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Short Note

Humpback Whale Movements in the Northeastern Atlantic: Madeira, A Crossing Point on the Migration Route

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The humpback whale (*Megaptera novaeangliae*) is distributed across all major ocean basins, ranging from tropical to polar regions. The species inhabits coastal waters, continental shelves, and deep oceanic waters, migrating between high-latitude feeding grounds and low-latitude breeding grounds (Clapham, 1996; Clapham & Mead, 1999).

This species has recently been classified as of "Least Concern" on the International Union for Conservation of Nature's *Red List*. Its global population is divided into several distinct groups, each with specific migratory patterns and breeding grounds, including major populations in the North Atlantic, North Pacific, and Southern Oceans. However, the only nonmigratory population resides in the Arabian Sea, where these humpback whales remain throughout the year due to the region's unique ecological conditions (Clapham, 2018; Cooke, 2018). Populations of humpback whales are at risk due to various threats. In the North Atlantic, harmful algal blooms, vessel collisions, and entanglements impact some populations (Volgenau et al., 1995; Bettridge et al., 2015). In the North Pacific, ship strikes, fishing gear entanglements, prey reduction, and acoustic disturbance are recognised as significant threats to humpback whale populations (Fisheries and Oceans Canada, 2013). In the Southern Hemisphere, moderate threats include energy exploration and fishing gear entanglements, with energy exploration representing a significant impact. The nonmigratory Arabian Sea population is notably impacted by energy exploration and fishing gear entanglements due to its limited range (Bettridge et al., 2015).

Humpback whales are highly conspicuous due to their acrobatic behaviours, such as breaching and tail-slapping, as well as their complex vocalizations. These traits have made them one of the most extensively studied cetaceans, yielding significant insights into marine mammal biology, social structures, and migratory behaviours (Payne & McVay, 1971; Clapham, 1996; Clapham & Mead, 1999). Additionally, humpback whales were among the first species to be studied using photo-identification techniques (Hammond et al., 1990), which have since become a fundamental tool in cetacean research. This methodology involves photographic documentation of the distinctive patterns on the ventral surface of the fluke. These fins are characterized by unique markings and black and white pigmentation patterns (Katona & Whitehead, 1981; Hammond et al., 1990; Smith et al., 1999; Stevick et al., 2003). Markings and shapes on dorsal fins are also useful to identify whales with images collected from both the right and left sides (Smith et al., 1999).

The North Atlantic population of humpback whales is one of the most extensively studied large whales (Wenzel et al., 2020). It was also

one of the most heavily targeted by the whaling industry. Historical whaling records indicate that humpback whales have been exploited since at least the 17th century (Smith & Reeves, 2003). Between 1885 and 1910, nearly 5,000 individuals were taken by early modern whaling operations across regions such as Norway and Iceland (Stevick et al., 2003), and other parts of northern Europe, resulting in the near extinction of the species in the Northeast Atlantic (Tønnessen & Johnsen, 1982). Following the moratorium on commercial whaling in 1985, it has shown notable recovery (Roman & Palumbi, 2003; Stevick et al., 2003; Clapham, 2018); and currently, there are more than 12,000 individuals identified in the North Atlantic Humpback Whale Catalogue (NAHWC), curated by Allied Whale (College of the Atlantic, Bar Harbor, ME, USA; https://www.coa.edu/allied-whale).

In the North Atlantic, five distinct feeding areas have been identified: (1) the Gulf of Maine, (2) Eastern Canada, (3) West Greenland, (4) Iceland, and (5) Northern Norway (Clapham & Mayo, 1987; Smith et al., 1999; Stevick et al., 2003, 2006). Regarding breeding areas, two distinct areas have been identified: (1) the West Indies and (2) Cabo Verde (Stevick et al., 1998, 2003, 2016; Jann et al., 2003; Wenzel et al., 2009, 2020). North Atlantic humpback whales exhibit strong fidelity to specific breeding and calving areas, consistently returning to the same areas year after year. The Cabo Verde population is estimated at no more than 300 individuals and is considered one of the most endangered worldwide (Punt et al., 2006; Bérubé et al., 2013; Wenzel et al., 2020).

Photo-identification has been used to better understand their movements and abundance in the North Atlantic (Katona & Whitehead, 1981; Smith et al., 1999). Other methodologies have been employed, including genetics (Palsbøll et al., 1997; Valsecchi et al., 1997) and satellite tagging (Kennedy et al., 2014; Kettemer et al., 2022), contributing to a better understanding of migratory patterns and fidelity to specific areas.

This study aims to provide an update on the movements of humpback whales in the Northeast Atlantic, documenting for the first time the movements of this species between Madeira Island and a feeding area in Iceland, as well as between Madeira Island and a breeding area in Cabo Verde (Figure 1).

The Madeira Archipelago is located in the warm temperate waters of the Macaronesia biogeographic

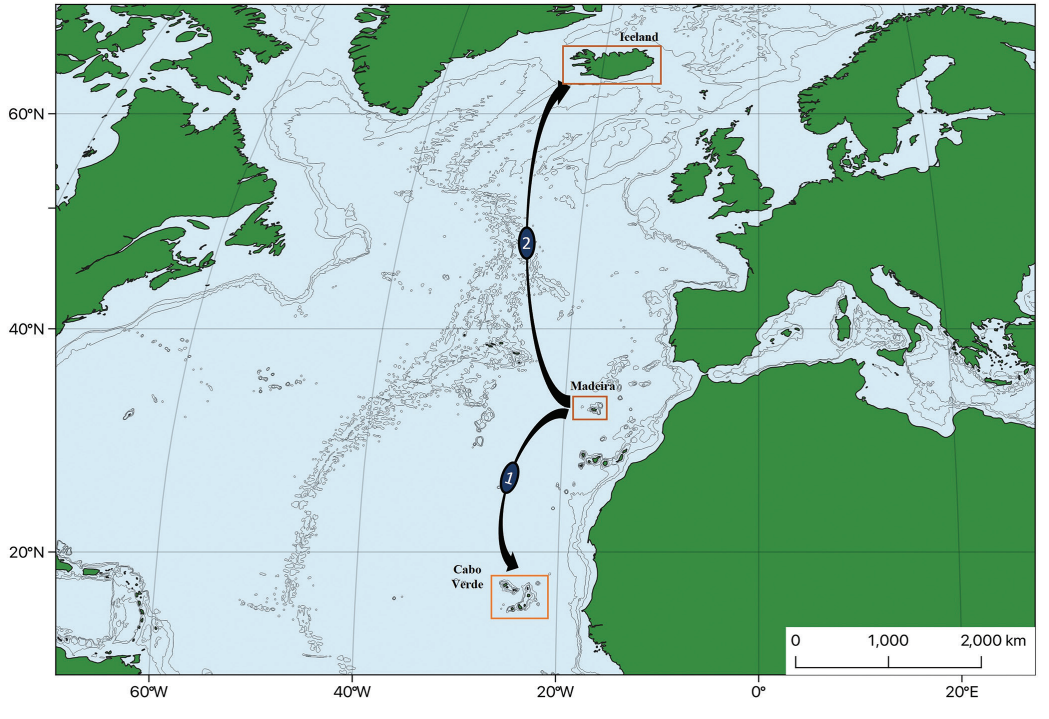

Figure 1. Map of locations where the data for humpback whale (*Megaptera novaeangliae*) matches were collected (Cabo Verde Islands, Madeira Archipelago, and Iceland). Bathymetric lines are represented every 1,000 m. The circles with the numbers represent the total number of matches between Madeira and the other two regions (Iceland and Cabo Verde).

region at 500 km from the West African coast and at 1,000 km from the European continent (Geldmacher et al., 2000). This region is noted for its dynamic oceanic features of a true, pelagic habitat (Caldeira et al., 2002; Caldeira & Sangrà, 2012; Carracedo & Troll, 2021), and it hosts a high biodiversity, including nearly 30 species of cetaceans (Freitas et al., 2012; Alves et al., 2018; Cartagena-Matos et al., 2021; McIvor et al., 2022). Connectivity with neighbouring archipelagos, particularly the Canaries and the Azores, has been shown to occur for several species of cetaceans, comprising toothed whales, such as short-finned pilot whales (*Globicephala macrorhynchus*; Alves et al., 2019), common bottlenose dolphins (*Tursiops truncatus*; Dinis et al., 2021), and sperm whales (*Physeter macrocephalus*; Ferreira et al., 2022); and baleen whales, such as Bryde's whales (*Balaenoptera brydei*; Ferreira et al., 2021) and sei whales (*Balaenoptera borealis*; Prieto et al., 2014). The geostrategic location of Madeira in the North Atlantic may encompass a migratory corridor for several cetacean species, which can use this area for travelling, feeding, resting, socialising, and calving (Alves et al., 2018).

Humpback whales were first recorded in Madeira Archipelago in 1957, during the whaling season, when five individuals were caught (Freitas et al., 2012). Subsequent records have been documented since 2003 on a yearly basis, but only with this area being used as a migratory corridor, mainly for travelling and resting (Freitas et al., 2012; Alves et al., 2018).

From 2015 to 2024, photographs of humpback whales were taken on board whale-watching vessels operating along the south coast of Madeira Island. A photo-identification catalogue was created, comprising 16 individuals from 17 captures. All the catalogued individuals were captured only once, except for one individual, OOM_Mn010, who was first captured on 1 May 2023 and then recaptured the following year on 24 April 2024.

Subsequently, the catalogue was uploaded to the Happywhale platform and compared with its database (https://happywhale.com). This platform employs an automated image recognition algorithm (Cheeseman et al., 2022), enabling rapid comparison against an image database of 102,000 individual humpback whales as of September 2024. This comparison showed that two catalogued individuals in Madeira were also catalogued in Iceland. The individual OOM_Mn003 was captured in Madeira on 3 July 2021, and then recaptured four times in Iceland between 2021 and 2023 (Table 1; Figure 2A & 2B). The individual OOM_Mn004 was captured in Madeira on 5 June 2021 and subsequently recaptured 20 times in Iceland between 2021 and 2024. The last capture was on 25 July 2024 (Table 1; Figure 2C & 2D).

Finally, the Madeira catalogue was compared with the NAHWC, where it was possible to confirm a photographic match between Madeira Island and Cabo Verde. The individual NA13658 of the NAHWC (corresponding to OOM_Mn002 in the Madeira catalogue) was captured in Madeira on 25 April 2015 and recaptured in Cabo Verde on 5 and 6 March 2024 (Table 2; Figure 3).

This study provides new insights into the movements and behaviour of humpback whales in the Northeast Atlantic, with a particular focus on the Madeira Archipelago, where information from photo-identification was non-existent. Despite only a few sightings of humpback whales in the Madeira Archipelago per year, the information presented herein can contribute to a better understanding of this species' migratory trajectories. The identification of an interannual match of one individual in Madeira, along with two long-distance movements involving a feeding area in Iceland and a breeding area in Cabo Verde, highlight the possible strategic importance of Madeira as a key transit area within the migratory routes of these whales, especially for the less known endangered population that breeds and calves in Cabo Verde Islands (Bérubé et al., 2013; Ryan et al., 2013; Wenzel et al., 2020; Chosson et al., 2024). Additionally, the integration of data from the NAHWC and the Happywhale platform corroborates broader migratory patterns that connect breeding and feeding grounds.

In the Macaronesia region, movements of humpback whales between breeding and feeding areas have been documented. The movement of individuals between Cabo Verde and Iceland highlights the connectivity between these critical habitats for the species (Jann et al., 2003; Wenzel et al., 2020; Chosson et al., 2024). Moreover, movements between the Azores and other feeding grounds, and between Cabo Verde and the Azores, illustrate the complexity and extent of these whales' migratory routes (Wenzel et al., 2009; Cucuzza et al., 2015; Peres dos Santos et al., 2022). These matches reveal a connection between various regions of Macaronesia and high-latitude areas, suggesting that the Northeast Atlantic population constitutes a single population with a wide-ranging habitat. This connectivity underscores the importance of coordinated conservation efforts across different regions to protect this extensive migratory network effectively. The new data from Madeira adds valuable information about this species in the region and emphasizes the archipelago's critical role in the conservation of humpback whales. Understanding these migratory behaviours and routes is essential for developing effective conservation strategies and ensuring the preservation of their habitats.

Table 1. Summary of photographic captures of two humpback whales (*Megaptera novaeangliae*) between Madeira Island and Iceland

	Sightings		
ID Happywhale	Date	Local	Contributors
OOM_Mn003	3 July 2021	Madeira Island	Nicolau Abreu
	8 Oct. 2021	Iceland (Westfjords)	Judith Scott
	10 Oct. 2021	Iceland (Westfjords)	Judith Scott
	6 Oct. 2023	Iceland (Westfjords)	Judith Scott
	15 Oct. 2023	Iceland (Westfjords)	Judith Scott
OOM_Mn004	5 June 2021	Madeira Island	H2O-Madeira
	7 Aug. 2021	Iceland (Westfjords)	Judith Scott
	8 Aug. 2021	Iceland (Westfjords)	Judith Scott
	25 Aug. 2021	Iceland (Westfjords)	Judith Scott
	26 Aug. 2021	Iceland (Westfjords)	Judith Scott
	18 Aug. 2022	Iceland (Westfjords)	Judith Scott
	22 Aug. 2022	Iceland (Westfjords)	Judith Scott
	8 July 2023	Iceland (Northeast)	Eva Gomez
	9 July 2023	Iceland (Northeast)	John Knutsson
	11 July 2023	Iceland (Northeast)	Klara Mist Palsdottir
	15 July 2023	Iceland (Northeast)	Arlette Zahn
	31 July 2023	Iceland (Northeast)	Klara Mist Palsdottir
	1 Aug. 2023	Iceland (Northeast)	Eva Gomez
	17 Aug. 2023	Iceland (Northeast)	Babsi Neubarth; Eva Gomez
	20 Aug. 2023	Iceland (Northeast)	Klara Mist Palsdottir
	18 June 2024	Iceland (Northeast)	Teun Verhagen; Alessandro Ballabio; Hannah Gatenby
	6 July 2024	Iceland (Northeast)	Bartek
	7 July 2024	Iceland (Northeast)	Jan Kowalski; Suki Niu
	8 July 2024	Iceland (Northeast)	Manja Richte
	15 July 2024	Iceland (Northeast)	MS Maud; Nigel Kendall; Uilleam Fraser
	23 July 2024	Iceland (Westfjords)	Judith Scott
	25 July 2024	Iceland (Westfjords)	Judith Scott

Table 2. Summary of the photographic captures of one humpback whale between Madeira Island and Cabo Verde

	Sightings		
Individual local ID	Date	Local	Contributors
OOM_Mn002; NA13658	25 April 2015	Madeira Island	Nicolau Abreu; Cláudio Martins
	5 March 2024	Cabo Verde	Bios.CV
	6 March 2024	Cabo Verde	Bios.CV

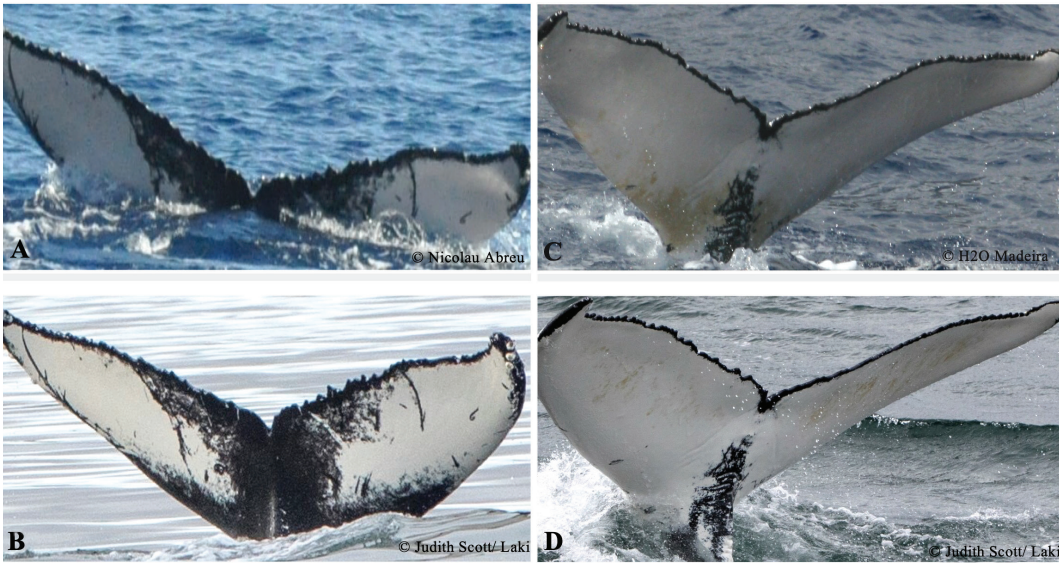

Figure 2. (A) OOM_Mn003 observed on 3 July 2021, Madeira Island (*Photo credit:* Nicolau Abreu); (B) OOM_Mn003 observed on 8 October 2021, Westfjords, Iceland (*Photo credit:* Judith Scott); (C) OOM_Mn004 observed on 5 June 2021, Madeira Island (*Photo credit:* H2O-Madeira); and (D) OOM_Mn004 observed on 26 August 2021, Westfjords, Iceland (*Photo credit:* Judith Scott)

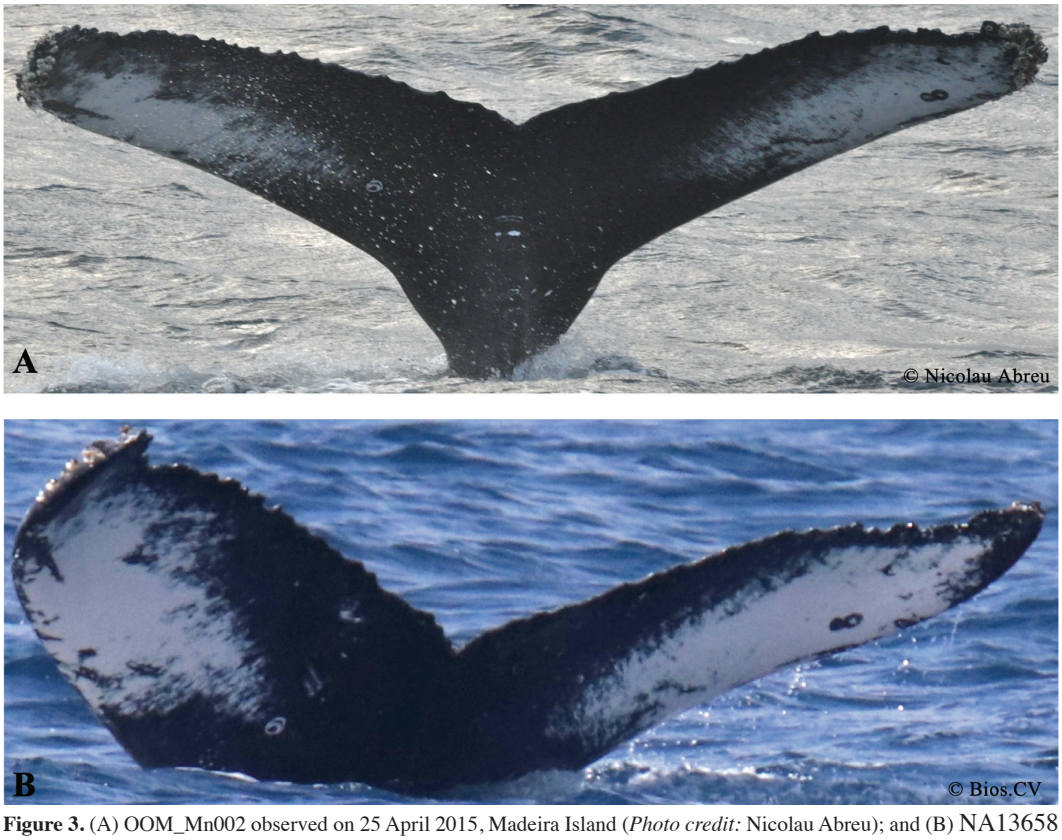

Figure 3. (A) OOM_Mn002 observed on 25 April 2015, Madeira Island (*Photo credit:* Nicolau Abreu); and (B) NA13658 observed on 5 and 6 March 2024, Cabo Verde Islands (*Photo credit:* Bios.CV)

Furthermore, this study corroborates that the continued development of photo-identification catalogues, coupled with other research efforts, provides important data on population trends in this region of the North Atlantic. Open-access platforms like Happywhale have been fundamental in obtaining these valuable insights. These catalogues enable collaboration and data sharing among various research groups, enhancing our understanding of humpback whale migratory routes and behaviour. This, in turn, significantly contributes to the long-term conservation and management of the species.

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