Marine Mammal Science

MARINE MAMMAL SCIENCE, 25(2): 462–477 (April 2009)

DOI: 10.1111/j.1748-7692.2008.00261.x

Evidence of a North Atlantic right whale calf (*Eubalaena glacialis*) born in northeastern U.S. waters

MELISSA R. PATRICIAN
Woods Hole Oceanographic Institution,
Biology Department, M.S. #32,
Woods Hole, Massachusetts 02543, U.S.A.
E-mail: mpatrician@whoi.edu

INGRID S. BIEDRON
Bioacoustics Research Program,
Cornell Laboratory of Ornithology,
159 Sapsucker Woods Road,
Ithaca, New York 14850, U.S.A.

H. CARTER ESCH
Woods Hole Oceanographic Institution,
Biology Department, M.S. #33,
Woods Hole, Massachusetts 02543, U.S.A.

FREDERICK W. WENZEL
National Marine Fisheries Service,
Northeast Fisheries Science Center,
166 Water Street,
Woods Hole, Massachusetts 02543, U.S.A.

LINDSAY A. COOPER
PHILIP K. HAMILTON
New England Aquarium,
Central Wharf,
Boston, Massachusetts 02110, U.S.A.

ALLISON H. GLASS
National Marine Fisheries Service,
Northeast Fisheries Science Center,
166 Water Street,
Woods Hole, Massachusetts 02543, U.S.A.

MARK F. BAUMGARTNER
Woods Hole Oceanographic Institution,
Biology Department, M.S. #33,
Woods Hole, Massachusetts 02543, U.S.A.

The general temporal and geographical patterns of North Atlantic right whale (*Eubalaena glacialis*) calving events have been clarified during the last quarter century of research (Kraus and Rolland 2007). Right whales give birth to a single calf every 3–5 yr after a 12–13-mo gestation period (Best 1994, Kraus and Hatch 2001). Most

Figure 1. Map of the eastern coast of the United States with the 2007 sightings of Eg 2360. On 30 March 2007 and 26 April 2007, Eg 2360 was seen without a calf (open symbols). All other sightings were with her 2007 calf, Eg 3760 (shaded symbols). Our sighting on 2 June 2007 is represented here with a star.

calves are born between December and March in the coastal waters of the southeastern United States, the only known calving ground for this species (Fig. 1) (Winn *et al.* 1986, Kraus *et al.* 2007). Although historical whaling records suggest that there were once two winter calving grounds, one off the southeastern United States and the other off northwestern Africa, it appears that only the former is still used today (Reeves and Mitchell 1986, 1988; Notarbartolo di Sciara *et al.* 1998). In the late winter, right whales leave the calving grounds and migrate to their foraging grounds off the northeastern United States and Canadian Maritimes (Fig. 1). North Atlantic right whales can be found in Cape Cod and Massachusetts Bays throughout the late winter and early spring (Schevill *et al.* 1986, Hamilton and Mayo 1990, Mayo and Marx 1990), in the Great South Channel during mid-spring to early summer

(Kenney *et al.* 1995), and in the Bay of Fundy (Kraus *et al.* 1982), and on the Scotian Shelf (Mitchell *et al.* 1986, Stone *et al.* 1988) during the summer and fall. Some individuals (mostly pregnant females and juveniles) return to the calving grounds off the southeastern United States in December and January, but the location of the rest of the population during those months is currently unknown (although recent evidence suggests that right whales are present in the Gulf of Maine and on the Scotian Shelf throughout the winter (Mellinger *et al.* 2007, T. Cole,[1] S. Van Parijs[2]).

These seasonal movements describe the typical distribution of the population, but there is a great deal of variability in habitat use among individuals. Adult females are seen less often in the foraging habitats described above than males and juveniles (Brown *et al.* 2001). The lower Bay of Fundy is the most common nursing ground for calves in the summer and fall; however, there are some mothers (referred to as "non-Fundy" animals) who do not visit the Bay of Fundy with their calves (Schaeff *et al.* 1993). There are additional documented habitat areas used by right whales, including Jeffrey's Ledge (Weinrich *et al.* 2000), the central Gulf of Maine (Waring *et al.* 2006), and the central Scotian Shelf (Mitchell *et al.* 1986). There have been opportunistic sightings of right whales in the Gulf of Mexico, northwestern Gulf of St. Lawrence, eastern and southern Newfoundland, southern Greenland, Iceland, and northern Norway (Lien *et al.* 1989, Knowlton *et al.* 1992, IWC 2001). These seemingly anomalous sightings appear to occur largely on alternative foraging grounds (except the Gulf of Mexico sightings), although there has been little documentation of alternative habitats used for calving.

Right whales are individually identified using scars on their bodies (Kraus 1990) and the pattern of callosity tissue on their head (Payne *et al.* 1983, Kraus *et al.* 1986). Callosities are areas of cornified skin that grow on the head, behind the blowholes, above the eyes, on the chin, and along the mandibles. The callosities are infested with cyamids, which are light in color and help to highlight the patches of callosity (Hamilton *et al.* 2007). The pattern of these growths are stable over time and photographs of right whale heads have been used to develop a detailed database of identified individuals, the North Atlantic Right Whale Catalog, in which each individual is assigned a unique identification number (*e.g.,* Eg XXXX) (Hamilton *et al.* 2007). Calves are born without any callosity and it can be several months before it begins to develop; the callosity is generally not fully developed until the late summer or fall of the birth year. Calves are also born with a prominent dip in their rostrum, forward of the blowholes, due to their undeveloped head. This dip becomes less apparent as they grow during their first year (Sironi *et al.* 2005, Hamilton *et al.* 2007).

On 2 June 2007 at 1700 GMT, a North Atlantic right whale was observed with a small calf in the Great South Channel (41.60°N, 68.79°W) from the NOAA Ship *Albatross IV* during a right whale foraging ecology cruise (Fig. 1). The mother/calf pair passed within 500 m of the vessel and was photographed (Fig. 2) with Nikon D50 and D70 digital cameras outfitted with 70–300-mm telescopic lenses. The adult

[1]Tim V. N. Cole, National Marine Fisheries Service, Northeast Fisheries Science Center, 166 Water Street, Woods Hole, MA 02543, February 2008.

[2]Sophie M. Van Parijs, National Marine Fisheries Service, Northeast Fisheries Science Center, 166 Water Street, Woods Hole, MA 02543, February 2008.

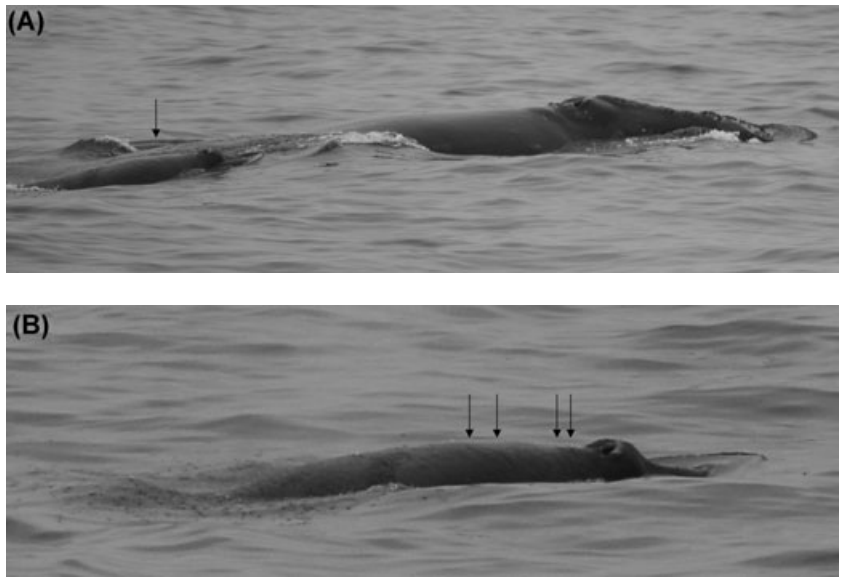

Figure 2. (A) Eg 2360 with calf on 2 June 2007 in the Great South Channel (41.60°N, 68.79°W). The arrow indicates the calf. (B) Close-up of calf (Eg 3760) showing lack of callosity growth and prominent dip in rostrum forward of the blowholes. The arrows indicate the grooves seen on the back, which may potentially be fetal folds. Photo credits: (A) and (B) Ingrid Biedron, Cornell Laboratory of Ornithology.

was identified as Eg 2360, a reproductively active female that had previously given birth to one other calf, Eg 3460.[3] The calf observed on 2 June (later designated Eg 3760) was approximately 6 m in length and was observed swimming in the nursing position next to the mother. It had a small undeveloped head and no visible callosity tissue or cyamids (although only a portion of the head was visible in the photographs). While this length approximation is our best estimate, we recognize that there are likely large error bounds with this estimate, due to the distance from which we were viewing the animals. Given the time of year of this sighting, it was expected that this calf would have been approximately 3–6 mo of age; however, its size, head shape, lack of callosity, and lack of cyamids suggest that it was much younger. Based on necropsy reports, newborn North Atlantic right whale calves are estimated to be between 4.0 and 5.5 m in length (Kraus *et al.* 1986, Moore *et al.* 2004), and Moore *et al*. (2004) estimated a 7.7-m-long ship-struck calf to be 3–4 mo old. These length estimates suggest that the calf we observed was quite young at the time of sighting. At the time of our sighting, the calf appeared to have grooves across its back (Fig. 2B) reminiscent of fetal folds found in newborn calves (folding of the skin caused by the calf's position in the womb). These grooves are similar to the fetal folds observed by Bonde (2004) on a stranded right whale calf that was 1 wk

[3]North Atlantic Right Whale Consortium Identification Database, New England Aquarium, Central Wharf, Boston, MA, 02110, June 2007.

old. Bottlenose dolphins and gray whales display fetal folds that are only visible on newborn calves and disappear quickly once a calf starts nursing (Eberhardt and Norris 1964, Sumich and Harvey 1986, Barco *et al.* 1999).

Eg 2360 was encountered in 2007 prior to our 2 June sighting by the NOAA Northeast Fisheries Science Center right whale aerial survey team. The aerial survey team observed Eg 2360 without a calf on 30 March 2007 (41.57°N, 69.37°W) and 26 April 2007 (41.27°N, 68.87°W), 48 and 37 km from our 2 June sighting, respectively (Fig. 1). On each occasion, the airplane circled for approximately 5 min to obtain identification photographs; it is unlikely that an accompanying calf would have been missed by the three experienced aerial survey observers and the pilots. As newborn calves have never been seen separated from their mothers,[4] Eg 2360 must have given birth after 26 April making the calf no older than 37 d when first sighted.

To further determine an estimated maximum age of Eg 3760 on 2 June, a subset of calves whose date of birth could be narrowed to less than 2 wk were reviewed (Fig. 3A, B). The development of callosity growth and cyamids colonization were analyzed for these calves. In all cases, cyamids first appeared on the margins of the lip within 6 to 15 d of birth. Although Eg 3760's head was not fully visible in the 2 June sighting, the right lip margin was visible in one image (Fig. 3C) and no cyamids were present. This suggests it was likely less than 2 wk of age. The photographs of Eg 3760 on 2 June were also compared to calves of known age (5–6 mo) in the Great South Channel (Fig. 3D, E). From this comparison, it is clear that the head of Eg 3760 is much less developed and has less callosity and cyamid coverage than expected of a 5–6-mo-old calf in the Great South Channel.

According to R. Leaper,[5] based on modeling sighting patterns of individually identified whales, it takes approximately 19 d for an adult right whale to travel from the southeastern U.S. calving grounds to the northern feeding grounds, suggesting an average swim speed of 1.8 kn. Firestone *et al.* (2008) suggest that it takes a right whale 21–24 d to make this same one-way trip. During August 2000, Eg 2320 was tagged with a satellite transmitter in the Bay of Fundy and later traveled from the Great South Channel to the coast of Georgia in 19 d (Baumgartner and Mate 2005). Because Eg 3760 could be no older than 37 d, and was likely less than 15-d old, we consider it highly unlikely that Eg 2360 could have traveled to the southeastern U.S. calving grounds after she was seen on 26 April to give birth and then return to the Great South Channel before being sighted on 2 June. While we cannot determine the exact location of the calving event given our observations, it is conceivable that Eg 2360 made a partial southward migration to the mid-Atlantic region (to a location between New Jersey and the Carolinas) to give birth. In the past, mother/calf pairs have been seen in the mid-Atlantic region without being seen in the southeastern United States during the same year, suggesting that calving may have occurred in this area before.[6] This scenario would still require a relatively quick journey of several

[4]Monica Zani, New England Aquarium, Central Wharf, Boston, MA 02110, March 2008.

[5]Russell Leaper, International Fund for Animal Welfare, England, December 2007.

[6]North Atlantic Right Whale Consortium Identification Database, New England Aquarium, Central Wharf, Boston, MA 02110, April 2008.

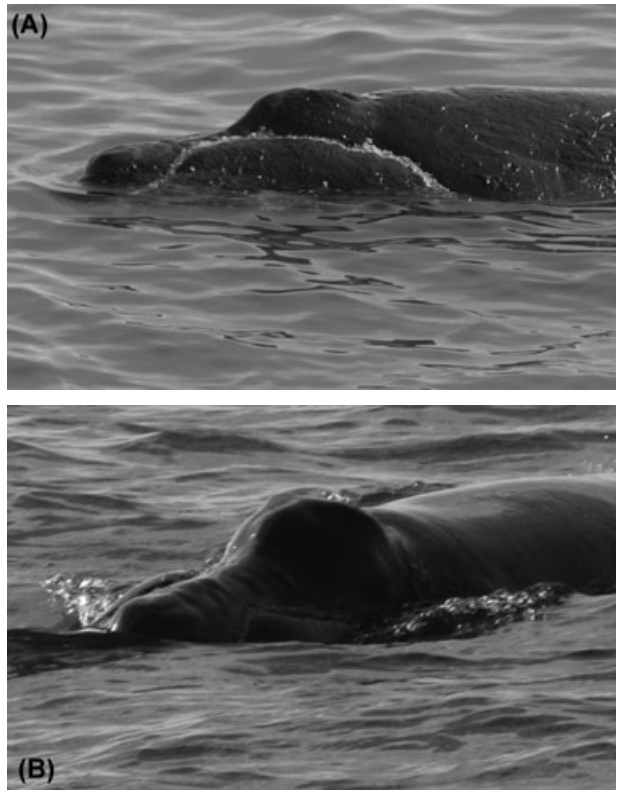

Figure 3. Photographs of Eg 3760 from the 2 June 2007 sighting were compared to both calves less than 2-wk old (photographed in the southeastern U.S. calving grounds) and also to calves 5–6 mo old in the Great South Channel (the expected age of calves in this region). (A) The 2007 calf of Eg 2614 was 12–17 d old at the time of this photograph. The first callosity tissue is seen here on the left chin (under the waterline) and cyamids are aggregating on the left lip margin of this calf. (B) The 2008 calf of Eg 1408 was less than 10 d old at the time of this photograph. There are no callosity growths or cyamid coverage on this young calf. (C) A close-up of the head of Eg 3760 from the 2 June 2007 sighting. The right lip margin of this animal is clearly visible in this photograph with no callosity tissue or cyamid coverage. (D) The 2005 calf of Eg 1970 and (E) the 2005 calf of Eg 1310 are both 5–6 mo old at the time of these photographs and have much larger heads and more callosity tissue and cyamid coverage than the younger calves in this figure. Photo credits: (A) and (B) Clay George, Georgia Department of Natural Resources; (C) Ingrid Biedron, Cornell Laboratory of Ornithology; (D) and (E) New England Aquarium.

hundreds of kilometers with a newborn calf. As most calves remain in the southeast for weeks to months after their birth,[7] it is slightly more plausible that the calf was born in waters off the northeastern United States, possibly off the coast of New England.

[7]Monica Zani, New England Aquarium, Central Wharf, Boston, MA 02110, August 2008.

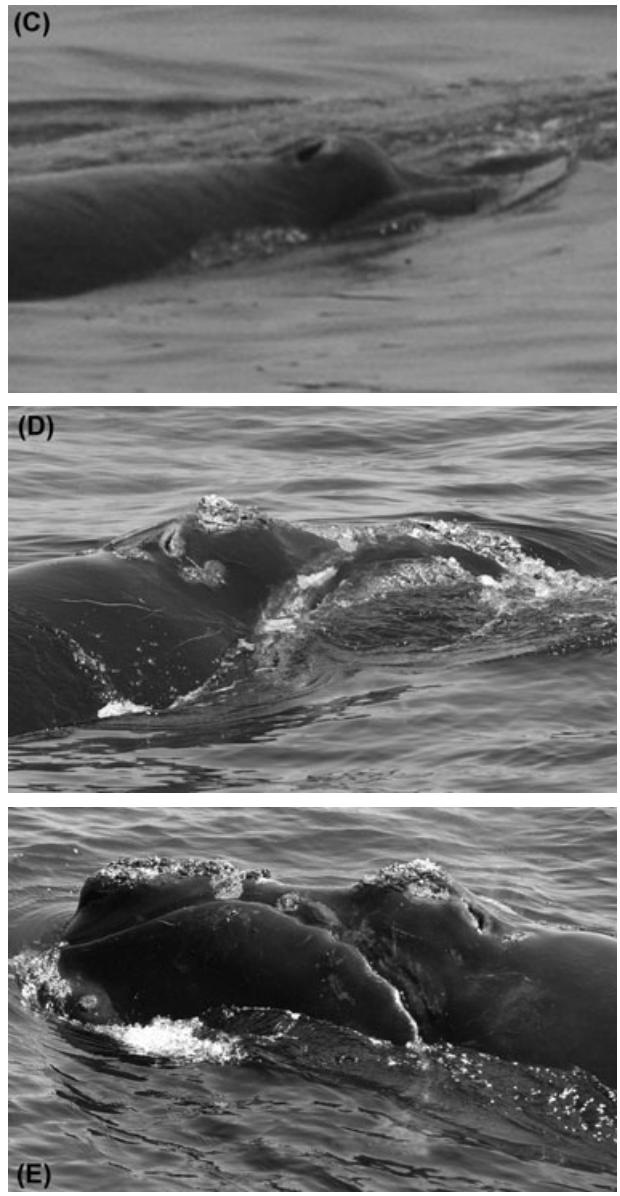

Figure 3. Continued.

Interestingly, Eg 2360 and her calf did eventually visit the southeastern U.S. calving grounds 1.5 mo after she was seen in the Great South Channel. On 17 July 2007, the mother/calf pair was photographed off the northeast coast of Florida (30.28°N, 81.23°W) by a fishing vessel, 6 mo after the peak time for mothers and calves in the area (Fig. 1). This is the first sighting of a North Atlantic right whale

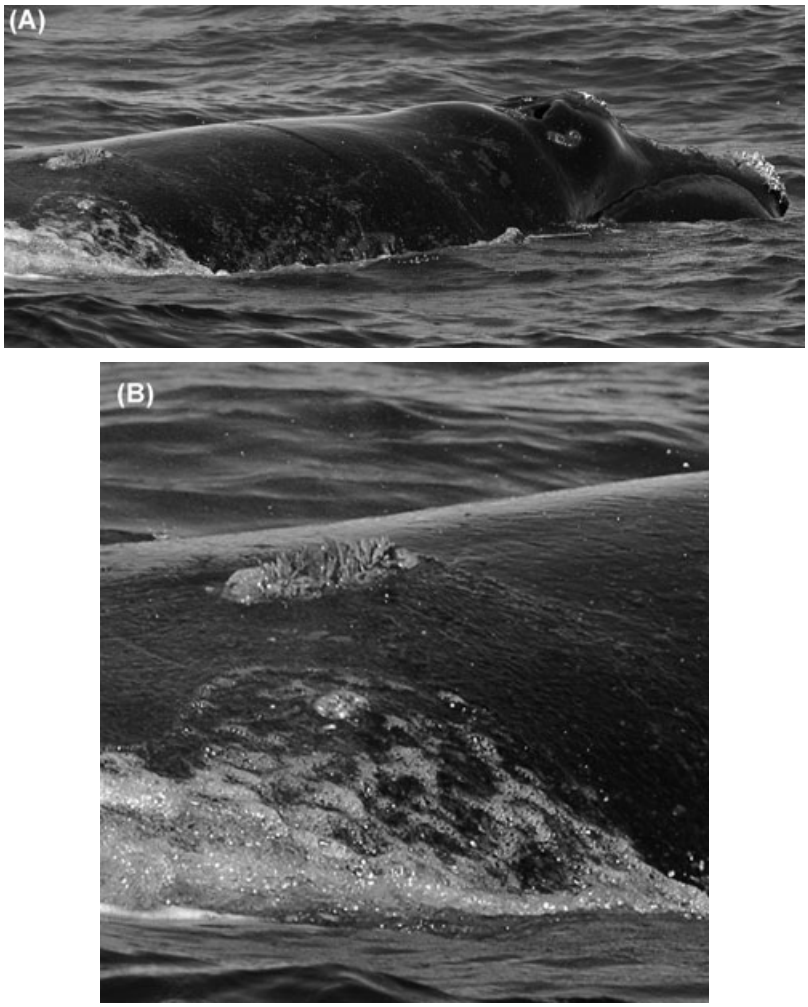

Figure 4. The callosity-like growths on the back and right flank of Eg 3760. (A) Eg 3760 on 30 September 2007 in the Bay of Fundy. (B) Close-up of one growth patch. (C) An aerial shot of Eg 3760 on 9 December 2007 that shows the pattern of these growths along the animals back and right flank. Photo credits: (A) and (B) Monica Zani, New England Aquarium; (C) Clay George, Wildlife Trust and Georgia Department of Natural Resources.

in the southeastern United States during the summer.[8] However, this is not the first anomalous sighting of Eg 2360. In April 2004, she brought her first calf (Eg 3460, born in the southeastern United States in January 2004) into the Gulf of Mexico, a very rare event (Kenney 2007). Eg 3760 (the second calf of Eg 2360) was easily identifiable in July 2007 and in subsequent sightings because of strange growths that resembled callosities on the animal's back and right flank (Fig. 4). These growths look

[8]North Atlantic Right Whale Consortium Identification Database, New England Aquarium, Central Wharf, Boston, MA 02110, December 2007.

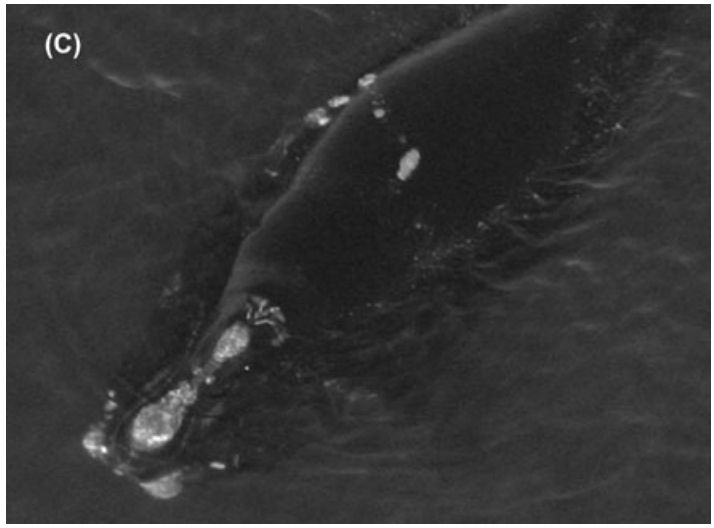

Figure 4. Continued.

like callosity tissue in their color, topography, texture, and temporal durability. They were first documented in the July 2007 sighting by the Marine Resource Council and were observed again by the New England Aquarium (Bay of Fundy, September 2007) and by Wildlife Trust (southeastern United States, December 2007) (Fig. 1). None of the 510 cataloged right whales have callosity tissue on their backs, nor has this condition been described in the other two right whale species, *E. australis* or *E. japonica*. The only comparable noncallosity growths that have been documented on right whales are the craterous eruptions described by Hamilton and Marx (2005). These lesions showed a developmental progression over several months, were rimmed by a raised crater, and were not infested with cyamids. The growths on Eg 3760, however, present for the 5-mo sighting history from July to December 2007, are not bordered by a raised rim, and show a similar cyamid infestation pattern to the callosities found on the head. These growths have not been biopsied, and as a result, their composition is still unknown.

Since the beginning of aerial surveys in the calving grounds of the southeastern United States (1994), six other North Atlantic right whale mother/calf pairs have been observed in the waters near the northeastern United States and Canada during the spring or summer without being seen in the southeastern United States during the preceding winter (Table 1). Until now, it had been assumed that these calves sighted only in waters in the northeast were all calves that were present but overlooked during the surveys in the southeastern United States during the calving season. However, our recent observations provide a case for reevaluating those data collected previously.

In order to estimate the age of the other six calves not seen in the southeast United States, as well as compare Eg 3760 to other calves, a baseline approximation of head

Table 1. The number of calves seen in the northeastern United States during the spring and summer that were not seen on the southeastern U.S. calving grounds in the winter of that year.

Year	Total born	Only seen in NE	Calf's first sighting date	Calf ID	Calf notes (consistent with northern birth[a])
1994	9	3	Late September	2479	Calf of 1179—normal head size and callosity growth
			Late March	2427	Calf of 1127—moderate head size, good callosity growth
			Mid April	2413	Calf of 1013—small head size but good callosity growth
1995	7				
1996	21				One calf seen in South Carolina and never in SEUS
1997	19	1	Early October	NA	Calf of 1412—normal head size and callosity growth
1998	5				
1999	4	1	Late May	2940	Calf of 2210—large calf, good callosity growth
2000	1				
2001	31	1	Early May	3145	Calf of 2145—small head size, little callosity[a]
2002	21				One calf seen in South Carolina and never in SEUS
2003	19	1	Early July	3308	Calf of 1608—moderate head size, good callosity growth
2004	16	1	Late April	3420	Calf of 2460—moderate head size and callosity growth
2005	28				
2006	19				
2007	22	3	Late April	NA	Calf of 1814—callosity visible
			Early June	3760	Calf of 2360—very small calf, small head size, no callosity[a]
			Early July	NA	Calf of 2912—small head size, callosity visible
					One calf seen in Virginia and never in SEUS

This table includes all data from when aerial survey effort started in the southeastern United States in 1994 to present.

[a]Calves that looked younger than the baseline photographs and therefore may be calves born outside of the southeastern U.S. calving grounds.

size, head shape (using dip in rostrum), and callosity formation for calves seen during the winter calving season, spring, and summer was developed using a large suite of photographs of many calves in the North Atlantic Right Whale Catalog. Photos of all seven calves were compared to the baseline images using the above three parameters. Analysis showed that the parameters for five of the seven calves were as expected for the time of year they were seen, indicating that, while not observed on the calving ground, they were likely born during the known December to March calving time. Eg 3760 and Eg 3145 (2001 calf of 2145), first seen in early May, had much smaller heads with a prominent dip in the rostrum and less callosity formation compared to the baselines images of calves seen during the spring. These two calves looked more like the baseline photos from winter. To further compare these two calves with other calves, images were reviewed for calves specifically seen in the southeastern United States and seen subsequently in the Bay of Fundy (making them approximately 8–9 mo old). Both Eg 3760 and Eg 3145 had less callosity development and a smaller head with a larger dip in the rostrum than the calves known to be 8–9 mo old (Fig. 5) and looked more like calves from the springtime baseline images. While a time frame for the birth of Eg 3145 cannot be identified as it can for Eg 3760, it is possible that Eg 3145 was also a calf born outside of the southeastern United States, and later in the year, but went unnoticed until now.

Our observations suggest that there may be a northern calving ground that is utilized by certain animals. There are historic reports that support the contention of calving outside of the southeastern United States. Cape Cod Bay has been hypothesized in the past to be an alternative calving ground; during 24 yr of observations, Watkins and Schevill (1982) and Schevill *et al*. (1986) inferred that at least two calves had been born in the Bay, because adults were seen without calves and then resighted within a week with extremely small calves. However, there were no photographic data of the females before and after to confirm these observations. Payne (1995) suggests that there are striking geographic similarities between Cape Cod Bay and Península Valdés, Argentina, one of the calving grounds for southern right whales: they are both at the same latitude (in opposite hemispheres); Peninsula Valdés and Cape Cod Bay and the islands are the same size; and both are virtually landlocked bays. Kenney (2002) suggested that Delaware Bay in the mid-Atlantic region might once have been a calving ground for North Atlantic right whales as well. According to historical whaling records, Delaware Bay was once an area of whaling activity that peaked during the winter, the same time of year during which North Atlantic right whales currently use the southeastern U.S. calving grounds (Reeves *et al.* 1978, 1999).

It is unclear how frequently calving events occur outside the southeast United States, but it appears from our observations and those of Watkins and Schevill (1982) and Schevill *et al.* (1986) that calving in northeastern U.S. waters is at least possible. According to data collected between 1980 and 1992, 25% of all reproductively active North Atlantic right whale females had never been seen in the southeastern U.S. calving grounds (Brown *et al.* 2001), suggesting that calving may consistently occur elsewhere. However, Brown *et al*.'s analysis may have been affected by the low survey effort in the southeast United States prior to the mid-1990s.

Photo-identification to monitor the right whale population currently takes place primarily in the southeastern United States in the winter and known northern foraging habitats in the spring and summer. However, if right whales are calving in northern waters outside of these known habitats, then an undetermined fraction of annual right whale reproduction may be unaccounted for. Moreover, improved monitoring and management of habitats, particularly offshore habitats like the Great South Channel, may be warranted during late winter and spring. Reproductively active females, including pregnant females and females accompanied by calves, spend

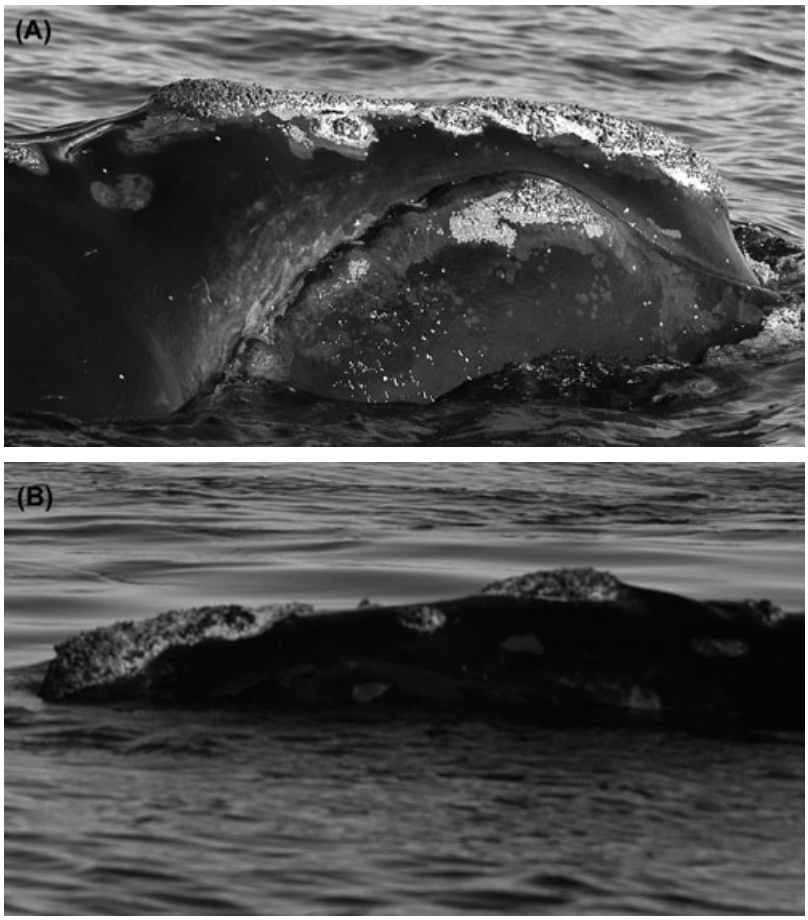

Figure 5. Comparison of known-age calves and Eg 3760 photographed in the Bay of Fundy during the late summer. (A) Eg 3522 (2005 calf of Eg 1622) and (B) Eg 3503 (2005 calf of Eg 1703) were two of the calves used as a baseline approximation of head size, callosity formation, and orange cyamid coverage for 8–9-mo-old calves. (C) Eg 3760 (2007 calf of Eg 2360) and (D) Eg 3145 (2001 calf of Eg 1245) both have smaller less-developed heads, less cyamid coverage, and less callosity formation than the baseline calves. Photo credits: (A) and (B) Philip Hamilton, New England Aquarium; (C) Marilyn Marx, New England Aquarium); (D) New England Aquarium.

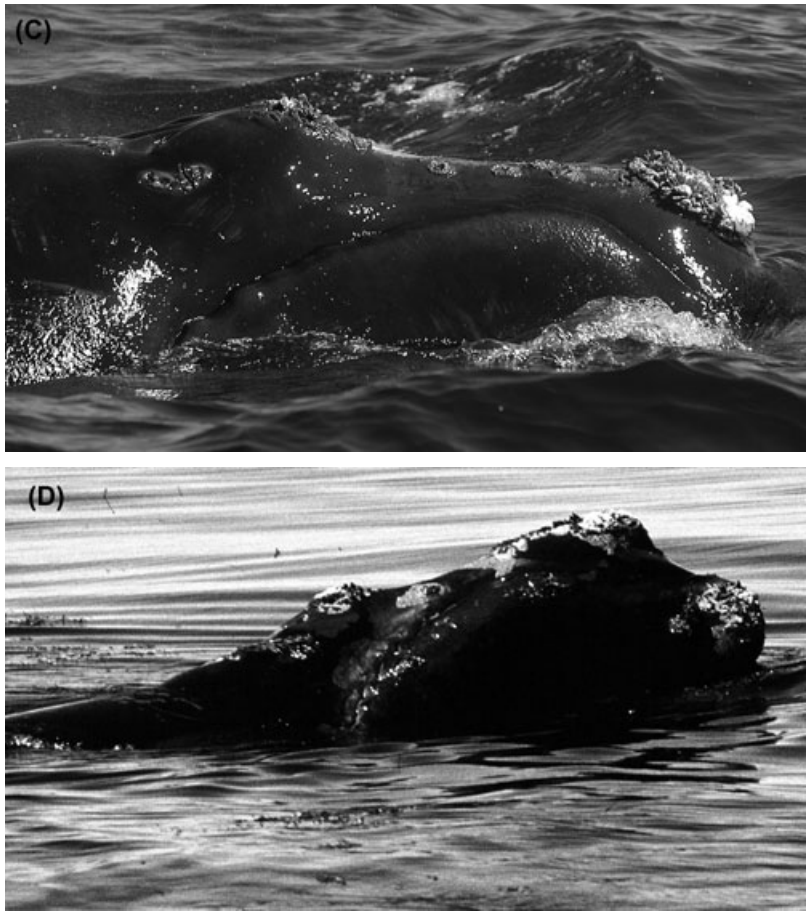

Figure 5. Continued.

more time at the surface, and therefore, may be at greater risk of ship strikes than the rest of the population (Baumgartner and Mate 2003). It is important to improve the understanding of right whale spatial and temporal use of alternative calving habitats in order to most effectively manage ship traffic and commercial fishing in these areas.

Acknowledgments

We thank Tim Cole, Jeremy Firestone, Timothy Frasier, Robert Kenney, Amy Knowlton, Scott Kraus, Russell Leaper, William McLellan, Michael Moore, Patricia Naessig, Sofie Van Parijs, Monica Zani, and the two anonymous reviewers of this manuscript for interesting and useful discussions and critiques. Also, we thank the officers, crew, and scientific staff of the NOAA Ship Albatross IV.

Literature Cited

Barco, S. G., W. M. Swingle, W. A. Mclellan, R. N. Harris and D. A. Pabst. 1999. Local abundance and distribution of bottlenose dolphins (*Tursiops truncatus*) in the nearshore waters of Virginia Beach, Virginia. Marine Mammal Science 15:394–408.

Baumgartner, M. F., and B. R. Mate. 2003. Summertime foraging ecology of North Atlantic right whales. Marine Ecology Progress Series 264:123–135.

Baumgartner, M. F., and B. R. Mate. 2005. Summer and fall habitat of North Atlantic right whales (*Eubalaena glacialis*) inferred from satellite telemetry. Canadian Journal of Fisheries and Aquatic Sciences 62:527–543.

Best, P. B. 1994. Seasonality of reproduction and the length of gestation in southern right whales *Eubalaena australis*. Journal of Zoology: Proceedings of the Zoological Society of London 232:175–189.

Bonde, R. K. 2004. RKB-1457 (*Eubalaena glacialis*): Necropsy examination report. U.S. Geological Survey, Florida Carribean Science Center, 412 NE 16th Avenue, Room 250, Gainesville, FL. 32601.

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

Eberhardt, R. L., and K. S. Norris. 1964. Observations of newborn pacific gray whales on Mexican calving grounds. Journal of Mammalogy 45:88–95.

Firestone, J., S. B. Lyons, C. Wang and J. 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 141:221–232.

Hamilton, P. K., and M. K. Marx. 2005. Skin lesions on North Atlantic right whales: Categories, prevalence and change in occurrence in the 1990s. Diseases of Aquatic Organisms 68:71–82.

Hamilton, P. K., and C. A. Mayo. 1990. Population characteristics of right whales (*Eubalaena glacialis*) observed in Cape Cod and Massachusetts Bays, 1978–1986. Report of the International Whaling Commission (Special Issue 12):203–208.

Hamilton, P. K., A. R. Knowlton and M. K. Marx. 2007. Right whales tell their own stories: The photo-identification catalog. Pages 75–104 *in* S. D. Kraus and R. M. Rolland, eds. The urban whale: North Atlantic right whales at the crossroads. Harvard University Press, Cambridge, MA.

IWC (International Whaling Commission). 2001. Report of the workshop on status and trends of western North Atlantic right whales. Journal of Cetacean Research and Management (Special Issue) 2:61–87.

Kenney, R. D. 2002. North Atlantic, North Pacific and Southern right whales. Pages 806–813 *in* W. F. Perrin, B. Würsig and J. G. M. Thewissen, eds. The encyclopedia of marine mammals. Academic Press, San Diego, CA.

Kenney, R. D. 2007. Right whales and climate change: Facing the prospect of a greenhouse future. Pages 436–459 *in* S. D. Kraus and R. M. Rolland, eds. The urban whale: North Atlantic right whales at the crossroads. Harvard University Press, Cambridge, MA.

Kenney, R. D., H. E. Winn and M. C. Macaulay. 1995. Cetaceans in the Great South Channel, 1979–1989: Right whale (*Eubalaena glacialis*). Continental Shelf Research 15:385–414.

Knowlton, A. R., J. Sigurjósson, J. N. Ciano and S. D. Kraus. 1992. Long-distance movements of North Atlantic right whales (*Eubalaena glacialis*). Marine Mammal Science 8:397–405.

Kraus, S. D. 1990. Rates and potential causes of mortality in North Atlantic right whales (*Eubalaena glacialis*). Marine Mammal Science 6:278–291.

Kraus, S. D., and J. J. Hatch. 2001. Mating strategies in the North Atlantic right whale (*Eubalaena glacialis*). Journal of Cetacean Research and Management (Special Issue) 2:237–244.

KRAUS, S. D., AND R. M. ROLLAND. 2007. Right whales in the urban ocean. Pages 1–38 *in* S. Kraus and R. M. Rolland, eds. The urban whale: North Atlantic right whales at the crossroads. Harvard University Press, Cambridge, MA.

KRAUS, S. D., J. H. PRESCOTT, P. V. TURNBULL AND R. R. REEVES. 1982. Preliminary notes on the occurrence of the North Atlantic right whale (*Eubalaena glacialis*) in the Bay of Fundy. Report of the International Whaling Commission 32:407–411.

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. Report of the International Whaling Commission (Special Issue 10):139–144.

KRAUS, S. D., R. M. PACE III AND T. R. FRASIER. 2007. High investment, low return: The strange case of reproduction in *Eubalaena glacialis*. Pages 172–199 *in* S. D. Kraus and R. M. Rolland, eds. The urban whale: North Atlantic right whales at the crossroads. Harvard University Press, Cambridge, MA.

LIEN, J., R. SEARS, G. B. STENSON, P. W. JONES AND I.-H. NI. 1989. Right whale, *Eubalaena glacialis*, sightings in waters off Newfoundland and Labrador and the Gulf of St. Lawrence, 1978–1987. Canadian Field-Naturalist 103:91–93.

MAYO, C. A., AND M. K. MARX. 1990. Surface foraging behavior of the North Atlantic right whale and associated plankton characteristics. Canadian Journal of Zoology 68:2214–2220.

MELLINGER, D. K., S. L. NIEUKIRK, H. MATSUMOTO, S. L. HEIMLICH, R. P. DZIAK, J. HAXEL AND M. FOWLER. 2007. Seasonal occurrence of North Atlantic right whale (*Eubalaena glacialis*) vocalizations at two sites on the Scotian Shelf. Marine Mammal Science 23:856–867.

MITCHELL, E., V. M. KOZICKI AND R. R. REEVES. 1986. Sightings of right whales, *Eubalaena glacialis*, on the Scotian Shelf, 1966–1972. Report of the International Whaling Commission (Special Issue 10):83–107.

MOORE, M. J., A. R. KNOWLTON, S. D. KRAUS, W. A. MCLELLAN AND K. BONDE ROBERT. 2004. Morphometry, gross morphology and available histopathology in North Atlantic right whale (*Eubalaena glacialis*) mortalities (1970–2002). Journal of Cetacean Research and Management 6:199–214.

NOTARBARTOLO DI SCIARA, G., E. POLITI, A. BAYED, P. C. BEAUBRUN AND A. R. KNOWLTON. 1998. A winter cetacean survey off southern Morocco, with a special emphasis on right whales. Report of the International Whaling Commission 48:547–550.

PAYNE, R. 1995. Among whales. Charles Scribner's Sons, New York, NY.

PAYNE, R., O. BRAZIER, E. M. DORSEY, J. S. PERKINS, V J. ROWNTREE AND A. TITUS. 1983. External features in southern right whales (*Eubalaena australis*) and their use in identifying individuals. Pages 371–445 *in* R. Payne, ed. Communication and behavior of whales. Westview Press, Boulder, CO.

REEVES, R. R., AND E. MITCHELL. 1986. American pelagic whaling for right whales in the North Atlantic. Report of the International Whaling Commission (Special Issue 10):221–254.

REEVES, R. R., AND E. MITCHELL. 1988. History of whaling in and near North Carolina. NOAA Technical Report NMFS 65:1–28.

REEVES, R. R., J. G. MEAD AND S. KATONA. 1978. The right whale, *Eubalaena glacialis*, in the western North Atlantic. Report of the International Whaling Commission 28:303–312.

REEVES, R. R., J. M. BREIWICK AND E. D. MITCHELL. 1999. History of whaling and estimated kill of right whales, *Balaena glacialis*, in the northeastern United States, 1620–1924. Marine Fisheries Review 61:1–36.

SCHAEFF, C. M., S. D. KRAUS, M. W. BROWN AND B. N. WHITE. 1993. Assessment of the population structure of western North Atlantic right whales (*Eubalaena glacialis*) based on sighting and mtDNA data. Canadian Journal of Zoology 71:339–345.

SCHEVILL, W. E., W. A. WATKINS AND K. E. MOORE. 1986. Status of *Eubalaena glacialis* off Cape Cod. Report of the International Whaling Commission (Special Issue 10):79–82.

SIRONI, M., S. D. KRAUS, E. V. NORDHEIM, V. J. ROWNTREE AND C. T. SNOWDON. 2005. Age estimation of North Atlantic right whales (*Eubalaena glacialis*) by allometric measurements on photographs. Paper SC/57/BRG7 presented to the International Whaling Commission Scientific Committee, June 2005. 14 pp.

STONE, G. S., S. D. KRAUS, J. H. PRESCOTT AND K. W. HAZARD. 1988. Significant aggregations of the endangered right whale, *Eubalaena glacialis*, on the continental shelf of Nova Scotia. Canadian Field-Naturalist 102:471–474.

SUMICH, J. L., AND J. T. HARVEY. 1986. Juvenile mortality in gray whales (*Eschrichtius robustus*). Journal of Mammalogy 67:179–182.

WARING, G., E. JOSEPHSON, C. P. FAIRFIELD AND K. MAZE-FOLEY. 2006. U. S. Atlantic and Gulf of Mexico marine mammal stock assessments—2006. NOAA Technical Memorandum NMFS-NE-201, 378 pp. National Marine Fisheries Service, Woods Hole, MA.

WATKINS, W. A., AND W. E. SCHEVILL. 1982. Observations of right whales, *Eubalaena glacialis*, in Cape Cod waters. Fishery Bulletin 80:875–880.

WEINRICH, M. T., R. D. KENNEY AND P. K. HAMILTON. 2000. Right whales (*Eubalaena glacialis*) on Jeffreys Ledge: A habitat of unrecognized importance? Marine Mammal Science 16:326–337.

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. Report of the International Whaling Commission (Special Issue 10):129–138.

Received: 7 April 2008
Accepted: 2 September 2008