

## Short Note

# Long-Range Longitudinal Movements of Sperm Whales (*Physeter macrocephalus*) in the North Atlantic Ocean Revealed by Photo-Identification

Keith D. Mullin,<sup>1</sup> Lisa Steiner,<sup>2</sup> Charlotte Dunn,<sup>3,4</sup> Diane Claridge,<sup>3,4</sup> Laura González García,<sup>5,6</sup> Jonathan Gordon,<sup>4</sup> and Tim Lewis<sup>7</sup>

<sup>1</sup>Marine Mammal and Turtle Division, Southeast Fisheries Science Center, NMFS, NOAA, Pascagoula, MS, USA  
E-mail: Keith.D.Mullin@noaa.gov

<sup>2</sup>Whale Watch Azores, Estrada da Caldeira, No. 2, Horta, 9900-089, Faial, Azores, Portugal

<sup>3</sup>Bahamas Marine Mammal Research Organisation, PO Box AB-20714, Marsh Harbour, Abaco, Bahamas

<sup>4</sup>Sea Mammal Research Unit, Scottish Oceans Institute, University of St Andrews, East Sands, St Andrews, KY16 8LB, UK

<sup>5</sup>Futurismo Azores Adventures, Marina Portas do Mar, 24-26 São Miguel Island, 9500-771 Ponta Delgada, Portugal

<sup>6</sup>Azorean Biodiversity Group (University of the Azores), Centre for Ecology, Evolution and Environmental Changes (CE3C), Rua Mãe de Deus, 9500-321 Ponta Delgada, Portugal

<sup>7</sup>NAMSC, Ale Oak Cottage, SY7 8QS, UK

Sperm whales (*Physeter macrocephalus*) are distributed throughout the world's oceans, mainly in waters greater than 200 m (Rice, 1989). Distribution and movements of individuals associated with social structure and age/sex have been previously described (Whitehead, 2003). Generally, mature females, their calves, and immature whales of both sexes live in matrilineal social groups throughout warm temperate to tropical waters. Females in matrilineal groups display long-term associations (Christal & Whitehead, 2001; Gero et al., 2015) and maintain regional ranging patterns (Whitehead et al., 2008; Engelhaupt et al., 2009). As males mature, their bonds with the matrilineal group weaken, and they associate in bachelor groups that are distributed in temperate and polar waters. When males reach sexual and social maturity, they are generally found alone or in small groups and periodically return to warm waters to mate with receptive females (Best, 1979; Rice, 1989; Whitehead, 2003). Worldwide, there are a number of studies that report on the movement patterns of individual whales within warm water habitats (Gero et al., 2007; Jochens et al., 2008; Whitehead et al., 2008; Carpinelli et al., 2014) and on the long-range movement patterns of males (Ivashin, 1967; Martin, 1982; Aguilar, 1985; Steiner et al., 2012; Mizroch & Rice, 2013; Straley et al., 2014). However, previously reported movements of whales from studies in warm waters of the Western North Atlantic (WNA) (e.g., Caribbean, Gulf of Mexico) were confined to the WNA (Gero et al., 2007; Jochens et al., 2008).

In the North Atlantic, sperm whale photo-identification (photo-ID) catalogues are maintained by researchers working within the Mediterranean Sea, Gulf of Mexico, Caribbean Sea, Bahamas, Azores, Canary Islands, Madeira, Norway, and Iceland, and some comprehensive catalogue comparisons have already been made (Steiner et al., 2012; Carpinelli et al., 2014). Based on a partial comparison of whales identified in the Gulf of Mexico and Bahamas in the WNA and those identified in the Azores in the Mid-Atlantic, we report new information on the movements of three sperm whales in the North Atlantic, including the movement of two whales between the WNA and the Azores. These represent the longest known movements of sperm whales in the North Atlantic outside of “Discovery” type tag results (Mitchell, 1970, 1975).

Sperm whale fluke photos for photo-ID (Arnbom, 1987) were collected in the Azores, Bahamas, and northern Gulf of Mexico during commercial whale-watching trips and/or dedicated cetacean research surveys. A brief description of each area (Figure 1) and the years covered are given below.

### Azores

The Azores archipelago is centred roughly in the middle of the North Atlantic along the Mid-Atlantic Ridge (~38° N, 28° W). Both female groups and mature males (~10% of whales identified) occur in the region (Pinela et al., 2009;

Steiner et al., 2012; van der Linde & Eriksson, 2019). Between 1987 and 1995, fluke photos were collected in the Azores by the International Fund for Animal Welfare (IFAW) during directed sperm whale research (Matthews et al., 2001). Fluke photos have been collected and catalogued by Whale Watch Azores (WWA) and Futurismo Azores Adventures (FAA) during whale-watching excursions since 1993 and 2009, respectively. FAA shares their catalogue with WWA on a yearly basis. In total, around 3,000 individuals have been identified in the archipelago.

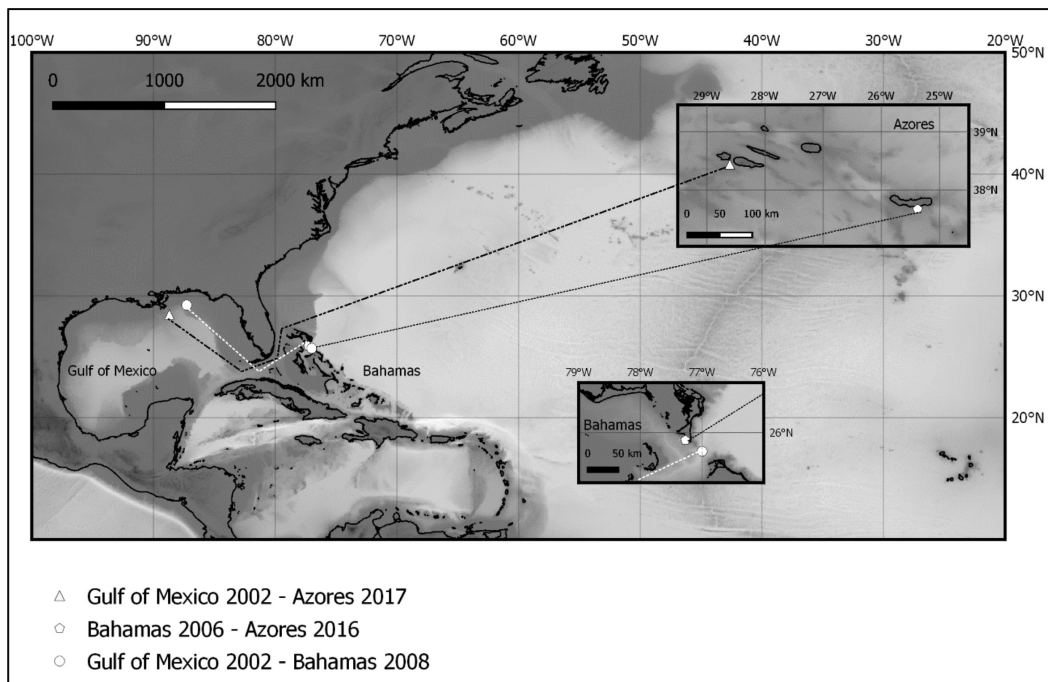
### Bahamas

The Bahamas are a group of islands in the western North Atlantic (~25° N, 78° W) north of Cuba and east of Florida. Sperm whales routinely inhabit the Great Bahama Canyon system, and groups consist of adult females and juveniles of both sexes (e.g., Ward et al., 2012). The Bahamas Marine Mammal Research Organization (BMMRO) has routinely conducted photo-ID surveys of sperm whales in this area since 1991 (BMMRO, unpub. data). The BMMRO catalogue contains 184 distinctively marked individuals and is shared with WWA.

Each year, approximately a third of the catalogued whales are resighted.

### Northern Gulf of Mexico

Sperm whale research in the Gulf of Mexico has focused on the northern (U.S.) Gulf where primary findings show that whales are distributed throughout oceanic waters, and groups, similar to other warm water areas, are composed of adult females and juveniles of both sexes. Sperm whale fluke photos of individuals (178) were collected from 1994 through 2003 in the northern Gulf during the GulfCet, SWAMP, and SWSS projects (Weller et al., 2000; Mullin et al., 2004; Jochens et al., 2008) and were contributed to the *North Atlantic and Mediterranean Sperm Whale Catalogue* (NAMSC). Additional fluke photos were collected during SWSS in 2004 and 2005 (Jochens et al., 2008) and intermittently since 2003 during other projects (D. M. Palacios, Oregon State University, unpub.; L. Aichinger Dias, UM-CIMAS/NMFS SEFSC, unpub.). However, these additional fluke photos are not in a centralized catalogue and were not used in this study.



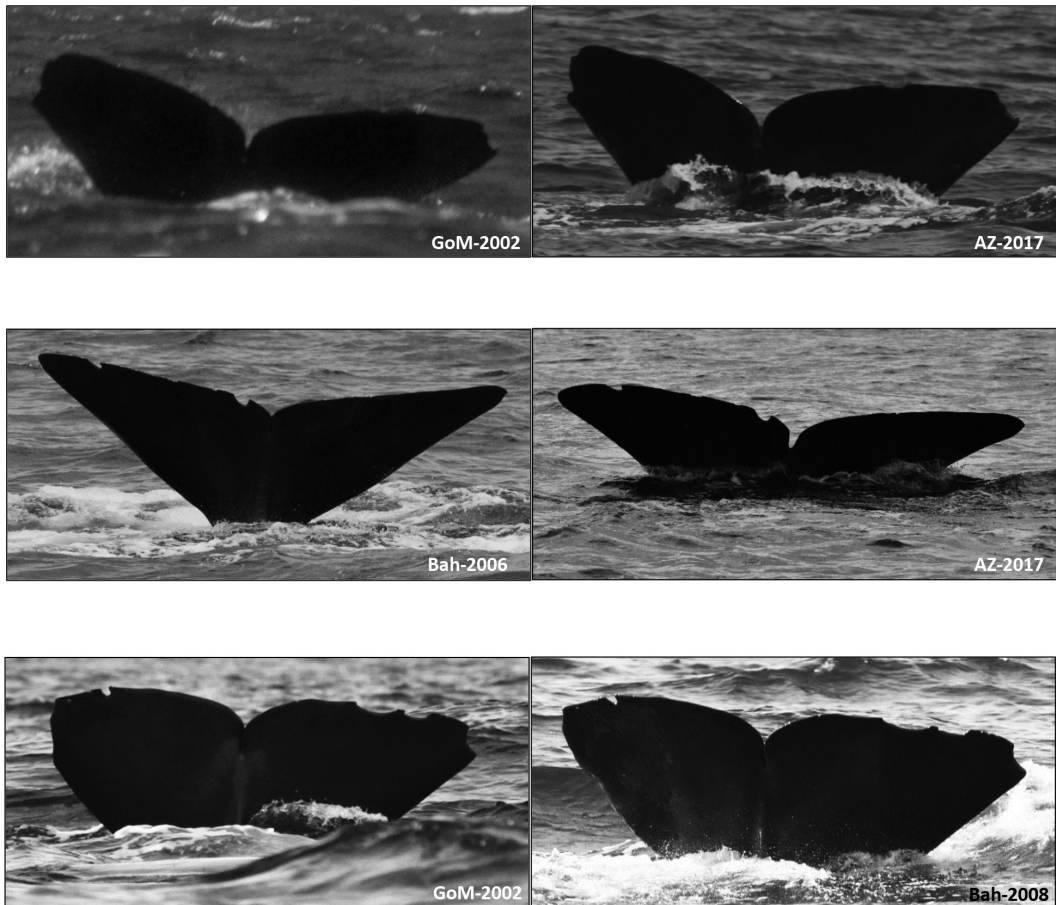
**Figure 1.** Locations of sperm whale (*Physeter macrocephalus*) photo-ID matches in the North Atlantic Ocean. Part of the Azores and the Bahamas archipelago are enlarged for better visualization of sighting locations. Lines between locations are to indicate the minimum distance travelled and are not meant to imply the actual route taken by each whale.

### Fluke Photo Matching

In general, data collection methods, photo-processing, and catalogue maintenance at all three locations were similar to those previously described (e.g., Steiner et al., 2012). NAMSC was established by IFAW in 1994 and was updated regularly until 2004. It contains images from the Bahamas (124), Caribbean Sea (761), and Gulf of Mexico (321) in the WNA and the Azores (2,356), as well as other North Atlantic locations, and the Mediterranean Sea. As new individuals are added to the combined WWA and FAA Azores catalogue, WWA routinely compares fluke photos from the combined catalogue to the BMMRO catalog and NAMSC as well as to several other independent catalogues around the North Atlantic. Photos are all matched using the *Phlex* and *Match* programs developed under the *Europhlukes* program (Beekmans et al., 2005).

Three WNA matches were found: (1) Gulf of Mexico to Azores, (2) Bahamas to Azores, and (3) Gulf of Mexico to Bahamas (Figures 1 & 2; Table 1). Distance and time between sightings ranged from 1,500 to 6,200 km and 5.9 to 14.9 y, respectively. When the Gulf of Mexico–Azores match was observed in the Azores, it was assessed to be a maturing male based on body size, the presence of a bulge on the head, and the lack of a callus on the dorsal fin (Figure 3).

The sperm whale photo-ID catalogue comparisons reported herein were based on the Azores catalogue and a subset of WNA catalogues. For example, catalogues from recent research in the Caribbean (e.g., Gero & Milligan, 2014) were not included and, as stated, the Gulf of Mexico whales in NAMSC are not up-to-date. Nonetheless, the comparisons yielded matches of note that indicate movements of up to 6,200 km. If the whales were males, which evidence supports in one of the cases,



**Figure 2.** Sperm whale fluke photo-ID matches between (A) the Gulf of Mexico (2002) and Azores (2017), (B) Bahamas (2006) and Azores (2017; first sighted in 2016), and (C) Gulf of Mexico (2002) and Bahamas (2008)



**Figure 3.** Sperm whale in the Azores on 23 August 2017 with a photo-ID match from the Gulf of Mexico in 2002. The whale is thought to be a male due to its size, presence of a bulge on the head, and lack of a callus on the dorsal fin.

**Table 1.** Details of sperm whale (*Physeter macrocephalus*) fluke photo-ID matches between the Gulf of Mexico and Azores, Bahamas and Azores, and Gulf of Mexico and Bahamas

First sighting				Second sighting				Distance (km)	Time (years)
Location	Date	Latitude	Longitude	Location	Date	Latitude	Longitude		
Gulf of Mexico <sup>1</sup>	18 Oct 2002	28.48	-88.74	Azores <sup>2</sup>	23 Aug 2017	38.44	-28.61	~6,200	14.9
Bahamas <sup>3</sup>	2 Aug 2006	25.88	-77.27	Azores <sup>1,4</sup>	11 May 2016	37.67	-25.38	~5,000	9.8
Gulf of Mexico <sup>1</sup>	28 June 2002	29.25	-87.28	Bahamas <sup>5</sup>	4 June 2008	25.70	-80.00	~1,500	5.9

<sup>1</sup>No additional information is available on whale size, group size, or the presence/absence of a dorsal fin callus.

<sup>2</sup>Recorded as a maturing male based on body size, bulge on the head, and the lack of a dorsal fin callus.

<sup>3</sup>Whale was in a group of whales and recorded as an adult female.

<sup>4</sup>Whale was also photographed near São Miguel, Azores, on 17 May 2017, but the position was not recorded.

<sup>5</sup>Whale was in a group of whales and was recorded as a subadult, sex unknown.

long distance movements are not unexpected given that males are born at lower latitudes, move to high latitude feeding areas, and periodically return to lower latitudes to breed (e.g., Whitehead 2003). However, the movements of two whales were primarily longitudinal between warm water locations and not necessarily explained by male sperm whale life history alone. The sperm whales that inhabit waters around the Azores are composed of a mix of female-offspring groups and mature males (Pinela et al., 2009; van der Linde

& Eriksson, 2019). Therefore, it is not clear if two of the whales travelled to the Azores to feed or breed, or as part of a migration.

Regardless of the reason for movements, data on individual sperm whales covering distances this large are limited. Based on Discovery tag recoveries, a male was shown to travel across the equator in the Atlantic 7,300 km from north to south Africa (Ivashin, 1967); a male moved ~4,300 km across the North Atlantic from Nova Scotia to Spain (Mitchell, 1975); and there were reports of

maximum movements of ~4,000 and ~5,000 km for female and male sperm whales, respectively, in the North Pacific (Mizroch & Rice, 2013). Steiner et al. (2012) reported movements between the Azores and Norway, a distance of ~4,400 km, for three male sperm whales. Photo-ID data suggest that females and both mature and immature male whales appear to remain within the Mediterranean Sea with a maximum movement distance of ~1,600 km (Carpinelli et al., 2014). Since 2001, 52 sperm whales have been satellite-tagged in the northern Gulf of Mexico (33 female, 6 apparently immature males based on size, 13 unknown), providing locations for an average of about 190 d. Of these, one whale, a male thought to be large enough to be sexually mature but too small to be a breeding bull, left the Gulf, travelled north to about the latitude of South Carolina in the Atlantic (~34° N), and returned to the Gulf (Jochens et al., 2008).

NAMSC was an early but important platform for centralizing North Atlantic photo-ID images while protecting the interests of individual researchers and allowing comparisons between catalogues. Despite being dormant for over a decade, the two Gulf of Mexico whale matches reported herein were found in NAMSC, and this demonstrates the importance of establishing and maintaining an up-to-date comprehensive North Atlantic catalogue. Computer-assisted matching software (e.g., Flukebook.org, Happywhale.com) and online databases should combine to facilitate this. One new algorithm for sperm whale matching developed by Capgemini Corporation through their annual Global Data Science Challenge was beta-tested on *Fluketracker* and the algorithm has been incorporated into *Happywhale*, a database that includes public participation for matching sperm whales. However, the success of these initiatives depends on researchers and citizen scientists agreeing to share images and data on an online platform. For example, the Gulf of Mexico catalogues are not currently combined, but the goal of a U.S. Bureau of Ocean Energy Management-funded project initiated in 2021, which is a collaboration of past and current Gulf of Mexico sperm whale researchers, is to form a centralized database of all photo-ID and genetic data (C. S. Baker, pers. comm., 21 April 2021).

Research on long-lived animals, such as sperm whales, whose lifespan can extend to at least 60 to 70 y (Rice, 1989), requires long-term datasets which will allow individuals to be re-identified over many years. Sperm whales are also a highly mobile cetacean species which undertake extensive movements, including crossing ocean basins, so this requires collaborative research efforts across borders and at an appropriate spatial scale. Dedicated long-term, broad-scale cetacean projects are difficult to maintain, due mainly to logistic and economic

constraints. The Azores whales matched to the Gulf of Mexico and Bahamas were photographed during WWA and FAA whale-watching operations. Thus, data collected opportunistically—for example, by whale-watching operators and citizen scientists—and the collaborative frameworks and tools to collect, collate, and maintain such data and to automate matching have become highly valuable in allowing research and monitoring to continue at an appropriate spatial and temporal scale. As whale watching becomes an increasingly significant component of the tourism sector worldwide, sustainable and responsible practices in which the link of tourism and science is present gain importance (O'Connor et al., 2009; Hoyt & Parsons, 2014).

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