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North Atlantic right whale distribution and seasonal occurrence in nearshore waters off New Jersey, USA, and implications for management

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ABSTRACT: The presence of endangered North Atlantic right whales *Eubalaena glacialis* in the mid-Atlantic region of the USA is not well understood. Adequate protection of right whales in the face of plans to develop offshore renewable energy requires more information about this species' distribution and occurrence in this region. We present findings from the first year-round study dedicated to marine mammals in New Jersey's nearshore waters using line transect surveys and passive acoustic monitoring. Four groups of right whales, including a cow–calf pair, were sighted. Right whales were detected acoustically during all seasons. Sightings of females and subsequent confirmations of these same individuals in the calving grounds a month or less later illustrate that these waters are part of this species' migratory corridor. Observations of skim-feeding behavior suggest that feeding may also occur in areas farther south than the main feeding grounds. Based on the year-round occurrence of right whales off New Jersey, we recommend that presumed seasonal migratory patterns not be used alone to determine the timing of construction activities or monitoring/mitigation efforts for offshore development. Our results also provide support for the expansion of existing critical habitat to include nearshore waters of the mid-Atlantic.

KEY WORDS: *Eubalaena glacialis* · North Atlantic right whale · Seasonality · Distribution · Conservation · Passive acoustic monitoring · Surveys

INTRODUCTION

General distribution

The North Atlantic right whale *Eubalaena glacialis* (hereinafter referred to as 'right whale') occurs primarily along the east coast of the USA and Canada but is known to range throughout the entire North Atlantic basin (Brown 1986, Winn et al. 1986, Jacobsen et al. 2004, Jefferson et al. 2008, Hamilton et al. 2009, Silva et al. 2012). Individuals occurring in the western North Atlantic are well studied. In 2010, the best estimate of cataloged whales in the western North Atlantic was 490 individuals (Pettis 2011). Most sightings are recorded in well-known, frequently used habitat areas, including the coastal waters of Georgia and Florida, within Cape Cod and Massachusetts Bays off the northeastern USA, east of Cape Cod in the Great South Channel, and in Canadian waters in the Bay of Fundy and over the Scotian Shelf (Winn et al. 1986, NMFS 2005).

Parturient female right whales undertake a well-defined, strongly seasonal migration in the mid-Atlantic between feeding grounds off the northeastern USA and Canada and calving grounds off the southeastern USA (Winn et al. 1986, Kenney 2001). Not all individuals in the population complete this migration, however, and the seasonal distribution of many whales is largely unknown. For example, right whales are detected often in these well-known habitat areas outside of the times of year when they typically concentrate there (Winn et al. 1986, Kenney 2001, Patrician et al.

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2009, NOAA Fisheries Service 2008 unpubl. data, available at www.noaanews.noaa.gov/stories2008/20081231_rightwhale.html). In addition, most of the population is not accounted for on the calving grounds during winter, and not all reproductively active females return to these grounds each year (Kraus et al. 1986, Brown et al. 2001). Some individuals, including cow–calf pairs, can be seen throughout the fall and winter on the northern feeding grounds with feeding observed (e.g. Sardi et al. 2005), and a large portion of the population may spend the winter in several areas off the northeastern USA, such as the Gulf of Maine and Cape Cod Bay (Cole et al. 2009, Clark et al. 2010, Mussoline et al. 2012).

Management

Right whales are afforded significant legal protection in the USA. They are protected under the Marine Mammal Protection Act (MMPA) and are listed as endangered under the Endangered Species Act (ESA). A number of mechanisms are in place to aid in the conservation and recovery of this population because of their low abundance, low reproductive rates, and continuing mortality related to anthropogenic factors such as collisions with vessels and entanglement in fishing gear (Kraus et al. 2005, Waring et al. 2012). The National Marine Fisheries Service [NMFS] has implemented a number of regulatory actions and voluntary guidelines to protect right whales by mitigating the threat of ship strikes and entanglement in fishing gear. Recent studies indicate that the efficacy of this protection is uncertain because many of the current protective measures encompass only a portion of right whale habitat or do not coincide with timeframes when whales are present (Firestone et al. 2008, Schick et al. 2009, Clark et al. 2010, van der Hoop et al. 2013).

Critical habitat as defined in Section 3(5)(A) of the ESA includes the physical and biological features essential to the conservation of a threatened or endangered species as well as any other areas that may require special management considerations or protection (Title 16 of the United States Code, Sections 1531 et seq.). Right whale critical habitat is currently designated for feeding grounds in Cape Cod Bay and the Great South Channel and for calving grounds off Georgia and northern Florida (NMFS 1994, 2005). Right whale occurrence is concentrated in these areas in February through June and November through March, respectively (Winn et al. 1986, Hamilton & Mayo 1990, Kenney et al. 1995, Nichols et al. 2008). However, right whales have been documented feeding and calving outside these areas (Zani et al. 2008, Pabst et al. 2009, Patrician et al. 2009, Foley et al. 2011), and common seasonal movements of some right whales are not representative of the entire population (Winn et al. 1986, Kenney 2001, Patrician et al. 2009, Silva et al. 2012, NOAA Fisheries Service 2008 unpubl. data, available at www.noaanews.noaa.gov/stories2008/20081231_rightwhale.html). As a result, new regulations to expand existing right whale critical habitat and to include areas in the mid-Atlantic along the migratory corridor have been proposed (NMFS 2010).

Right whales and renewable energy off New Jersey, USA

New Jersey waters are within the known migratory route that right whales follow as they travel between their feeding areas and calving grounds; however, no year-round, dedicated marine mammal studies have previously been conducted in this portion of the mid-Atlantic. Prior to the present study, occurrences of right whales off New Jersey were known only from broader regional studies, opportunistic sightings, stranding records, and fine-scale studies in adjacent waters (e.g. CETAP 1982, Bowman et al. 2001, Knowlton et al. 2002, Biedron et al. 2009).

Nearshore waters (between the coastline and the 30 m isobath) off New Jersey are prime areas of development for potential offshore renewable energy projects. Currently, several wind development projects are planned or in progress in these waters (Bureau of Ocean Energy Management [BOEM], Renewable Energy Programs, www.boem.gov/Renewable-Energy-Program/State-Activities/New-Jersey.aspx). In advance of this development, there is a need for more information about the presence of endangered right whales in this area to inform management decisions. Although development of offshore wind farms may provide a significant source of energy for the USA, development in the marine environment has the potential for biological, physical, and socioeconomic impacts (see MMS 2007). From January 2008 through December 2009, Geo-Marine, Inc. (GMI) conducted an Ecological Baseline Study (EBS) in coastal waters of New Jersey to document the year-round occurrence of marine mammals, sea turtles, and seabirds and provide the state with baseline data in advance of offshore wind energy development. This was the first year-round study focused on marine mammals in nearshore waters off New Jersey. In the present

paper, we summarize the right whale sightings and acoustic detections collected during visual surveys and passive acoustic monitoring of the EBS. We discuss the management implications of these data and include recommendations for how they may be used to inform the current management framework in advance of large-scale offshore renewable energy development along the US east coast.

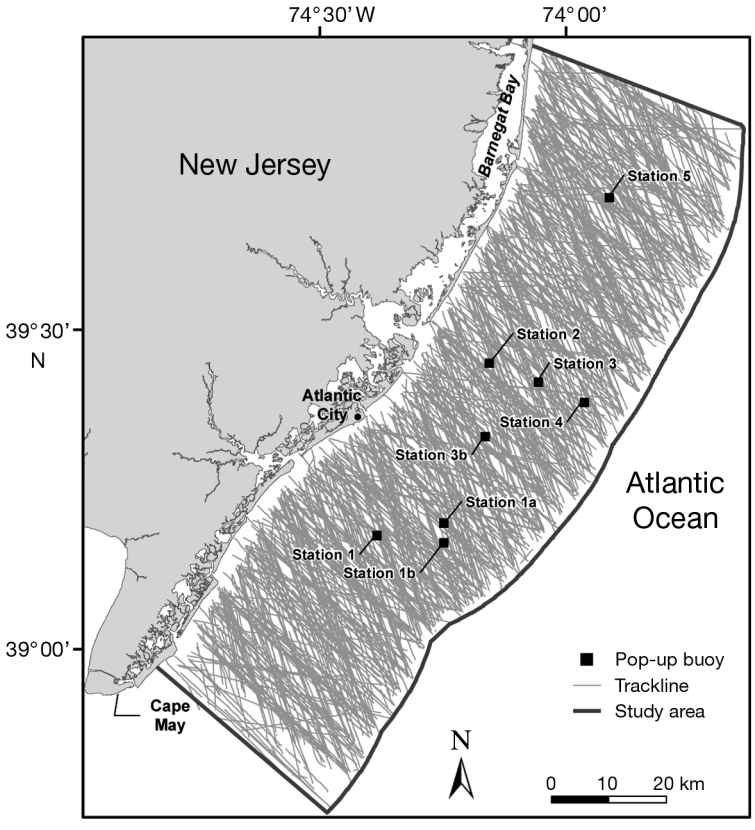

Fig. 1. Study area, completed survey tracklines, and configuration of pop-up buoy stations used throughout the Ecological Baseline Study (EBS)

MATERIALS AND METHODS

Shipboard visual surveys

Monthly shipboard surveys were conducted from January 2008 through December 2009 (except in July 2009) using standard line-transect methods (Buckland 2001) and a single observation platform on the University of Delaware's RV 'Hugh R. Sharp'. The surveys followed randomly generated tracklines in a double saw-tooth pattern to provide comparable spatial and temporal coverage of the entire study area. Surveys covered nearshore waters of New Jersey (shoreline to around 37 km offshore) between Cape May and the northern end of Barnegat Bay (Fig. 1).

The marine mammal visual survey team consisted of 3 experienced observers who recorded observations from the flying bridge during daylight hours when the Beaufort sea state (BSS) was identified as ≤5 and visibility was ≥2 km. Two observers used 25 × 150 power Fujinon binoculars ('bigeyes') mounted on the port and starboard sides of the vessel, while the third observer scanned the trackline with the naked eye or 7 × 35 hand-held binoculars and served as data recorder. Observers rotated through these 3 tasks every 40 min.

Environmental conditions, including BSS, wind speed, swell height and direction, direction of sun, and visibility, were recorded every 40 min and when conditions changed. A GPS unit recorded latitude and longitude of the vessel and the vessel's course and speed at 2 min intervals for correlation with field observations. The following data fields were recorded for each marine mammal sighting: geographic position (latitude and longitude), initial time of sighting, estimated bearing and distance of sighting from vessel, species, number of individuals (group size), behavior of animals observed, and the first cue (e.g. blow or splash) of the sighting. When feasible, digital photographs were taken for photo-identification purposes.

Aerial visual surveys

Line-transect aerial surveys were conducted once monthly between February and May 2008 and twice monthly (when possible) between January and June 2009. The survey aircraft for the 2008 surveys was a twin-engine, high-winged Cessna Skymaster 337 with bubble windows on each side of the aircraft to allow unobstructed views of the trackline directly beneath the plane. During the 2009 surveys, a Cessna Skymaster without bubble windows was used, resulting in limited visibility below the aircraft. Surveys were flown at ~229 m altitude and a speed of ~220 km h^{-1} during daylight hours when there was at least 3.7 km visibility and a BSS ≤5. Tracklines were randomly generated in a parallel design (perpendicular to the coastline) for the first monthly survey, but were changed to a double saw-tooth pattern for the

remainder of the surveys to provide better spatial and temporal coverage (Fig. 1).

A team of 3 scientists recorded visual observations during the 2008 surveys. Two experienced observers searched for animals at the surface from directly beneath the aircraft out to a perpendicular distance of ~1500 m. The third person acted as data recorder and was stationed in the co-pilot seat. During the 2009 surveys, a co-pilot was added as an additional safety measure, thus eliminating the dedicated data-recorder position. Thereafter, data recording was conducted with one observer recording the time and position of each sighting on a laptop and the second observer verbally recording additional sighting information on a digital tape recorder. Tapes were transcribed each evening.

The aircraft's position along the trackline was collected every 10 s on a computer interfaced with the aircraft's GPS. Environmental conditions (e.g. BSS, solar glare, water color, and transparency) affecting animal detections were recorded prior to the start of each trackline and updated as needed while on effort. All sighting data, including time, position, declination angle, group size, species, and behavior, were recorded.

Passive acoustic monitoring

Marine autonomous acoustic recording units ('pop-ups') developed by scientists at the Bioacoustics Research Program [BRP] in Cornell University's Laboratory of Ornithology, Ithaca, NY (see Clark et al. 2002 and www.birds.cornell.edu/brp/hardware/pop-ups) were deployed in 5 locations throughout the study area (Fig. 1). Each pop-up had an approximate detection range of 9 km (Clark et al. 2010), although exact range distance is not calculable, because signal strength and reception can be affected by environmental conditions, depth, substrate type, unit sample rate, call intensity, and other factors. Pop-ups were deployed on a quarterly schedule from March 2008 through December 2009, yielding data from 6 deployments. Two deployment locations (Stns 1 and 3) were moved because of equipment loss at the original locations, resulting in variation in the number of pop-ups deployed each quarter. Between 3 and 6 pop-ups that resulted in usable data were deployed at any given time. Deployment depths ranged from 17.8 to 29.8 m. From March to June 2008, all pop-ups were configured with a sample rate of 2 kHz and a continuous duty cycle to capture baleen whale vocalizations. From June 2008 forward, 2 or 3 pop-ups per deployment were programmed with a 2 kHz sample rate and continuous duty cycle, while the other units were configured for odontocete sounds.

A cross-configuration (2 intersecting lines, one stretching north–south and the other east–west) was selected for placement of the 5 pop-ups, with roughly 72 km between the southern (Stn 1 at 18.9 km perpendicularly from shore) and northern (Stn 5 at 18.7 km) locations, and approximately 24 km between the eastern (Stn 4 at 29.6 km) and western (Stn 2 at 12.4 km) locations (Fig. 1). The cross-configuration deployment scheme was selected to maximize coverage of the study area within logistical constraints. Details related to the deployment, recovery, and refurbishment of the recording units can be found in Dudzinski et al. (2011) and GMI (2010).

All low-frequency data were processed for right whale up-calls using custom software algorithms (i.e. Israt2; Urazghildiiev & Clark 2006, Urazghildiiev et al. 2009). Sample spectrograms of several right whale up-calls are available for viewing and listening at www.dolphincommunicationproject.org/publications/supplemental.html. Positive detections were verified by 2 experienced acousticians. Because the EBS protocol required confirmation of daily detection only of right whales, no analyses related to possible vocal behavior patterns were conducted. As such, an acoustic 'detection day' represents the presence of at least 1 confirmed up-call and not a total count of the number of up-calls detected on a given day.

RESULTS

The following periods were used as seasonal designations based on oceanographic data: winter (18 December to 9 April), spring (10 April to 21 June), summer (22 June to 27 September), and fall (28 September to 17 December).

Survey and acoustic sampling effort

Survey and acoustic sampling effort is summarized in Table 1. The shipboard surveys covered a total of 12 893 km of on-effort trackline, and shipboard effort was evenly distributed throughout the seasons: winter (3696 km), spring (2704 km), summer (3830 km), and fall (2663 km). The aerial surveys covered a total of 12 222 km of on-effort trackline, and aerial effort varied among seasons due to logistical constraints: winter (6188 km), spring (4084 km), and summer (1950 km). No aerial surveys were conducted during the fall.

Table 1. *Eubalaena glacialis*. Survey effort (km of trackline covered), acoustic recordings (number of days that pop-ups recorded per month), acoustic detections (total number of days a right whale was detected in the study area each month, including detections on different pop-ups [stations] on the same day), and day-detection rates (this standardizes the number of detections per month, including multiple unit detections, and was calculated by dividing the number of detections by the number of days in that month for which a pop-up was deployed and recording). Sightings are listed per month. Blank cells represent no effort

Year and month	Shipboard survey effort (km)	Aerial survey effort (km)	Acoustic recordings (d)	Acoustic detections (d)	Day-detection rate	Right whale sightings
2008						
Jan	335					0
Feb	109	549				0
Mar	589	728	6	10	1.67	0
Apr	464	850	30	25	0.83	0
May	413		31	37	1.19	1
Jun	570		24	6	0.25	0
Jul	711		31	2	0.06	0
Aug	706		31	5	0.16	0
Sep	780		18	5	0.28	0
Oct	794		31	1	0.03	0
Nov	479		30	6	0.20	1
Dec	347		21	1	0.05	0
2009						
Jan	561	1600	31	1	0.03	1
Feb	898	1770	28	5	0.18	0
Mar	837	1542	31	3	0.10	0
Apr	462	1728	30	2	0.07	0
May	579	1507	31	4	0.13	0
Jun	583	1948	7	0	0	0
Jul						
Aug	1208		21	3	0.14	0
Sep	592		30	7	0.23	0
Oct	203		31	4	0.13	0
Nov	508		30	1	0.03	0
Dec	165		7		0	1

Pop-ups recorded for a total of 530 d between March 2008 and December 2009; this total does not reflect the simultaneous days of recordings for the multiple pop-ups. The total days of recordings varied among pop-ups because of hard-drive or circuit-board malfunctions and the loss of some of the units (see GMI 2010 and Dudzinski et al. 2011). A total of 1363 unit-recording days were analyzed for right whales across the 5 pop-up stations throughout all seasons: winter (194 d), spring (376 d), summer (419 d), and fall (374 d). Pop-up data are summarized in Table 2. Of the 530 d of acoustic recordings, 97 overlapped with shipboard and/or aerial survey effort. The shipboard and aerial surveys were conducted simultaneously during only 1 d in February 2009. The shipboard surveys were conducted over 103 d of effort from January 2008 through December 2009. The aerial surveys were conducted over 21 d of effort from February through May 2008 and January through June 2009.

Sightings and acoustic detections

Four groups of right whales were sighted during shipboard surveys, and no right whales were sighted during aerial surveys (Table 1). Sightings occurred in water depths ranging from 17 to 26 m (mean: 22.5 m). Distances from shore ranged from 19.9 to 31.9 km (mean: 23.7 km). Group sizes ranged from 1 to 2 whales; all 5 of the adult/juvenile whales sighted were matched to the North Atlantic Right Whale Catalog maintained by researchers at the New England Aquarium in Boston, MA. Cataloged individual No. 3115 was sighted with her calf on 10 May 2008. No. 2320, an adult female, was sighted on 17 November 2008. Two juveniles, No. 3421 (male) and No. 3460 (unknown sex), were sighted together on 10 January 2009. Adult female No. 3123 was sighted on 12 December 2009 (see Fig. 2).

Right whale up-calls were detected on a total of 128 d (including detections from different pop-ups on the same day) (Table 1). A total of 76 d had detections on only 1 pop-up on the given day, while 95 d were observed to have up-calls detected on ≥1 pop-ups. Nevertheless, each day with multiple pop-up detections is counted only once; March, April, and May were the 3 months for which multiple pop-ups (2, 3, and 4 units) detected right whale up-calls on the same day (9, 7, or 3 d, respectively). Total detection days per

Table 2. *Eubalaena glacialis*. Days per season per station for which pop-up data were examined for right whale vocalizations. See Fig. 1 for station locations. Total: total no. of days of recordings per season

Stn	Winter	Spring	Summer	Fall	Total d stn^{-1}
1	0	0	85	0	85
1a	15	59	0	0	74
1b	0	0	48	71	119
2	15	51	48	71	185
3	119	69	0	68	256
3b	0	0	48	71	119
4	30	128	55	0	213
5	15	69	135	93	312
Total	194	376	419	374	1363

season were as follows (totals include multiple pop-up detections on the same day): winter 2008, 16 detections; spring 2008, 62 detections; summer 2008, 12 detections; fall 2008, 8 detections; winter 2009, 9 detections; spring 2009, 6 detections; summer 2009, 9 detections; and fall 2009, 6 detections (Table 1). It is possible that right whale up-calls might have been recorded on multiple pop-ups on the same days from March through May 2009; however, loss of gear resulted in no data for this time period.

During the 97 d of simultaneous survey effort (shipboard and/or aerial) with pop-up recordings, there was 1 d when whales were sighted but not heard and 94 d when whales were heard but not sighted by either the shipboard or aerial survey teams. Right whales were neither heard nor sighted during 459 of the total 556 d on which at least one method (aerial or shipboard visual surveys or passive acoustic monitoring) was utilized.

Seasonal occurrence

Right whales were sighted in winter, spring, and fall, and detected acoustically during all seasons (Fig. 2). They were sighted in waters with sea surface temperatures (SSTs) ranging from 5.5 to 12.2°C (mean: 10.0°C). Sightings were distributed throughout the study area (Fig. 2). Acoustic detections were greatest at the pop-up stations in the northern (Stn 5) and central (Stns 2, 3, 4) portions of the study area (Table 2). The total number of days with acoustic detections was much lower from the pop-up stations in the southern (Stns 1, 1a, 1b) portion of the study area even though 3 of the 4 sightings were recorded in the southern half of the study area (Fig. 2). Loss of pop-ups from the southern area may have contributed to the observed differences in detections between stations.

A peak number of acoustic detection days was documented for April and May (Fig. 3a), although rates of up-call detections per day were greatest from March through June (Fig. 3b). The 2 juveniles (No. 3421 and No. 3460) were sighted in the northern portion of the study area during winter, and the cow–calf pair (No. 3115 and calf) was sighted offshore of Atlantic City during spring (Fig. 2). Right whale up-calls were detected sporadically in the eastern and northern areas of the study area during the summer through the fall. Although no sightings were recorded during the summer, No. 3123 and No. 2320 were both sighted in the southern portion of the study area during late fall (Fig. 2).

Movement and habitat use

Based on sightings and acoustic detections recorded during the present study, we confirmed the movement of right whales through the study area between the main feeding and calving grounds. Adult female No. 2320 was sighted in November 2008 northeast of Cape May prior to being observed on the calving grounds off the coast of Florida in mid-December 2008 (M. Zani pers. comm.). The sighting of No. 3123, also an adult female, was northeast of Cape May in December 2009; she was later sighted off the coast of Georgia in early January 2010 (M. Zani pers. comm.). No. 3115 and her calf, which were sighted in waters near the 17 m isobath southeast of Atlantic City in May 2008, were previously confirmed off the southeast USA in January and February and subsequently sighted in the Bay of Fundy in August of the same year (M. Zani pers. comm.).

Additionally, occurrence of some right whales off New Jersey may be associated with feeding. The 2 juvenile whales observed during January 2009 (No. 3460 and No. 3421) were engaged in skim-feeding behavior for approximately 1 h in 26 m of water offshore of Barnegat Bay in the northern portion of the study area. We were unable to collect any prey samples, and no prey patches were evident, so we could not confirm feeding.

DISCUSSION

There is relatively little information on the geographic and temporal extent of the right whale's migratory corridor (Winn et al. 1986, Kenney 2001, Firestone et al. 2008, Patrician et al. 2009, Schick et al. 2009). Our sightings of females in the study area and subsequent confirmation of these same individuals in the calving grounds a month or less later confirm the nearshore waters of New Jersey as part of a migratory corridor between feeding grounds in the northeast and calving grounds in the southeast. In addition, we confirmed that the cow–calf pair sighted in the study area was en route to the Bay of Fundy from the calving grounds. A previously tagged cow and her calf were also tracked from the Bay of Fundy to New Jersey and back within a 6 wk period (Knowlton et al. 2002). The sightings and acoustic data from the present study also suggest that the nearshore waters of New Jersey may serve habitat functions other than migration for this species. From as early as November and through April, right whales are known to be on their calving grounds off the southeast USA

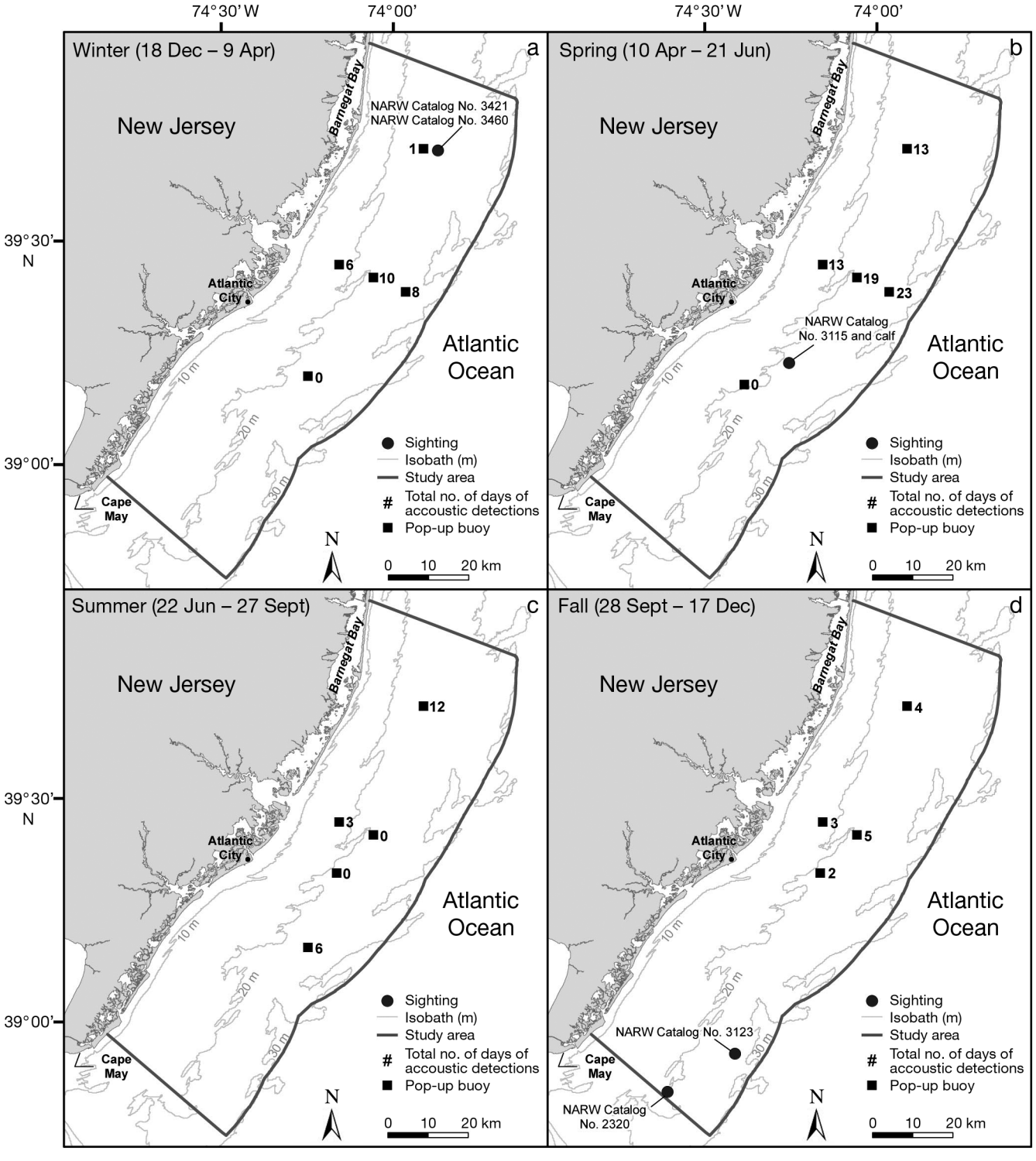

Fig. 2. *Eubalaena glacialis*. Seasonal occurrence of sightings and acoustic detections of right whales in the study area: (a) winter, (b) spring, (c) summer, and (d) fall. ID numbers for individuals matched to the North Atlantic Right Whale (NARW) Catalog are shown

(Winn et al. 1986, Kenney 2001, Firestone et al. 2008). Although we detected right whales on 74 days outside of this time period, the other sightings and acoustic detections from the present study are consistent with the known migration time periods. These data support the hypothesis that right whales are

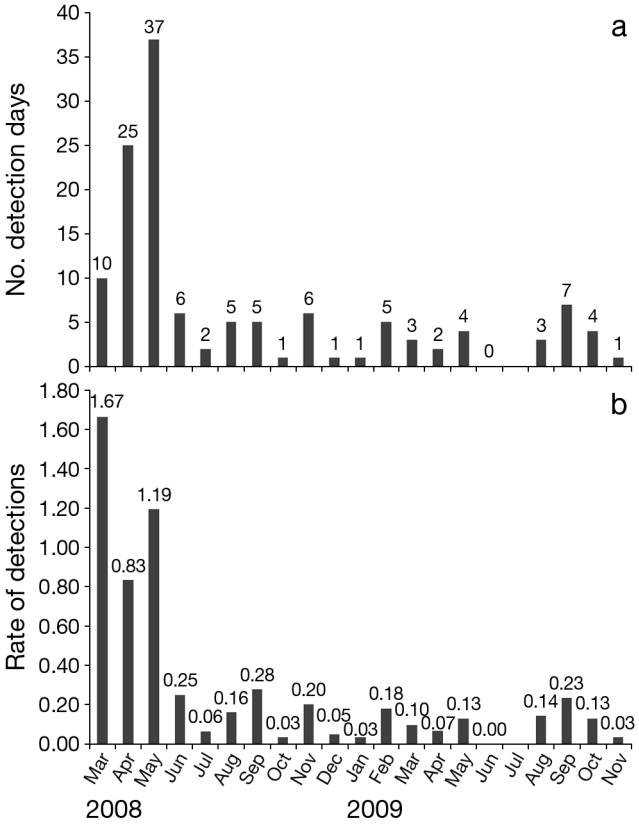

Fig. 3. *Eubalaena glacialis*. (a) Monthly summary of number of up-call detections from March 2008 through November 2009. (b) Rate of acoustic detections per month based on number of detection days divided by number of days per month with pop-ups deployed. No pop-ups were deployed from 15 June to 11 August 2009; therefore no data are shown for July 2009. Detections on multiple deployed pop-ups per day are included (i.e. not total detections per day per pop-up but multiple detection days on >1 pop-up; see 'Results' for details)

using the nearshore waters of New Jersey as they travel between main feeding and calving grounds but may also utilize these waters for more than just a migratory pathway.

Parks et al. (2011) obtained detailed information on call rates for 35 individual right whales with respect to specific behaviors; whales engaged in surface activity or traveling were more vocal than those foraging or logging. The findings of Parks et al. (2011) may support our lack of acoustic detections when 2 juveniles were exhibiting feeding behavior in January 2009. Although actual feeding could not be confirmed, this behavior off Barnegat Bay suggests that feeding may occur outside the typical feeding period of spring through early fall and in areas farther south than the main feeding grounds (Winn et al. 1986, Gaskin 1987, 1991, Hamilton & Mayo 1990, Kenney et al. 1995). This skim-feeding behavior has been observed as far south as the calving grounds (P. Naessig pers. comm.).

Acoustic detections of right whale calls confirm the occurrence of this species in the study area during all seasons, with a peak number of detection days during the months of March through June. Mussoline et al. (2012) detected an increase in up-call rates in January to March, with a peak in April, on Stellwagen Bank; the consecutive month detections between Stellwagen Bank and the New Jersey coastline suggest that right whales may be moving between these regions during this time of year. The peak detections documented off New Jersey could also be related to whales returning from the calving area to the south; for example, the cow–calf pair sighted in May off New Jersey had been on the calving grounds earlier in the year. Thus, the peak detections in spring could reflect the northward movement of whales towards their summer feeding grounds. Peak detections may correspond to a higher number of right whales present or simply an increase in vocalizations or both. Fewer detections during the rest of winter, in summer, and in fall may indicate that right whales are not as numerous in the study area during these times of year, or that they are present but vocalizing less.

Management considerations

Our results demonstrate the presence of right whales off New Jersey throughout all seasons; therefore, the known seasonal migratory patterns should not be used alone to determine appropriate management actions in this region. This is particularly important for the planning and execution of offshore renewable energy development in the mid-Atlantic. Offshore wind power is a nascent industry in the USA; the EBS was commissioned specifically to provide baseline data in advance of any development off New Jersey. Our data clearly show that right whales may occur in mid-Atlantic waters year-round. The timing of meteorological tower installations and wind farm construction and decommissioning should take into consideration the fact that right whales may be present at any time. In addition, monitoring and mitigation plans should include specific protocols for the likely presence of right whales throughout the year.

The year-round occurrence and confirmed migration of right whales through the study area also provide support for extending the current areas of critical habitat designated for this species. Critical habitat as defined by the ESA should include the

specific geographical area occupied by the species; however, the ESA does not provide for simply swathing the whole of a species' range with the label 'critical habitat'. Rather, it must take into account the physical and biological features within that range essential to the conservation of the species, and that may require special management considerations. Our data show that the nearshore waters of New Jersey, and likely the waters connecting this area to both the feeding and calving grounds in the northeast and southeast USA, respectively, fulfill this definition of critical habitat. The migratory corridor along the US mid-Atlantic coast, including off New Jersey, is essential to the successful movement of right whales between feeding and calving grounds, and is utilized by adult, juvenile, and reproductively active individuals. Individuals in the nearshore waters of New Jersey were documented exhibiting obvious skim-feeding behavior, suggesting that this area is not only important to the movement of right whales among existing critical habitat areas but also provides specific physical and biological features essential to the species' survival.

Our data also provide important information for determining the extent of the migratory corridor. A review of previous sightings data collected in the mid-Atlantic found that 94% of all right whale sightings were within 56 km from shore (Knowlton et al. 2002). Based on the results of that review and our present study, we recommend that a migratory corridor critical habitat be designated from the shoreline to at least 50 km from shore and include all of the nearshore waters of New Jersey. This is within the range of suitable habitat that Schick et al. (2009) estimated for right whales along the mid-Atlantic migratory corridor, and such a designation is supported by our sightings/acoustic detections, the observed right whale behavior in our study area, and subsequent sightings of individuals. Because we acoustically detected right whales throughout the year, not just during 'typical' migratory periods, and because we observed them engaged in skim-feeding behavior, we strongly recommend that any mitigation measures and management considerations implemented (e.g. mitigation for construction or the designation of the migratory corridor as critical habitat) be year-round to maximize protection of the species.

Although the present study was not intended to compare the methods of shipboard surveys, aerial surveys, and passive acoustic monitoring, our results do provide some useful information that can be applied to future research and monitoring/mitigation efforts in this region and other relatively small-scale, low-density areas. As is evident from our present study results, as well as those in Clark et al. (2010) and Morano et al. (2012), acoustic monitoring is a more reliable method of detecting the presence of right whales than visual survey methods simply because the former offers a higher probability of detection over a longer period of time and is often less directly labor-intensive and more economical. Detections by acoustic devices are also not limited to availability and perception biases that can hinder detections by visual surveyors (see Marsh & Sinclair 1989, Barlow 1999, Buckland et al. 2001, Hobbs & Waite 2010).

Passive acoustic monitoring provides the best current method of detecting right whales over a long period of time with minimal effort, which is critical for evaluating and updating current management protocols in a specific region. Since the detection of just one right whale is enough to trigger management protocols, occurrence information is a priority over abundance information (Clark et al. 2010). Therefore, the deployment of additional passive acoustic monitoring devices within the known migratory pathway along the US east coast in waters farther offshore and outside the current critical habitats (calving and feeding grounds) provides the best option to better assess the current distribution of right whales. Acoustic detections of right whales in these currently non-critical habitat areas will provide a more comprehensive assessment of when whales are present, which will better inform and redefine management programs. Acoustic monitoring is also an ideal, cost-effective tool for assisting planners in near-real time on where and when to conduct construction or other activities associated with offshore wind development.

CONCLUSIONS

Right whales are not present in large numbers off New Jersey, but individual whales use these waters regularly as a migratory corridor and, at least occasionally, for other activities. Management of potentially deleterious activities should take the presence of these highly endangered whales into account and adopt appropriate mitigation measures. The following is a summary of the primary conclusions from the present study:

(1) North Atlantic right whales are present off New Jersey throughout the year and not only during 'typical' migratory periods.

(2) Photo-identification data of right whales indi-

cate that various age and sex classes (adult females, cow–calf pairs, and juvenile males) utilize nearshore waters off New Jersey.

(3) Nearshore waters off New Jersey are part of a right whale migratory corridor and may also be a feeding habitat for this species.

(4) Peak acoustic detections were in winter and spring (March to June); peak detections may correspond to a higher number of right whales present or simply an increase in vocalizations, or both. It is possible that right whales frequent the study area during fall and summer but vocalize less during these seasons or utilize a more offshore migratory route during this time of year.

Our results augment the current understanding of right whale seasonal distribution and movement patterns along their migratory corridor. Our data provide support for the extension of the critical habitat to include the entire migratory path and also provide vital information for developing monitoring and mitigation protocols for this region.

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