately 85 percent) by 2025 (Enfield and Serrano 2006), resulting in a decrease in sea surface temperatures of 0 to 0.5°C and a shrinking of the AWP by 16 percent from its current size (Enfield and Serrano 2009). This expected transition of the AMO from a warm to a cool phase will likely moderate the predicted 0.25°C ±0.75°C increase in North Atlantic Ocean sea surface temperatures by 2020-2025 (Enfield and Serrano 2009). Therefore, sea surface temperatures within the specific area for right whale calving in the SAB are still likely to experience some cooling due to a cool phase AMO, and this expected cooling will not be a significant change from past fluctuations in observed North Atlantic Ocean sea surface temperatures. Further, sea state conditions within the specific area for right whale calving in the SAB are not expected to significantly change due to changes in storm activity. Calving season (November-April) occurs predominately outside of hurricane season (June 1 through December 1); however, the AWP is expected to shrink in size in response to the expected AMO cool phase, which will partially offset the effects of global climate change on hurricane frequency.

Over the next generation, however, global climate change is expected to be nonlinear, and it is likely that the AMO will have less influence over sea surface temperature

oscillations than anthropogenic global climate change in the North Atlantic (Enfield and Serrano 2009). This in turn will affect the relative size of the AWP. Depending on the degree to which the influence of the AMO is reduced, the 1 to 3°C increase in ocean sea surface temperatures predicted by IPCC AR4 (2007) may negatively impact the essential features for right whale calving habitat. Further, relaxation of the present rate of increase in hurricane activity may never occur (Enfield and Serrano 2009), potentially impacting seasonal sea state conditions in the specific area by increasing the frequency of major hurricanes passing through the specific area. The essential physical features for North Atlantic right whales on their calving grounds are calm sea surface conditions of Force 4 or less on the Beaufort Wind Scale, sea surface temperatures from a minimum of 7°C, and never more than 17°C, and water depths of 6 to 28 meters. These features are present over contiguous areas of at least 231 nmi^2 of ocean waters between November and April each year.

The essential feature of sea surface temperature may be negatively impacted by global climate change, depending on the degree to which the influence of the AMO is reduced. Negative impacts include a direct upward shift in the range of sea surface temperature values available in the specific area. There is potential that in the future the preferred temperature range (7°C to 17°C) may no longer be available, or available only within smaller areas comprising all three physical features. Additionally, increases in sea surface temperatures have the potential to shift where the preferred temperature range for right whale calving is located in the specific area such that the selectability of dynamic, optimal combinations of all the essential features is reduced. Sea surface temperatures within the preferred ranges may become available only within smaller areas with the preferred water depth and sea surface conditions, thereby reducing the area capable of

providing dynamic, optimal combinations of the essential features and reducing the ability of the specific area to support the key conservation objective of facilitating successful calving. Additionally, more frequent hurricane activity has the potential to alter the relatively calm sea surface state conditions in the specific area, particularly at the beginning of the calving season when there are more neonates present. Neonates are relatively weak swimmers and are more vulnerable to changes from calm to rough sea state conditions. Therefore, increased temperatures and hurricane activity due to global climate change may alter sea surface conditions within the specific area such that the area capable of providing dynamic, optimal combinations of the essential features is reduced and the ability of the specific area to support the key conservation objective of facilitating successful calving is reduced.

We believe large-scale activities and conditions, such as offshore energy development, large-scale offshore aquaculture operations, and global climate change may result in negative impacts not only to the preferred ranges of the essential features, but the ability of these features to provide calving area functions (i.e., support successful calving). As stated previously, the ability of these features to support successful calving is what makes these features essential to the conservation of the species. Therefore, the essential features may require special management considerations or protections to preserve the ability of these features to provide for successful calving of North Atlantic right whales.

8.0 Specific Areas outside the Geographical Area Occupied by the Species at the Time it is Listed

ESA section 3(5)(A)(ii) defines critical habitat to include specific areas outside the geographical area occupied if the areas are determined by the Secretary to be essential for

the conservation of the species. Regulations at 50 CFR 424.12(e) specify that NMFS shall designate as critical habitat areas outside the geographical area presently occupied by a species only when a designation limited to its present range would be inadequate to ensure the conservation of the species. We have not identified any areas outside the geographical area occupied by the species that are essential for their conservation. Therefore, we are not proposing to designate any unoccupied areas for the North Atlantic right whale.

LITERATURE CITED

Angell, C. M. 2006. Body Fat Condition of Free-Ranging Right Whales, Eubalaena glacialis and Eubalaena australis. Boston University.

Appenzeller, C., T.F. Stocker, and M. Anklin. 1998. North Atlantic Oscillation dynamics recorded in Greenland ice cores. Science 282: 446-449.

Backus, R. H. 1987. (ed) Georges Rank. MIT Press, Cambridge, Massachusetts, 593 p

Ball, M.M., R.E. Mattick and R.B. Powers. 1987. The petroleum potential of Georges Bank Basin. In: Backus, R. H. 1987. (ed) Georges Rank. MIT Press, Cambridge, Massachusetts, 593 p

Baumgartner, Mark, Tim V.N. Cole, Phillip J. Clapham, and Bruce R. Mate. 2003a. North Atlantic right whale habitat in the lower Bay of Fundy and on the SW Scotian Shelf during 1999-2001. Marine Ecology Progress Series. 264: 137-154.

Baumgartner, Mark, Tim V.N. Cole, Robert G. Campbell, Gregory J. Teegarden, and Edward G. Durbin. 2003b. Associations between North Atlantic right whales and their prey, *Calanus finmarchicus*, over diel and tidal time scales. Marine Ecology Progress Series. 264: 155-166

Baumgartner, Mark, Bruce R. Mate. 2003. Summertime foraging ecology of North Atlantic right whales. Marine Ecology Progress Series. 264: 123-135.

Baumgartner, Mark and Bruce R. Mate. 2005. Summer and fall habitat of North Atlantic right whales inferred from satellite telemetry. Canadian Journal of Fisheries and Aquatic Sciences. 62: 527-543.

Baumgartner , M. F. , Mayo , C. A. , and Kenney , R. D. 2007. Enormous carnivores, microscopic food, and a restaurant that's hard to find. In "The Urban Whale: North Atlantic Right Whales at the Crossroads" (S. D. Kraus and R. M. Rolland , eds.) , pp. 138 – 171 . Harvard University Press, Cambridge, MA .

Beardsley, Robert C., Ari W. Epstein, Changsheng Chen, Karen F. Wishner, Michael C. Macaulay, and Robert D. Kenney. 1996. Spatial variability in zooplankton abundance near feeding right whales in the Great South Channel. Deep Sea Research II. 43(7-8): 1601-1625.

Benfield, M. C. 2000. Counting copepods: a geostatistical estimation of the size of the diapausing stock of *Calanus finmarchicus* in Wilkinson Basin, Gulf of Maine based on video plankton recorder data. EOS Trans. AGU, Ocean Sci. Meet. Suppl. Abstract OS32H-02.

Best, P.B., A. Branadâo and D.S. Butterworth. 2001. Demographic parameters of southern right whales off South Africa. J. Cetacean Res. Manage. (Special issue) 2:161-169.

Betke, K., M. Schultz-von Glahn, and R. Matuschek. 2004. Underwater noise emissions from offshore wind turbines. Proceedings of the Joint Congress of CFA/DAGA 2004. Strasbourg, France.

Bigelow HB. 1927. Physical oceanography of the Gulf of Maine. Bull US Bur Fish 40:511-1027

Boehlert, G.W., G.R. McMurray, and C.E. Tortorici (eds.). 2008. Ecological Effects of Wave Energy Development in the Pacific Northwest. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-F/SPO-92. 174 p.

Boehm, P.D., G. Perry and D.L. Fiest. 1978. Hydrocarbon chemistry of the water column of Georges Bank and Nantucket Shoals, February-November 1977. In In the Wake of the Argo Merchant, proceedings of a symposium, Center for Ocean Management Studies, University of Rhode Island, Kingston, Rhode Island, pp. 58-64.

Bothner, M.H., and B. Butman (eds.), 2007. Processes influencing the transport and fate of contaminated sediments in the coastal ocean- Boston Harbor and Massachusetts Bay: U.S. geological Survey Circular 1302, 89p.

Brodie, P. F. 1975. Cetacean energetics, an overview of intraspecific size variation. Ecology 56:152–159.

Brooks, David A. 1985. Vernal circulation in the Gulf of Maine. J. of Geophysical Research. 90(C7):4687-4706.

Brown, C. W. and H. Winn. 1989. Relationship between the distribution pattern of right whales, *Eubalaena glacialis*, and satellite-derived sea surface thermal structure in the Great South Channel. Continental Shelf Research. 9(3): 247-260.

Brown, W.S., and Irish, J.D. 1992. The annual evolution of geostrophic flow in the Gulf of Maine: 1986–87. J. Phys. Oceanogr. 22: 445–473.

Brown, M.W., Brault, S., Hamilton, P.K., Kenney, R.D., Knowlton, A.R., Marx, M.K., Mayo, C.A., Slay, C.K., and Kraus, S.D. 2001. Sighting heterogeneity of right whales in the western North Atlantic: 1980-1992. J. Cetacean Res. Manage. (Special Issue 2): 245-250.

Bucklin, Ann and Thomas D. Kocher. 1996. Source regions for recruitment of *Calanus finmarchicus* to George's Bank: evidence from molecular population genetic analysis of mtDNA. Deep Sea Research II. 43(7-8): 1665-1681.

Bue, B. G., S. Sharr and J. E. Seeb. 1998. Evidence of damage to pink salmon populations inhabiting Prince William Sound, Alaska, two generations after the Exxon Valdez oil spill. Transactions of the American Fisheries Society 127:35-43.

Bue, B. G., S. Sharr, S. D. Moffitt, and A. K. Craig. 1996. Effects of the Exxon Valdez oil spill on pink salmon embryos and preemergent fry. Proceedings Of The Exxon Valdez Oil Spill Symposium, American Fisheries Society Symposium 18:619-627.

Cabioch, L., J. C. Dauvin, J. Mora Bermudez, and C. Rodriguez Babio. 1980. Effects of the Amoco Cadiz oil spill on the sublittoral benthos, north of Brittany. Helgolander Meeresuntersuchungen: Hamburg, 33:192-208.

Calanus®. 2009. Products. www.calanus.no/Products.aspx

Calanus®. 2008a. Renewal of fishing permit – 10.01.08. www.calanus.no/UserFiles/File/renew.pdf

Calanus®. 2008b. Contract with SKRETTING – 10.04.2008. www.calanus.no/UserFiles/File/contra.pdf

Calanus®. 2008c. New patent application for Calanus Trawl – 30.5.08. www.calanus.no/News.aspx

Calanus®. 2007a. Filing of patent application – 18.11.07. www.calanus.no/UserFiles/File/fill.pdf

Calanus®. 2007b. Research grant – 10.10.07. www.calanus.no/UserFiles/File/rew.pdf.

Canadian Department of Fisheries and Ocean Science (DFO). 1997. Proceedings of the workshop on ecosystem considerations for krill and other forage fisheries. Canadian Stock Assessment Proceedings Series 97/5.

Carls, M. G., S. D. Rice, and J. E. Hose. 1999. Sensitivity of fish embryos to weathered crude oil: Part I. Low-level exposure during incubation causes malformations, genetic damage, and mortality in larval Pacific herring (*Clupea pallasi*). Environmental Toxicology and Chemistry 18:481-493.

Capuzzo, J. M. 1987. Biological effects of petroleum hydrocarbons: assessments from experimental results. In: Boesch, D. F , Rabalais, N. N. (eds.) Long-term environmental effects of offshore oil and gas development. Elsevier Applied Science, London, p, 343-410.

Capuzzo, J. M., M.N. Moore and J. Widdows. 1988. Effects of toxic chemicals in the marine environment: Predictions of impacts from laboratory studies. Aquat. Toxicol. 11:303-311.

Carls, M.G., S.D. Rice, and J.E. Hose. 1999. Sensitivity of fish embryos to weathered crude oil: Part I. Low level exposure during incubation causes malformations, genetic damage, and mortality in larval Pacific herring (Clupea pallasi). Environ. Toxicol. Chem. 18:481-493.

Caswell, H., M. Fujiwara, and S. Brault. 1999. Declining survival probability threatens the North Atlantic right whale. Proceedings of the National Academy of Sciences 96(6):3308-3313.

Center for Coastal Studies (CCS). 2003. Surveillance, monitoring and management of North Atlantic Right Whales in Cape Cod Bay and adjacent waters-2003 Final Report.

Center for Coastal Studies (CCS). 2004. Surveillance, monitoring and management of North Atlantic right whales in Cape Cod Bay and adjacent waters-2004 Final Report.

Center for Coastal Studies (CCS). 2005. Surveillance, monitoring and management of North Atlantic right whales in Cape Cod Bay and adjacent waters-2005 Final Report.

CCS 2008. Surveillance, Monitoring and Management of North Atlantic Right Whales in Cape Cod Bay and Adjacent Waters - 2008 - Final Report. Ruth H. Leeney, Karen Stamieszkin, Nathalie Jaquet, Charles A. Mayo, David Osterberg and Marilyn K. Marx.

Cetacean and Turtle Assessment Program. 1982. A characterization of marine mammals and turtles in the mid- and north-Atlantic areas of the U.S. outer continental shelf, Annual Report for 1980. Contract AA551-CT8-48. Bureau of Land Management, Washington, DC. (NTIS# PB-81-243289.)

Chen, C. 2000. A Modeling Study of the Episodic Cross-Frontal Water Transport over the Inner Shelf of the South Atlantic Bight. Journal of Physical Oceanography. 30: 1722-1742.

Chen, C., R. C. Beardsley and R. Limeburner. 1995. A numerical study of stratified tidal rectification over Georges Bank. J. Phys. Oceanogr., 25,211 I-2128.

Clapham, P. J. 2001. Why do baleen whales migrate? A response to Corkeron and Connor. Marine Mammal Science 17:432–436.

Clapham, Phillip J., ed. 2004. Improving right whale management and conservation through ecological research. Report of the Working Group Meeting 16 April 2004.

Clapham, P.J., Good, C., Quinn, S.E., Reeves, R.R., Scarff, J.E. and Brownell, R.L., Jr. 2004. Distribution of North Pacific right whales (Eubalaena japonica) as shown by 19th and 20th century whaling catch and sighting records. J. Cetacean Res. Manage. 6(1):1-6.

Clapham, Phillip J. and Richard M. Pace. 2001. Defining triggers for temporary area closures to protect right whales from entanglements: issues and options. NEFSC Ref. Doc 01-06.

Clapham, Philip (Ed.). 2002. Report of the Working Group on Survival Estimation for North Atlantic Right Whales, 27th September 2002.

Conversi, Alessandra, Sergey Piontkovski, and Sultan Hameed. 2001. Seasonal and interannual dynamics of *Calanus finmarchicus* in the Gulf of Maine (Northeastern US shelf) with reference to the North Atlantic Oscillation. Deep Sea Research II. 48: 519-530.

Connell, D. W., and G. J. Miller. 1984. Chemistry and Ecotoxicology of Pollution. John Wiley & Sons, New York. 444 pp.

Conover, R. J. 1971. Some relations between zooplankton and bunker C oil in Chedabucto Bay, following the wreck of the tanker Arrow. Journal of Fisheries Research Board of Canada 28:1327-1330.

Continental Shelf Associates, Inc. 1997. Gulf of Mexico Produced Water Bioaccumulation Study. Definitive Component Technical Report. Prepared for Offshore Operators Committee, by Continental Shelf Associates, Inc., Jupiter, FL.

Corkeron, P.J. and R.C. Conner. 1999. Why do baleen whales migrate? Marine Mammal Science 15 1228-1245.

Costa, Amy DeLorenzo, Edward G. Durbin, Charles A. Mayo, and Edward G. Lyman. 2006. Environmental factors affecting zooplankton in Cape Cod Bay: implications for right whale dynamics. Marine Ecology Progress Series. 323: 281-298

CRS. 2005. Outer Continental Shelf: Debate Over Oil and Gas Leasing and Revenue Sharing Updated October 27, 2005 - Congressional Research Service - Resources, Science, and Industry Division, The Library of Congress.

Dafydd, I. 2010. "Two offshore wind farm plans unveiled off Welsh coast." BBC News. Published January 8, 2010 at

http://news.bbc.co.uk/2/hi/uk_news/wales/8447366.stm. Retrieved on June 25, 2010.

Dale, T., E. Bagøien, W. Melle, And S. Kaartvedt. 1999. Can predator avoidance explain varying overwintering depth of Calanus in different oceanic water masses? Mar. Ecol. Prog. Ser. 179: 113–121.

Davis, C.S. 1987 Zooplankton life cycles "In: Backus, R.H., Bourne, D.W. (Eds.), Georges Bank. MIT Press, Cambridge, MA" p. 254-267.

Department of Energy (DOE). 2008. 20% Wind Energy by 2030: Increasing Wind Energy's Contribution to U.S. Electricity Supply, available at www.nrel.gov/docs/fy08osti/41869.pdf.

Department of Energy (DOE). 2009. Report to Congress on the Potential Environmental Effects of Marine and Hydrokinetic Energy Technologies. U.S. Department of Energy, Wind and Hydropower Technologies Program. DOE/GO-102009-2599.

Department of the Interior, 1977. Final Environmental Impact Statement, OCS Lease Sale 42, Bureau of Land Management.

Donkin, P., J. Widdows, S. V. Evans, C. M. Worrall and M. Carr. 1990. Quantitative structure-activity relationships for the effect of hydrophobic chemicals on rate of feeding by mussels (Mytilus edulis). Aquatic Toxicology 14:277-294.

Dormann CF, Purschke O, García MárquezJR, Lautenbach S, Schröder B (2008) Components of uncertainty in species distribution analysis: A case study of the great grey shrike. Ecology 89: 3371–3386.

Durbin, Edward G., Sharon L. Gilman, Robert G. Campbell, and Ann G. Durbin. 1995. Abundance, biomass, vertical migration and estimated development rate of the copepod *Calanus finmarchicus* in the southern Gulf of Maine during late spring. Continental Shelf Research. 15(4/5): 571-591.

Durbin EG. 1997. Zooplankton dynamics of the Gulf of Maine and Georges Bank region. In: Wallace GT, Braasch EF [eds.]. Proceedings of the Gulf of Maine Ecosystems Dynamics: Scientific Symposium and Workshop. Regional Assoc for Research on the Gulf Maine Report 97-1; p. 53-67.

Durbin EG, Runge JA, Campbell RG, Garrahan PR, Casas MC, Plourde S. 1997. Late fall-early winter recruitment of *Calanus finmarchicus* on Georges Bank. Mar Ecol Prog Ser. 151:103-114.

Durbin, Edward G., P.R. Garrahan, and M.C. Casas. 2000a. Abundance and distribution of *Calanus finmarchicus* on the George's Bank during 1995 and 1996. ICES Journal of Marine Sciences. 57:1664-1685.

Durbin, Edward G., P.R. Garrahan, and M.C. Casas. 2000b. Depth distribution of *Calanus finmarchicus* nauplii on the Georges Bank during 1995-1996. ICES Journal of Marine Sciences. 57: 1686-1693.

Durbin E.G, Campbell R.G., Casas M.C., Ohman M.D., Niehoff B., Runge J., and Wagner M. 2003. Interannual variation in phytoplankton blooms and zooplankton productivity and abundance in the Gulf of Maine during winter. Mar Ecol Prog Ser. 254:81–100.

Durbin E.G., and Casas M.C. 2006. Abundance and spatial distribution of copepods on Georges Bank during the winter/spring period. Deep-Sea Res Part II. 53 [23-24]: 2537–2569.

Durbin, Edward G. 1996. Zooplankton dynamics of the Gulf of Maine and Georges Bank Region. Proceedings of the Gulf of Maine Ecosystem Dynamics Scientific Symposium and Workshop, p. 53-67.

Early, G. The Impact of Aquaculture on Marine Mammals. In: Tlusty, M.F., D.A. Bengston, H.O. Halvorson, S.D. Oktay, J.B. Pearce, and R.B. Rheault, Jr. (eds.). Marine Aquaculture and the Environment: A Meeting for Stakeholders in the Northeast. Cape Cod Press, Falmouth, Massachusetts.

Edwards, M., and A. Richardson. 2004. Impact of climate change on marine pelagic phenology and trophic mismatch. Nature 430: 881–884.

Elmgren, R., G. A. Vargo, J. F. Grassle, J. P. Grassle, D. R. Heinle, G. Longelis and S. L. Vargo. 1980. Trophic interactions in experimental marine ecosystems perturbed by oil. Pages 779-800 in J. P. Giesy (ed., Microcosms in Ecological Research. United States Department of Energy, Washington, D.C.

Elmgren, R., S. Hanson, U. Larson, B. Sundelin, and P. D. Boehm. 1983. The Tsesis: Acute and long-term impact on the benthos. Marine Biology 73:51-65.

Elwen, S.H. and P.B. Best. 2004. Environmental factors influencing the distribution of southern right whales (Eubalaena australis) on the south coast of South Africa I: Broad scale patterns. Marine Mammal Science 20: 567–582.

Enfield, D.B., and L. Cid-Serrano. 2009. Secular and multidecadal warmings in the North Atlantic and their relationships with major hurricane activity. Journal of Climatology. Published Online: March 16, 2009.

Epstein, A.W., and Beardsley, R.C. 2001. Flow-induced aggregation of plankton at a front: a 2-D Eulerian model study. Deep- Sea Res. II, 48: 395–418.

Erstes, P.J. and H.C. Rosenbaum. 2003. Habitat preference reflects social organization of humpback whales (Megaptera novaengliae) on a wintering ground. Journal of Zoology. 260: 337-345.

Firestone, Jeremy, Shannon B. Lyons, Chengfeng Wang, James J. Corbett (2008) Statistical modeling of North Atlantic right whale migration along the mid-Atlantic region of the eastern seaboard of the United States. Biological Conservation 141 (2008) 221 – 232

Fish, C.J., and Johnson, M.W. 1937. The biology of the zooplankton population in the Bay of Fundy and Gulf of Maine with special reference to production and distribution. J. Fish. Res. Board Can. 3: 189–322.

Fish, C. J. 1936. The Biology of Pseudocalanus minutus in the Gulf of Maine and Bay of Fundy. Biological Bulletin, Vol. 70, No. 2 (Apr., 1936), pp. 193-216.

Foley, H. J., R. C. Holt, R. E. Hardee, P. B. Nilsson, K. A. Jackson, A. J. Read, D. A. Pabst and W. A. McLellan. 2011. Observations of a western North Atlantic right whale (*Eubalaena glacialis*) birth offshore of the protected southeast U.S. critical habitat Marine Mammal Science, 27(3): 234–240).

Franks, P. J. S., Anderson, D. M. 1992a. Alongshore transport of a toxic phytoplankton bloom in a buoyancy current: Alexandrium tamarense in the Gulf of Maine. Mar. Biol. 112:153-164

Franks, P. J. S., Anderson, D. M. 1992b. Toxic phytoplankton blooms in the southwestern Gulf of Maine: testing hypotheses of physical control using historical data. Mar. Biol.

Fromentin J-M, Planque B. 1996 Calanus and environment in the eastern North Atlantic. Influence of the North Atlantic Oscillation on C. finmarchicus and C. helgolandicus. Mar Ecol Prog Ser 134:111–118.

Frumhoff, P.C., McCarthy, J. J., Melillo, J. M., Moser, S.C., and Wuebbles, D. J. 2007. Confronting Climate Change in the U.S. Northeast: Science, Impacts and Solutions. Cambridge, Massachusetts: Union of Concerned Scientists. Available online: www.climatechoices.org/ne/resources_ne/nereport.html. p. 85

Fujiwara, M. and H. Caswell. 2001. Demography of the endangered north Atlantic right whale. Nature 414:537–541.

Gangopadhyay, Avijit, Allan R. Robinson, Patrick J. Haley, Wayne G. Leslie, Carlos J. Lozano, James J. Bisagni, and Zhitao Yu. 2003. Feature-oriented regional modeling and simulations in the Gulf of Maine and Georges Bank. Continental Shelf Research.

Garrison, L.P. 2007. Defining the North Atlantic Right Whale calving habitat in the Southeastern United States-an application of a habitat model. NOAA Technical Memorandum. NMFS-SEFSC-553, 2007.

Gentleman, W. 1999. Factors controlling the seasonal abundance and distribution of *Calanus finmarchicus* in the Gulf of Maine/Georges Bank region. Ph.D., Dartmouth College.

Geraci, J. R. 1990. Physiologic and toxic effects on cetaceans. In: Sea Mammals and Oil: Confronting the Risks. J. R. Geraci, and D. J. St. Aubin [eds.]. Academic Press. San Diego, CA, pp. 167-197.

Geraci, J. R., and D. J. St. Aubin. 1987. Effects of offshore oil and gas development on marine mammals and turtles. In Long Term Environmental effects of offshore oil and gas development. D. F. Boesch and N. N. Rabalais [eds.]. Elsevier Applied Science Publishers, London, UK and New York, pp. 587-617.

Geraci, J. R., and D. J. St. Aubin (Eds.). 1990. Sea Mammals and Oil: Confronting the Risks. Academic Press, San Diego, 282pp. Geraci, J. R., and D. J. St. Aubin (Eds.). 2000. Sea mammals and oil, confronting the risks. Academic Press, San Diego, CA, XVI + 282pp.

Geyer, W. Gardner, G., Brown, W., Irish, J., Butman, B., Loder, T., and Signell, R. 1992. Physical oceanographic investigation of Massachusetts and Cape Cod Bays. Tehcnical Report, WHOI-92, Woods Hole Oceanographic Institution. Woods Hole, MA. Hopkins, T. S. and N. Garfield. 1979. Gulf of Maine intermediate water. J. Mar. Res., 39, 103-139.

Glass, A.H., T.V.N. Cole and M. Garron 2009. Mortality and serious injury determinations for baleen whale stocks along the United States eastern seaboard and adjacent Canadian Maritimes, 2003-2007. Northeast Fish. Sci. Cent. Ref. Doc. 09-04. 19 pp.

Good, C. 2008. Spatial Ecology of the North Atlantic Right Whale (Eubalaena Glacialis). Ph.D. Dissertation, Duke University. Available at: http://dukespace.lib.duke.edu/dspace/handle/10161/588

Greene, C. H. and A.J. Pershing. 2000. The response of *Calanus finmarchicus* populations to climate variability in the Northwest Atlantic: basin-scale forcing associated with the North Atlantic Oscillation. ICES Journal of Marine Sciences. 57: 1536-1544.

Greene, C.H., and A.J. Pershing. 2003. The flip-side of the North Atlantic Oscillation and modal shifts in slope water circulation patterns. Limnology and Oceanography 48: 319-322.

Greene, C.H., R.D. Kenney, and J.W. Jossi. 2003. Impact of Climate Variability n the recovery of endangered North Atlantic right whales. Oceanography. 16(4):98-103.

Greene, C. H., A.J. Pershing, A. Conversi, B. Planque, C. Hannah, D. Sameoto, E. Head, P.C. Smith, P.C. Reid, J. Jossi, D. Mountain, M.C. Benfield, P.H. Wiebe, and E. Durbin. 2003. Trans-Atlantic responses of *Calanus finmarchicus* populations to basin-scale forcing associated with the North Atlantic Oscillation. Progress in Oceanography. 58: 301-312.

Greene, C. H. and A.J. Pershing. 2004. Climate and the conservation biology of North Atlantic right whales: the right whales at the wrong time? Front. Ecol. Environ. 2(1):29-34.

Greene, C. H. and A.J. Pershing. 2007. Climate drives sea change. Science. 315: 1084-1085.

Grigg, H., And S. J. Bardwell. 1982. Seasonal observations on moulting and maturation in stage V copepodites of *Calanus finmarchicus* from the Firth of Clyde. J. Mar. Biol. Assoc. U.K. 62: 3 15-327.

Grose, P.L., and J. S. Mattson, 1977. The Argo Merchant oil spill: a preliminary scientific report. National Oceanographic and Atmospheric Administration, Boulder, Colorado, 133 pp.

Hain, James, ed. 1992. The Right whale in the western North Atlantic: a science and management workshop. 14-15 April 1992, Silver Spring MD.

Hamilton, P.K., A.R. Knowlton, M.K. Marx and S.D. Kraus. 1998a. Age structure and longevity in North Atlantic right whales, Eubalaena glacialis, and their relation to reproduction. Mar. Ecol. Prog. Ser. 171:285-292.

Hamilton, P.K., M.K. Marx and S.D. Kraus. 1998b. Scarification analysis of north Atlantic right whales (Eubalaena glacialis) as a method of assessing human impacts. Final report to NMFS Northeast Fisheries Science Center, contract No. 4EANF-6-0004.

Hamilton, P.K., Knowlton, A.R., Marx, M.K. 2007. Right Whales Tell Their Own Stories: The Photo-Identification Catalog. In Kraus, SD and Rolland, RM (eds). The Urban Whale: North Atlantic Right Whales at the Crossroads. Harvard University Press. 514 pp.

Hannah, C. G., C.E. Naime, J.W. Loder, and F.E. Werner 1998 Upper-ocean transport mechanisms from the Gulf of Maine to Georges Bank, with implications for Calanus supply. Continental Shelf Research. 17(15): 1887.

Harding, G. C. H. 1999. Ecological factors to be considered in establishing a new krill fishery in the Maritimes region. DFO Atlantic Fisheries Research Document 96/99.

Harris, Roger P. 1996. Feeding ecology of Calanus. Ophelia. 44: 85-109.

Harwood J. 2001. Marine mammals and their environment in the twenty-first century. J Mammal 82:630–640.

Heintz, R. A., J. W. Short, and S. D. Rice. 1999. Sensitivity of fish embryos to weathered crude oil: Part II. Increased mortality of pink salmon (Onchohynchus gorbuscha) embryos incubating downstream from weathered Exxon Valdez crude oil . Environmental Toxicology and Chemistry 18:494-503.

Heintz, R. A., S. D. Rice, A. C. Wertheimer, R. F. Bradshaw, F. P. Thrower, J. E. Joyce, and J. W. Short. 2000. Delayed effects on growth and marine survival of pink salmon Onchohynchus gorbuscha of exposure to crude oil during embryonic development. Marine Ecology Progress Series 208:205-216.

Hillaire-Marcel, C., A. de Vernal, G. Bilodeau, and A.J. Weaver. 2001. Absence of deep-water formation in the Labrador Sea during the last interglacial period. Nature 410: 1073-1077.

Hiby, A.R. and P.S. Hammond 1989. Survey techniques for estimating abundance of cetaceans, Rep. Int. Whale Comm. (Special Issue 11): 47-80.

Hirche, H.-J., 1989. Spatial distributionof digestive enzyme activities of *Calanus finmarchicus* and C. hyperboreas in Fram Straight/Greenland Sea. Journal of Plankton Research 11, 431–443.

Hirche, H. J., 1996a. Diapause in the marine copepod, *Calanus finmarchicus* - a review. Ophelia 44, 129–143.

Hirche H.J., B. Niehoe 1996b. Reproduction of the Arctic copepod Calanus hyperboreus in the Greenland Sea ± ®eld and laboratory observations. Polar Biol 16: 209±219.

Hodgkins, G.A., and Dudley, R.W. 2005. Changes in the magnitude of annual and monthly streamflows in New England, 1902–2002. Scientific Investigations Report 2005-5235. US Geological Survey, Reston, Va.

Hoerling, M.P., J.W. Hurrell, and T. Xu. 2001. Tropical origins for recent North Atlantic climate change. Science 292: 90-92.

Howarth, Robert W. 1987 “Potential Effects Of Petroleum On Marine Organisms On Georges Bank” In Georges Bank ed. by Backus, Richard H. MIT Press

Hurrell, J.W., Y. Kushnir, and M. Visbeck. 2001. The North Atlantic Oscillation. Science 291:603-605.

Hurrell, J.W., Y. Kushnir, G. Ottersen, and M. Visbeck. 2003. An overview of the North Atlantic Oscillation, Pages 1-35 in J.W. Hurrell, Y. Kushnir, G. Ottersen, and M. Visbeck, editors, The North Atlantic Oscillation: Climatic Significance and Environmental Impact. American Geophysical Union, Washington, D.C.

IPCC (Intergovernmental Panel on Climate Change). 2007a. Climate Change 2007: Synthesis Report, An Assessment of the Intergovernmental Panel on Climate Change, 52 pp.

IPCC (Intergovernmental Panel on Climate Change). 2007b. Climate Change Synthesis Report Summary for Policymakers. IPCC Plenary XXVII (Valencia, Spain, 12-17 November 2007). 22p.

Jacobson, S. M., and D. B. Boylan, 1973. Effects of seawater soluble fraction of kerosene on chemotaxis in a marine snail, Nassarius obsoletus. Nature 241: 213-215.

Jaquet, Nathalie, Charles A. Mayo, David Osterburg, Owen C. Nichols, and Cynthia L. Browning. 2006. Surveillance, monitoring and management of North Atlantic right whales in Cape Cod Bay and adjacent waters-2006 Final Report.

Jiang, S., T. Dickey, D. Steinberg and L. Madin, 2007, Temporal variability of zooplankton biomass from ADCP backscatter time series data at the Bermuda Testbed Mooring Site, Deep Sea Res. I, 54, 608-636.

Johannson S., 1980. Impact of oil on the pelagic ecosystem. In: The Teisis Oil Spill J.J. Kineman, R. Elmgren, and S. Hannson eds., U.S. Department of Commerce, National Oceanographic and Atmospheric Administration, Washington, D.C., pp. 61-80.

Johnson, Catherine, James Pringle, and Changsheng Chen. 2006. Transport and retention of dormant copepods in the Gulf of Maine. Deep-Sea Research II. 53: 2520–2536.

Johnson, F.G., 1977. Sublethal biological effects of petroleum hydrocarbons exposure: bacteria, algae and invertebrates. In Effects of Petroleum on Arctic and Subarctic Marine Environments and Organisms, vol 2, D.C. Malins, ed., Academic Press, New York, pp 271-318.

Jones, P.D., T.J. Osborn, and K.R. Briffa. 2001. The evolution of climate over the last millennium. Science 292: 662-667.

Kaartvedt, S. 1996. Habitat preference during overwintering and timing of seasonal vertical migration of *Calanus finmarchicus*. Ophelia 44: 145–156.

Karl, T. R., and R. W. Knight, 1998: Secular trends of precipitation amount, frequency, and intensity in the United States. Bull. Amer. Meteor. Soc., 79, 1107–1119.

Karl, T. R., J. M. Melillo, and T. C. Peterson (eds) (2009). Global Climate Change Impacts in the United States, Cambridge University Press.

Keller CA, Ward-Geiger LI, Brooks WB, Slay CK, Taylor CR, Zoodsma BJ. 2006. North Atlantic right whale distribution in relation to seasurface temperature in the southeastern United States calving grounds. Marine Mammal Science 2006;22(2):426–45.

Keller, C. A., L. Garrison, R. Baumstark, L. I. Ward-Geiger, and E. Hines. 2012. Application of a habitat model to define calving habitat of the North Atlantic right whale in the southeastern United States. Endangered Species Research 18(1):73-87.

Kennedy, T.A., Naeem, S., Howe, K.M., Knops, J.M.H., Tilman, D. & Reich, P. 2002 Biodiversity as a barrier to ecological invasion. Nature, 417, 636–638.

Kenney, R. D., Martin A. Hyman, Ralph E. Owens, Gerald P. Scott, and Howard E. Winn. 1986. Estimation of prey densities required by western North Atlantic right whales. Marine Mammal Science. 2(1): 39095.

Kenney, R. D., Howard E. Winn, and Michael Macaulay. 1995. Cetaceans in the Great South Channel, 1979-1989: right whale (Eubalaena glacialis). Continental Shelf Research. 15(4/5): 385-414.

Kenney, R. D. and Karen F. Wishner. 1995. The South Channel Ocean Productivity Experiment. Continental Shelf Research. 15 (4/5): 373-384.

Kenney, R. D., Charles A. Mayo, and Howard E. Winn. 2001. Migration and foraging strategies at varying spatial scales in western North Atlantic right whales: a review of hypotheses. J. CETACEAN RES. MANAGE. (SPECIAL ISSUE) 2: 251-260.

Kenney, R. D. 1990 SCOPEX: Whale Ecosystem Interactions. Maritimes. 34:1.

Kenney R.D. 2001. Anomalous 1992 spring and summer right whale (Eubalaena glacialis) distributions in the Gulf of Maine. J Cetacean Res Manage. (Spec Issue) 2: 209 - 223.

Kenney, R. D. 2002. North Atlantic, North Pacific and southern right whales. Pages 806-813 In W. F. Perrin, B. Wursig, J. G. M. Thewissen (eds.), Encyclopedia of marine mammals. Academic Press, San Diego, CA.

Kenney, R D. 2007. Right Whales and Climate Change. . In “The Urban Whale: North Atlantic Right Whales at the Crossroads ”(S. D. Kraus and R. M. Rolland , eds) , pp. 436 – 459 . Harvard University Press, Cambridge, MA

Knight, J. R., C. K. Folland, and A. A. Scaife (2006), Climate impacts of the Atlantic Multidecadal Oscillation, Geophys. Res. Lett., 33.

Knowlton, A.R., Sigurjónsson, J., Ciano, J.N. and Kraus, S.D. 1992. Long-distance movements of North Atlantic right whales (Eubalaena glacialis). Mar. Mammal Sci. 8(4):397-405.

Knowlton, A.R., S.D. Kraus and R.D. Kenney. 1994. Reproduction in north Atlantic right whales (Eubalaena glacialis). Can. J. Zool. 72:1297-1305.

Knowlton, A.R. and S.D. Kraus. 2001. Mortality and serious injury of northern right whales (Eubalaena glacialis) in the western North Atlantic Ocean. J. Cet. Res. Manage (Special issue) 2:193-208.

Knowlton, Amy R., J.B. Ring, and B. Russell. 2002. Right Whale Sightings and Survey Effort in the Mid Atlantic Region: Migratory Corridor, Time Frame, And Proximity to Port Entrances.

Kraus, S.D., J.H. Prescott, A.R. Knowlton and G.S. Stone. 1986. Migration and calving of right whales (Eubalaena glacialis) in the western north Atlantic. Rep. Int. Whal. Comm. (Special issue) 10:139-151.

Kraus, S.D., and R.D. Kenney. 1991. Information on right whales (Eubalaena glacialis) in three proposed critical habitats in U.S. waters of the western North Atlantic Ocean. U.S. National Tech. Info. Serv. Publ. PB91-194431. 65 p.

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

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

Kraus, S. D. , Pace , R. M. , III , and Frasier , T. R. 2007 . High investment, low return: The strange case of reproduction in Eubalaena glacialis . In “The Urban Whale: North Atlantic Right Whales at the Crossroads ”(S. D. Kraus and R. M. Rolland , eds) , pp. 172 – 199 . Harvard University Press, Cambridge, MA .

Kraus, Scott D. 2005. North Atlantic right whales in crisis. Science. 309: 561.

Krebs, C. T., and K. A. Burns. 1977. Long-term effects of an oil spill on populations of the salt marsh crab, Uca pugnax. Science 197:484-487.

Kuhnhold, W.W., D. Everich, J.J. Stegman, J. Lake and R. E. Wolke. 1978. Effects of low levels of hydrocarbons on embryonic, larval and adult winter flounder (Pseudopleuronectis americanus). In Proceedings of conference on Assessment of Ecological Impacts of Oil Spills, American Institute of Biological Sciences, Washington. D.C., pp 677-711.

Lavigne, D. M., S. Innes, G. A. J. Worthy And E. F. Edwards. 1990. Lower critical temperatures of blue whales, Balaenoptera physalus. Journal of Theoretical Biology 144:249–257.

Lee, R.F, Furlong, E., and Singer, S. 1977. Metabolism of hydrocarbons in marine invertebrates: aryllhydrocarbon hydroxylasae from the tissues of the blue crab, Callinectes sapidus, and the polychaete worm, Nereis sp. In Pollutant effects on marine organisms (ed. C. S. Giam(, pp 111-124. Lexington, Mass: D.C. Heath.

Lee, R.F., M. Takahashi, J.R. Beers, W.H. Thomas, D.L.R. Siebert, P. Koeller and D.R. Green. 1977. Controlled ecosystems: their use in the study of the effects of petroleum hydrocarbons on plankton. In Physiological Responses of Marine Biota to Pollutants, F.J. Vernberg, A. Calabrese, F.P. Thurberg and W.B. Vernberg, eds., Academic Press, New York. Pp. 323-342.

Lee, R. F., Takahashi, M., Beers J. 1978. Short term effects of oil on plankton in controlled ecosystems. Proceedings of Conference on Assessment of Ecological Impacts of Oil Spills, 14-17 June 1978. American Institute of Biological Sciences, New York.

Long, D. G. and B. R. Hicks. 2005. Standard BYU QuikSCAT/SeaWinds Land/Ice Image Products. Microwave Earth Remote Sensing Laboratory, Brigham Young University.

Longwell, A.C. 1978. Field and Laboratory measuremenst of stree responses at the chromosome and cell levels in planktonic fish eggs and the oil problem. In In the Wake of the Argo Merchant, proceedings of a symposium, Center for Ocean Management Studies, University of Rhode Island, Kingston, Rhode Island, pp. 116-125.

Lynch, Daniel R., Wendy C. Gentleman, Dennis J. McGillicuddy, and Cabell S. Davis. 1998. Biological/ physical simulations of *Calanus finmarchicus* population dynamics in the Gulf of Maine. Marine Ecology Progress Series. 169: 189-210.

Macaulay, M.C., K. F. Wishner, and K. Daly. 1995. Acoustic scattering from zooplankton and micronekton in relation to a whale feeding site near George's Bank and Cape Cod. Continental Shelf Research. 15(4/5): 509-537.

Madsen, P.T., M. Wahlberg, J. Tougaard, K. Lucke, and P. Tyack. 2006. Wind turbine underwater noise and marine mammals: implications of current knowledge and data needs. Mar. Ecol. Prog. Ser. 309: 279-295.

Marshall S. M. and A. P. Orr. 1955. The biology of a marine copepod. Oliver and Boyd, Edinburgh.

Mate, B.R., S.L. Nieukirk and S.D. Kraus. 1997. Satellite-monitored movements of the northern right whale. J. Wildlife Manage. 61(4):1393-1405.

Mayo, Charles. A. and Marilyn K. Marx. 1990. Surface behavior of the North Atlantic right whale, Eubalaena glacialis, and associated zooplankton characteristics. Canadian J. of Zoology. 68(10): 2214-2220.

Mayo CA, Nichols OC, Bessinger MK, Brown MW, Marx MK, Browning CL. 2004. Surveillance, monitoring, and management of North Atlantic right whales in Cape Cod Bay and adjacent waters-2004. Final report submitted to the Commonwealth of Massachusetts, Division of Marine Fisheries. Center for Coastal Studies, Provincetown, MA

McLellan, W.A., E. Meagher, L. Torres, G. Lovewell, C. Harper, K. Irish, B. Pike, and A.D. Pabst. 2004. Winter right whale sightings from aerial surveys of the coastal waters of the US Mid-Atlantic. Presented at the 15th Biennial Conference on the Biology of Marine Mammals.

Meehl, G. A., et al. (2007), Global climate projections, in Climate Change 2007: The Physical Science Basis, edited by S. Solomon et al., pp. 747–845, Cambridge Univ. Press, Cambridge, U.K.

Meise, C. J. and J.E. O'Reilly. 1996. Spatial and seasonal patterns in abundance and age-composition of *Calanus finmarchicus* in the Gulf of Maine and on Georges Bank: 1977-1987. Deep Sea Research II. 43(7-8):1473-1501.

Mellinger, D., Nieukirk, S., Klinck. K., Klinck, H., Dziak, R.P., Clapham, P. and Brandsdóttir, B. (2011). Confirmation of right whales near a historical whaling ground east of southern Greenland. Biology Letters, doi 10.1098/rsbl.2010.1191.

MERCINA. 2001. Oceanographic responses to climate in the Northwest Atlantic. Oceanography 14: 76-82.

Merrick, R. L. 2005. Seasonal management areas to reduce ship strikes of Northern right whales in the Gulf of Maine. NEFSC Red. Doc. 05-19.

Milewski, I. 2001 Impacts of Salmon Aquaculture on the Coastal Environment: A Review. In: Tlusty, M.F., D.A. Bengston, H.O. Halvorson, S.D. Oktay, J.B.

Pearce, and R.B. Rheault, Jr. (eds.) 2001. Marine Aquaculture and the Environment: A Meeting for Stakeholders in the Northeast. Cape Cod Press, Falmouth, Massachusetts.

Miller, C.B., Cowles, T.J., Wiebe, P.H., Copley, N.J., Grigg, H.,1991. Phenology in *Calanus finmarchicus*: hypotheses aboutcontrol mechanisms. Marine Ecology Progress Series 72, 79–91.

Miller, C.B., Lunch, D.R., Carlotti, F., Gentleman, W. and Lewis, C.V.W. 1998. Coupling of an individual-based population dynamical model of *Calanus finmarchicus* to a circulation mode for the Georges Bank region. Fish. Oceanogr. 7:219-234.

Miller, C.B, J.A. Crain, and C. A Morgan. 2000. Oil Storage variability in *Calanus finmarchicus*. ICES Journal of Marine Sciences. 57: 1786-1799.

MMS (Mineral Management Service). 2000. Georges Bank Petroleum Exploration Atlantic Outer Continental Shelf. Gary M. Edson Donald L. Olson Andrew J. Petty U.S. Department of the Interior Minerals Management Service Gulf of Mexico OCS Region New Orleans Office of Resource Evaluation May 2000.

MMS (Mineral Management Service). 2006. Report to Congress: Comprehensive Inventory of U.S. OCS Oil and Natural Gas Resources, Energy Policy Act of 2005 – Section 357. February 2006. U.S. Department of the Interior Minerals Management Service Mineral Management Service Offshore Minerals Management Program.

Moore, J.C., and E. Clark. 1963. Discovery of right whales in the Gulf of Mexico. Science 141(3577):269.

Moore, M. N., D. R. Livingstone and J. Widdows. 1989. Hydrocarbons in marine molluscs: Biological effects and ecological consequences. Pages 291-328 in U. Varanasi [ed.]. Metabolism of polycyclic aromatic hydrocarbons in the aquatic environment. CRC Press, Boca Raton, FL.

Mountain, D.G. 2002. Potential consequences of climate change for the fish resources in the mid-Atlantic region. Pages 185–194 in N.A. McGinn, editor. Fisheries in a changing climate. American Fisheries Society, Symposium 32, Bethesda, Maryland.

Moy, C.M., Dunbar, R.B., Moreno, P., Francois, J.P., Villa-Martinez, R., Guilderson, T.P., Garreaud, R.D. 2008. Isotopic evidence for hydrologic change related to the westerlies in SW Patagonia, Chile, during the last millennium. Quaternary Science Reviews 27, 1335–1349.

Murison, L.D. and D.E. Gaskin. 1989. The distribution of right whales and zooplankton in the Bay of Fundy, Canada. Canadian J. of Zoology. 67(6): 1411-1420.

NMFS (National Marine Fisheries Service). 1993. NOAA Fisheries Endangered Species Act Section 7 Consultation – Biological Opinion, Boston Harbor Project: Issuance of a National Pollution Discharge Elimination System (NPDES) Permit for the Massachusetts Water Resources Authority (MWRA) Outfall. 84. pp.

NMFS (National Marine Fisheries Service). 2005. Recovery plan for the northern right whale, Eubalaena glacialis, revision. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Office of Protected Resources. 137 pp.

NMFS (National Marine Fisheries Service). 2006. Review of the status of the right whales in the North Atlantic and North Pacific. http://www.nmfs.noaa.gov/pr/pdfs/statusreviews/rightwhale2006.pdf

NOAA. 2010, March 31. U.S. Marine Aquaculture. Retrieved from http://aquaculture.noaa.gov/us/welcome.html#us.

National Research Council (NRC). 1975. Petroleum in the Marine Environment. National Academy Press, Washington, D.C.

National Research Council (NRC). 1985. Oil in the Sea: Inputs, Fates, and Effects. National Academy Press, Washington, D.C.

National Research Council. 2003. Oil and the Sea III: Inputs, Fates and the Effects. National Academy Press. Washington, DC 2003.

Nedeau, E. 2004. Knowledgebase: Effects of Climate Change on the Gulf of Maine Region. Available online: http://www.gulfofmainesummit.org/docs/index.html [January 2006].

Nicol, S. and Y. Endo. 1997. Krill Fisheries of the World. FAO Fisheries Technical Paper 367.

Nicol, S. and Y. Endo. 1999. Krill fisheries: development, management and ecosystem implications. Aquat. Living Resour. 12(2): 105-120.

Nicol, S. and J. Foster. 2003. Recent trends for Antarctic krill. Aquat. Living. Resour. 16: 42-45.

Oftedal, O.T. 1997. Lactation in whales and dolphins: Evidence of divergence between baleen- and toothed-species. Journal of Mammary Gland Biology and Neoplasia. 2: 205-230.

Oftendal O.T. 2000. Use of maternal reserves as a lactation strategy in large mammals. Proceedings of the Nutrition Society. 59: 99-106.

Orr, J. C., Jutterstr¨om, S., Bopp, L., Anderson, L. G., Fabry, V. J., Fr¨olicher, T. L., Jones, P., Joos, F., Maier-Reimer, E., Segschneider, J., Steinacher, M., and Swingedouw, D.: Arctic ocean acidification, Nature, submitted, 2008.

Østvedts, O.J., 1955. Zooplankton investigations from weathership ''M'' in the Norwegian Sea, 1948–1949. Hvalrad Skr 40, 1–93.

Pace, R.M. III and R. Merrick. 2008. Northwest Atlantic Ocean Habitats Important to the Conservation of North Atlantic Right Whales (Eubalaena glacialis). NEFSC Ref. Doc. 08-07.

Parsons, T.R., W.K.W. Li, and R. Waters. 1976. Some preliminary observations on the enhancement of phytoplankton growth by low levels of mineral hydrocarbons. Hydrobiologia. 51: 85-89.

Patenaude, N.J. and C.S. Baker. 2001. Population status and habitat use of southern right whales in the sub-Antarctic Auckland Islands of New Zealand. Journal of Cetacean Research and Management (Special Issue 2):111-116.

Payne, M. F., R.J. Rippingale, and J.J. Cleary. 2001. Cultured copepods as food for West Australian dhufish (Glaucosoma hebraicum) and pink snapper (Pagrus auratus) larvae. Aquaculture 194 (137–150).

Payne, P.M., Wiley, D.N., Young, S.B., Pittman, S., Clapham, P.J. and Jossi, J.W. 1990. Recent fluctuations in the abundance of baleen whales in the southern Gulf of Maine in relation to changes in selected prey. Fish. Bull. 88:687-96.

Payne, R. 1986. Age at sexual maturity and calf mortality as determined from identified calves. Rep. Int. Whal. Comm. (Special issue) 10:31-32. VI-5

Perry, S.L., D.P. DeMaster and G.K. Silber. 1999. The great whales: history and status of six species listed as endangered under the U.S. Endangered Species Act of 1973. Marine Fisheries Review 61(1): 1-74.

Peterson, C. H. 2001. The Exxon Valdez oil spill in Alaska: Acute, indirect, and chronic effects on the ecosystem. Advances in Marine Biology 39:1-103.

Peterson, C. H., M. C. Kennicutt II, R. H. Green, P. Montagna, D. E. Harper, Jr., E. N. Powell, and P. F. Roscigno. 1996. Ecological consequences of environmental perturbations associated with offshore hydrocarbon production: a perspective from study of long-term exposures in the Gulf of Mexico. Canadian Journal of Fisheries and Aquatic Sciences 53:2637-2654.

Pettigrew, N.R., Townsend, D.W., Xue, H., Wallinga, J.P., Brickley, P., 1998. Observations of the Eastern Maine Coastal Current and its Offshore Extensions in 1994. Journal of Geophysical Research 103 (C13), 30,623±30,639.

Piasecki, W., Goodwin, A. E, Eiras, J. C., and B. F. Nowak. 2004. Importance of Copepoda in freshwater aquaculture. Zoological Studies. 43(2): 193-205.

Planque, B. and S.D. Batten. 2000. *Calanus finmarchicus* in the North Atlantic: the year of Calanus in the context of interdecadal change. ICES Journal of Marine Sciences. 57: 1528-1535.

Plourde, S. and J. A. Runge. 1993. Reproduction of the planktonic copepod, *Calanus finmarchicus*, in the Lower St. Lawrence Estuary: relation to the cycle of phytoplankton production and evidence for a Calanus pump. Mar. Ecol. Prog. Ser. 102: 217-227.

PCCS (Provincetown Center for Coastal Studies). 2005. Effects of Boston Outfall on the Marine Community of Cape Cod Bay. March 7, 2005.

Reeb, D., P. B. Best, and S. H. Kidson. 2007. Structure of the integument of southern right whales, Eubalaena australis. *The Anatomical Record: Advances in Integrative Anatomy and Evolutionary Biology* 290, no. 6: 596-613.

Reeves, R.R., and R.D. Kenney. 2003. Baleen Whales: Right Whales and Allies, in Wild Mammals of North American: Biology, Management, and Conservation; G.A. Feldhamer, B.C. Thompson, and J.A. Chapman, eds. The Johns Hopkins University Press; 2nd edition. Pp. 425-460.

Reeves, R. R., R. Rolland, and P. J. Clapham (eds.). 2001. Causes of reproductive failure in North Atlantic right whales: new avenues of research. Ref. Doc. 01-16. Northeast Fisheries Science Center, Woods Hole, Mass.

Richardson, A. J., And D. S. Schoeman. 2004. Climate impact on plankton ecosystems in the Northeast Atlantic. Science 305: 1609–1612.

Riebesell U. 2004. Effects of CO2 enrichment on marine phytoplankton. J Oceanogr 60: 719–29.

Right Whale Consortium (2010). North Atlantic Right Whale Consortium Photographic Identification Database 3/9/2010 (New England Aquarium, Boston, MA, U.S.A.).

Right Whale Consortium. 2015. North Atlantic Right Whale Consortium Sightings Database 09/15/2015. New England Aquarium, Boston, MA, U.S.A.

Right Whale Consortium. 2015b. North Atlantic Right Whale Consortium Sightings Database 09/15/2015. New England Aquarium, Boston, MA, U.S.A.

Rosenbaum, H.C, R.L. Brownell Jr., M.W. Brown, C. Schaeff, V. Portway, B.N. White, S. Malik, L.A. Pastene, N.J. Patenaude, C.S. Baker, M. Goto, P.B. Best, P.J. Clapham, P. Hamilton, M. Moore, R. Payne, V. Rowntree, C.T. Tynan and R. DeSalle. 2000. Worldwide genetic differentiation of Eubalaena: questioning the number of right whale species. Molecular Ecology 9:1793-1802.

Rowntree, V.J, Payne, R.S. and D.M. Schell. 2001. Changing patterns of habitat use by southern right whales (Eubalaena australis) identified on the nursery ground at Peninsula Valdes, Argentina. Journal of Cetacean Research and Management (Special Issue 2):33-144.

Royal Commission on Environmental Pollution. 1981. Oil Pollution of the Sea. London. 307 p. As cited in National Research Council (1985). Rozas, L. P., T. J. Minello, and C. B. Henry. 2000. An assessment of potential oil spill damage to salt marsh habitats and fishery resources in Galveston Bay, Texas. Marine Pollution Bulletin 40:1148-1160.

Royal Society. 1980. The Effects of Oil Pollution: Some Research Needs. Her Majesty's Stationary Office, London, 103 pp.

Runge, J. and P. Joly. 1995. Zooplankton (Euphasiisa and Calanus) in the estuary and Gulf of St. Lawrence. Can. Manuscr. Rep. Fish. Aquat, Sci. 2323: 124-132.

Runge, Jeffrey A. and Stephane Plourde. 1996. Fecundity characteristics of *Calanus finmarchicus* in coastal waters of eastern Canada. Ophelia. 44: 171-187.

Ryg, M., C. Lydersen, L. Ø. Knutsen, A. Bjørge, T. G. Smith And N. A. Øritsland. 1993. Scaling of insulation in seals and whales. Journal of Zoology, London 230:193–206.

Sameoto, D. D. (1983). Euphausiid distribution in acoustic scattering layers and its significance to surface swarms. J. Plankton Res. 5: 129-143.

Sanders, H. L. 1981. Environmental effects of oil in the marine environment. In: Safety and Offshore Oil: Background Papers of the Committee on Assessment of Safety of OCS Activities. National Research Council, National Academy Press, Washington, D.C., pp. 117-146.

Sanders, H. L., J. F. Grassle, G. R. Hampson, L. S. Morse, S. Garner-Price and C. C. Jones. 1980. Anatomy of an oil spill: Long-term effects from the grounding of the barge Florida off West Falmouth, Massachusetts. Journal of Marine Research, 38:265-380.

Saumweber, Whitley J. and Edward G. Durbin. 2006. Estimating potential diapause duration in *Calanus finmarchicus* Deep-Sea Research II. 53:2597–2617.

Saumweber, W. J. 2006. Implications of energetic limitation for diapausing *Calanus finmarchicus*: Towards a Gulf of Maine Calanus budget EOS Trans. AGU, Ocean Sci. Meet. Suppl. Abstract OS33H-0687: 36.

Scavia, D., J. C. Field, D. F. Boesch, R. W. Buddemier, V. Burkett, D. R. Cayan, M. Fogarty, M. A. Harwell, R. W. Howarth, C. Mason, D. J. Reed, T. C. Royer, A. H. Sallenger, and J. G. Titus. 2002. Climate change impacts on U.S. coastal and marine ecosystems. Estuaries 25:149–164.

Schick, R. S., P. N. Halpin, A. J. Read, C. K. Slay, S. D. Kraus, B. R. Mate, M. F. Baumgartner, J. J. Roberts, B. D. Best, C. P. Good, S. R. Loarie, J.S. Clark. 2009. Striking the Right Balance in Right Whale Conservation. Canadian Journal of Fisheries and Aquatic Sciences 66(9):1399-1403.

Schmidly. D.J., C.O. Martin, and G.F. Collins. 1972. First occurrence of black right whale (Balaena glacialis) along the Texas coast. Southwest Naturalist. 17:214-215.

Schmidly, David J. and Betty A. Melcher. 1974. Annotated Checklist and Key to the Cetaceans of Texas Waters. The Southwestern Naturalist, Vol. 18, No. 4 (Jan. 31, 1974), pp. 453-464.

Singer, Laura Taylor and Laura Ludwig, eds. 2005. Proceedings from a workshop on right whale foraging in the nearshore waters of the northern Gulf of Maine.

Slay, C.K., S.L. Swartz, A.R. Knowlton, S.Martin, J. Roman, A. Martinez, and J. Tobias. 2002. VHF-Radio Tracking of a North Atlantic Right Whale (Eubalaena glacialis) Female and calf in the Calving Ground: Preliminary Results 1999. NOAA Technical memorandum NMFS-SEFSC-476, 21pp.

Smith P. C. 1989. Seasonal and interannual variability of current, temperature and salinity off southwest Nova Scotia. Canandian Journal of Fisheries and Aquatic Sciences. 46 (Supl.1) 4-20.

Smultea, M.A. 1994. Segregation by humpback whale (Megaptera novaeangliae) mothers with a calf in coastal habitat near the island of Hawaii. Canadian Journal of Zoology 72:805-811.

Spies, R.B., P.H. Davis and D.H. Stuermer. 1980. Ecology of a submarine petroleum seep off the California coast. In Marine Environmental Pollution, vol. 1. Hydrocarbons, R. Geyer, ed., Elsevier, Amsterdam, pp. 208-263.

Spies, R. B. 1987. The biological effects of petroleum hydrocarbons in the sea: Assessments from the field and microcosms. Long-Term Environmental Effects of Offshore Oil and Gas Development. D. F. Boesch and N. N. Rabalais, (eds.). Elsevier Applied Science, London, pp. 411-467.

Steele, R. L., 1977. Effects of certain petroleum products on reproduction and growth of zygotes and juvenile stages of the alga Fucus edentatus De la Pyl (Phaeophyceae: Fucales). In Fate and Effects of Hydrocarbons in Marine Ecosystems and Organisms, D.A. Wolfe, ed., Pergamon, Oxford, pp. 115-128.

Steurmer, D. H., R. B. Spies and P. H. Davis. 1981. Toxicity of Santa Barbara seep oil to starfish embryos. I. Hydrocarbon composition of test solutions and field samples. Marine Environmental Research 5:275-286.

Stegmann, P. M., and J. A. Yoder. 1996. Variability of sea-surface temperature in the South Atlantic bight as observed from satellite: Implications for offshore-spawning fish. Continental Shelf Research 16(7):843-861.

Steurmer, D. H., R. B. Spies, P. H. Davis, D. J. Ng, C. J. Morris, and S. Neal. 1982. The hydrocarbons in the Isla Vista marine seep environment. Marine Chemistry 11:413-426.

Stevenson, David, Louis Chiarella, Dianne Stephan, Robert Reid, Kurt Wilhelm, John McCarthy, and Michael Pentony. Characterization of the Fishing Practices and Marine Benthic Ecosystems of the Northeast U.S. Shelf, and an Evaluation of the Potential Effects of Fishing on Essential Fish Habitat NOAA Technical Memorandum NMFS-NE-181. January 2004.

Suontama, Jorma. 2004. Lack of suitable raw materials for fish feed – could we use plankton? Institute of Marine Research Norway. Marine Research News. Volume 5.

Swartz, S.L. 1986. Gray whale migratory, social and breeding behaviour. Report of the International Whaling Commission (Special Issue 8):207-229.

Tande, K. S. and C.B. Miller. 2000. Population dynamics of Calanus in the North Atlantic: Results from the Trans-Atlantic study of *Calanus finmarchicus*. ICES Journal of Marine Sciences. 57:1527

Taylor, A. H., and Stephens, J. A. 1998. The North Atlantic Oscillation and the latitude of the Gulf Stream. Tellus, 50A. 134–142.

Teal, J. M., and R. W. Howarth. 1984. Oil spill studies, a review of ecological effects. Environmental Management 8:27-44.

Teal, J. M., J. W. Farrington, K. A. Burns, J. J. Stegeman, B. W. Tripp, B. Woodin, and C. Phinney. 1992. The West Falmouth oil spill after 20 years: Fate of fuel oil compounds and effects on animals. Marine Pollution Bulletin 24:607-614.

Thomas, P. and S. Taber. 1984. Mother-infant interaction and behavioral development in southern right whales, Eubalaena australis. Behavior 88:42-60.

Thomsen, F., K. Lüdemann, R. Kafemann and W. Piper. 2006. Effects of offshore wind farm noise on marine mammals and fish, biola, Hamburg, Germany on behalf of COWRIE Ltd.

Townsend, D.W., L.M. Carmen, J.P. Christensen, S.G. Ackleson, M.D. Keller, E.M. Haugen, S. Corwin, W.K. Bellows, and J.F. Brown. 1991. Seasonality of oceanographic conditions in Massachusetts Bay. Bigelow Laboratory of Ocean Sciences, Tech Rep. No. 83, 109pp.

Turner, Jefferson T. 2004. The Importance of Small Planktonic Copepods and Their Roles in Pelagic Marine Food Webs. Zoological Studies. 43(2): 255-266.

Vandermeulen, J.H. And Gordon,D.C. 1976. Re-entry of five-year-old stranded Bunker C fuel oil from a low-energy beach into the water, sediments and biota of Chedabucto Bay, Nova Scotia. Journal Fisheries Research Board Canada 33(9):2002-2010.

Vandermeulen, J. H., and J. M. Capuzzo. 1983. Understanding sublethal pollutant effects in the marine environment. Paper No. 9 in Ocean Waste Management: Policy and Strategies. Background Papers of Symposium, May 2-6, 1983, University of Rhode Island, Kingston.

Vandermeulen, J. 1982. What levels of oil contamination may be expected in water, sediments and what would be the physiological consequences for biota? In Consultation of the Consequences of Offshore Oil Production on Offshore Fish Stocks and Fishing Operations, A. Longhurst ed., Canadian Technical Report of Fisheries and Aquatic Sciences. 1096: 22-53.

Visser AW, Jónasdóttir SH. 1999. Lipids, buoyancy and the seasonal vertical migration of *Calanus finmarchicus*. Fish Oceanogr. 8 (Suppl.1): 100–106.

Ward-Geiger, L. I., and coauthors. 2011. Recent Sightings of the North Atlantic Right Whale in the Gulf of Mexico.—In the Gulf of Mexico, North. Gulf of Mexico Science 29(1):74-78.

Waring, G.T., and R.M. Pace, J.M. Quintal, C.P.Fairfield and K. Maze-Foley. 2004. U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments – 2003. NOAA Tech Memo. NMFS-NE-182. 287 pp.

Waring, G.T., E. Josephson, C.P. Fairfield and K.Maze-Foley (eds.). 2006. U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments – 2005 NOAA Technical Memorandum NMFS-NE-194. 358 pp.

Waring GT, Josephson E, Fairfield-Walsh CP, Maze-Foley K, (eds.). 2009. U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments -- 2008. NOAA Tech Memo NMFS NE 210; 440 p.

Waring GT, Josephson E, Maze-Foley K, Rosel, PE, editors. 2013. U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments -- 2012. NOAA Tech Memo NMFS NE 223; 419 p.

Waring GT, Josephson E, Maze-Foley K, Rosel, PE, editors. 2015. U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments -- 2014. NOAA Tech Memo NMFS NE 223; 419 p.

Watkins WA, Schevill WE (1976) Right whale feeding and baleen rattle. J Mammal 57:58–66.

Watkins, William A. and William E. Schevill. 1979. Aerial Observation of Feeding Behavior in Four Baleen Whales: Eubalaena glacialis, Balaenoptera borealis, Megaptera novaeangliae, and Balaenoptera physalus. Journal of Mammalogy. 60(1): 155-163.

Watts, P., S. Hansen and D. M. Lavigne. 1993. Models of heat loss by marine mammals: Thermoregulation below the zone of irrelevance. Journal of Theoretical Biology 163:505–525.

Werme, C. and C.D. Hunt, 2003 Outfall monitoring overview. Boston: Massachusetts. 2004, Massachusetts Water Resources Authority - Environmental Quality Department Report. ENQUAD 2004-13. p. 97.

Werme C., and C.D Hunt. 2006. 2005 outfall monitoring overview. Boston, Massachusetts Water Resources Authority. Report ENQUAD 2006-18. 105p.

Whitehead, H. and J. Mann. 2000. Female reproductive strategies of cetaceans: Life histories and calf care. In Cetacean Societies: Field Studies of Dolphins and Whales. J. Mann, R.C. Connor, P.L. Tyack, and H. Whitehead, eds. University of Chicago Press, Chicago. Pp. 219-234.

Whitehead, H. and M.J. Moore. 1982. Distribution and movements of West Indian humpback whales in winter. Canadian Journal of Zoology 60:2203-2211.

Whitehead, H. 1987. Updated status of the humpback whale, *Megaptera novaeangliae*, in Canada. Canadian Field-Naturalist 101(2):284-294.

Winn, H.E., C.A. Price and P.W. Sorensen. 1986. The distributional biology of the right whale (Eubalaena glacialis) in the western north Atlantic. Rep. Int. Whal. Comm. (Special issue) 10:129-138.

Winn, Howard E., Jeffrey D. Goodyear, Robert D. Kenney, and Richard O. Petricig. 1995. Dive patterns of tagged right whales in the Great South Channel. Continental Shelf Research. 15(4/5): 593-611.

Wiseman, R.J., J. Payne, and S. Akenhead, 1982. Rapporteurs' comments. In Consultation of the Consequences of Offshore Oil Production on Offshore Fish Stocks and Fishing Operations, A. Longhurst ed., Canadian Technical Report of Fisheries and Aquatic Sciences. 1096: 85-94.

Wishner, Karen F., E. Durbin, A. Durbin, M. Macaulay, H. Winn, R. Kenney. 1988. Copepod patches and right whales in the Great South Channel off New England.Bulletin of Marine Science. 43(3):825-844.

Wishner, Karen F., Jill R. Schoenherr, Robert Beardsley, and Changsheng Chen. 1995. Abundance, distribution and population structure of the copepod *Calanus finmarchicus* in a springtime right whale feeding area in the southwestern Gulf of Maine. Continental Shelf Research. 15(4/5): 475-507.

Wood, R.A., A.B. Keen, J.F.B. Mitchell, and J.M. Gregory. 1999. Changing spatial structure of the thermohaline circulation in response to atmospheric CO2 forcing in a climate model. Nature 399: 572-575.

Xue, H., Chai, F., Pettigrew, N.R., 2000. A model study of the seasonal circulation in the Gulf of Maine. Journal of Physical Oceanography 30, 1111–1135.

Young, S.B. 2001. Potential Adverse Effects of Aquaculture on Marine Mammals. In: Tlusty, M.F., D.A. Bengston, H.O. Halvorson, S.D. Oktay, J.B. Pearce, and R.B. Rheault, Jr. (eds.). Marine Aquaculture and the Environment: A Meeting for Stakeholders in the Northeast. Cape Cod Press, Falmouth, Massachusetts.