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Documenting humpback whale presence off Senegal, West Africa, using passive acoustic monitoring

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INTERNATIONAL
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Documenting humpback whale presence off Senegal, West Africa, using passive acoustic monitoring

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Abstract

Passive acoustic monitoring was conducted off Dakar, Senegal (14.6° N, 17.6° W), from June 2021 to January 2023, to evaluate the temporal occurrence of humpback whale song and the potential utilization of this habitat as a breeding area for both Northern and Southern Hemisphere humpback whale populations. No song was detected during the single boreal winter period. However, humpback song was detected during two austral winter periods, in September 2021 and from July – November 2022, corresponding to the Southern Hemisphere breeding season. Song structure was compared to a sample recorded in August 2022 from Conkouati, Republic of Congo, and was found to match all phrase types. While there were relatively few days with detections of song in 2021, humpback song was much more consistently present during the austral winter of 2022, with a peak daily occurrence of 17hr/day in August. The lack of humpback song presence during the boreal winter does not necessarily indicate a lack of animal presence, and strandings data do indicate the presence of humpback whales in Senegal in boreal winter months. However, the results reinforce previous reports of Southern Hemisphere humpback whales occurring in the North Atlantic, off West Africa and Cape Verde Islands. Acoustic monitoring effort is ongoing, and additional studies are needed to determine whether this region may ultimately serve as a breeding area for populations from both hemispheres.

Introduction

Critical data gaps exist for large whales in the eastern tropical North Atlantic Ocean, especially a basic understanding of migratory and breeding areas for multiple species of baleen whales. Historic whaling and stranding data along the northwestern African coast, as well as limited data from shipboard surveys indicate the presence of multiple species of baleen whales off the coasts of Mauritania and Senegal (eg.,Van Waerebeek et al. 2013; Bilal et al. 2023; Mullié et al. in prep) but stock identity is often poorly understood in the eastern tropical Atlantic.

Although the North Atlantic humpback whale is among the most rigorously researched baleen whale population to date, questions on eastern North Atlantic population dynamics remain unresolved (Wenzel et al. 2020; Valente et al. 2019). There are two known breeding grounds for North Atlantic humpbacks. The main breeding area is located in the West Indies region of the Caribbean Sea; the other is the Cape Verde Islands (CVI), a part of the group of islands comprising Macaronesia in the eastern North Atlantic. Individuals that winter in the CVI belong to the endangered Cape Verde distinct population segment (DPS) (Bettridge et al. 2015) (Figure 1). Humpbacks primarily occupy these waters between January and May (Wenzel et al. 2009; Ryan et al. 2014). This period agrees with historical whaling records from the mid-19th century around

the Cape Verde Island when humpbacks were hunted from mid-February to mid-June (Reeves et al. 2002). Sightings histories (photo-ID matches) of humpbacks in the CVIs have been matched to northern feeding grounds off Iceland and Norway (Katona and Beard 1990; Jann et al. 2003). Visual surveys provided the most recent estimate for the total number of animals using the CVI breeding area between 2010 and 2018 as 272 individuals (SE 10) (Wenzel et al. 2020). It is also suspected that the coastal waters of West Africa east of the Cape Verdes may comprise additional habitat for this DPS, however there has been little evidence to support this (Bettridge et al. 2015). Despite the apparent lack of evidence, it seems reasonable that the coasts of Senegal and adjacent countries could be breeding habitat for this humpback population, given that the CVIs are located approximately 600km from the coast of Senegal. Some recent evidence supports this supposition, as several strandings and sightings reported between December and April off the coast of Mauritania (summarized in Bilal et al. 2023) are presumed to represent animals from the Northern Hemisphere population. In addition, the Senegal Stranding Network, led by the African Aquatic Conservation Fund (AACF), has recorded strandings of 9 humpback whales, between Dakar and St. Louis, Senegal from 2016-2021 (Mullié et al., in prep).

The Gulf of Guinea and the west coast of Central Africa are well established as a breeding area for Southern Hemisphere humpback whales (Breeding Stock B1) from both whaling data and modern research (Figure 1). There are records of hunting Southern Hemisphere humpback whales at several locations in the Gulf of Guinea (Annobón, Pagalu**,** Equatorial Guinea, Aguilar 1985; Cap Lopez, Gabon, Budker and Roux 1968; and São Tomé, Carvalho et al. 2022) mainly during the Austral winter and spring (May to October). Only recently have we started to understand the stock identity of this eastern South Atlantic breeding population, through work in the past 10-15 years in the Gulf of Guinea primarily off Gabon (Collins et al. 2010; Rosenbaum et al. 2014; Carvalho et al 2014, 2022).

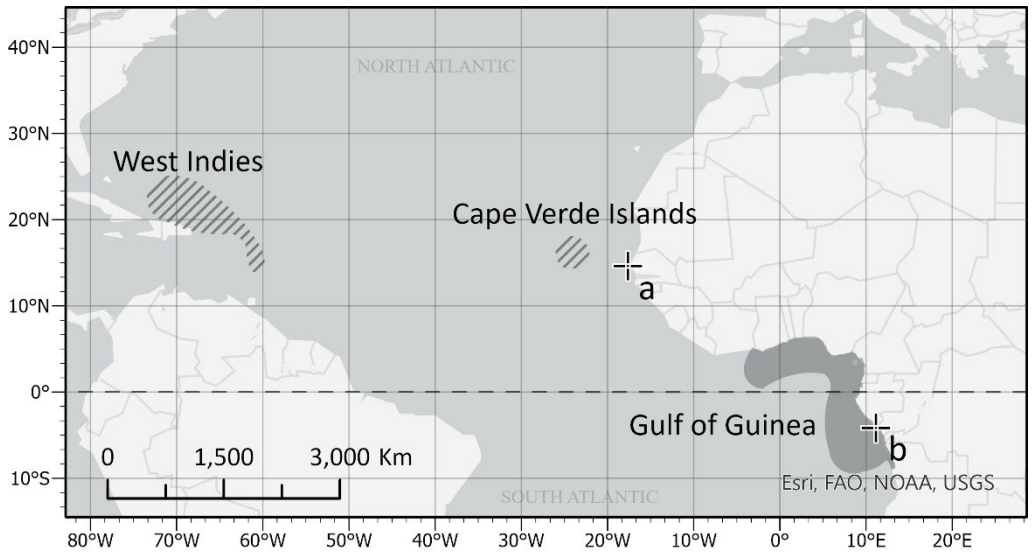

Figure 1. Map of the humpback whale breeding grounds in the Northern (hatched) and Southern (shaded) Hemisphere referenced in this paper. The locations where song was collected are indicated by the plus (+) symbols. a) Study area off Dakar, Senegal; b) Conkouati, Republic of Congo (provided by Godefroy De Bruyne).

While it is known that the CVIs are a boreal breeding destination for North Atlantic humpbacks, breeding behaviors (i.e., mother-calf sightings, song) have also been opportunistically documented in these waters during the austral winter (Hazevoet et al. 2011; Ryan et al. 2019). Presumed Southern Hemisphere humpback whales have also been documented in the Northern Hemisphere along the West African coast (Bamy et al. 2010; Van Waerebeek et al. 2013). Detections of putative Southern Hemisphere animals along the West African coast likely represent an extension of this B1 breeding stock; transequatorial humpback movements or migration has also been documented in other breeding areas (e.g., Rasmussen et al. 2007; Cerchio et al. 2016).

Effective conservation and management of humpback whale populations utilizing the West African coast and the CVIs requires a foundational understanding of their spatiotemporal distribution and stock identity. To assess the seasonal occurrence of humpback whales off the coast of Senegal, we initiated a new passive acoustic monitoring (PAM) project. It is well-established that humpback whale song can be used as a reliable indicator both of breeding habitat, as well as stock identity (Payne & Guinee 1983, Cerchio et al. 2001). Here we present the first long-term PAM data from offshore waters of Senegal and West Africa as a whole. We collected acoustic data at two sites across three deployments from June 2021 to January 2023 off the coast of Dakar, Senegal. Our goals were to i) systematically document the spatiotemporal presence of humpback whale song throughout the year, ii) compare any songs recorded during the boreal and austral winters, and iii) determine if timing of occurrence and song structure comparisons support identification of which humpback stocks may be utilizing Senegalese waters.

Methods

We conducted year-long passive acoustic monitoring off the shelf break of the coast of Dakar, Senegal at two sites, across three deployments (Table 1, Figure 2). We deployed two SoundTrap ST600-STD Long Term Recorders (Ocean Instruments, New Zealand), floated approximately 7 m above the seafloor, and attached to an INNOVASEA VR2AR acoustic release and receiver (Table 1). The recorders were positioned 13.9 km apart at ~300 m on the continental slope past the steep drop off from the shelf. This allowed for an unobstructed acoustic "view" of offshore deep water habitat, at the head of the Dakar submarine canyon. Recording parameters were set to continuously record at a sample rate (SR) of 48 kHz.

Table 1. Summary metadata for the three deployments of SoundTrap ST600-STD recorders off Dakar, Senegal.

Deploy #	Site #	Depth (m)	Lat	Long	Deploy date	Record End Date	Duration (complete days)
1	1	319	14.616	-17.631	06 Jun 2021	16 Nov 2021	162
1	2	313	14.742	-17.636	06 Jun 2021	16 Nov 2021	162
2	1	306	14.615	-17.630	17 Nov 2021	11 Jun 2022	205
2	2	313	14.742	-17.636	17 Nov 2021	LOST	-
3	1	283	14.618	-17.628	16 Jul 2022	14 Jan 2023	181

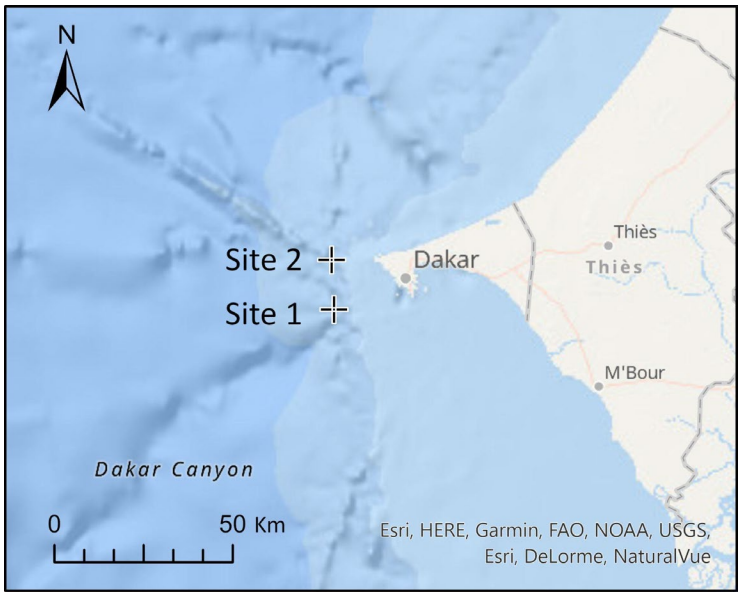

Figure 2. Map showing deployment positions off the Dakar Peninsula between 6 June 2021 and 14 January 2023.

The deployments to date have allowed for monitoring during two austral winters and one boreal winter season. The first deployment collected data at both sites, during the austral winter from June to November 2021 (Table 1). The second deployment collected data during the boreal winter, from November 2021 to June 2022. Unfortunately, the acoustic release at Site 2 did not respond during the recovery attempts, and therefore the recorder was lost and data were obtained only from Site 1. This single recorder was redeployed at Site 1 from July 2022 to January 2023, for a second austral winter period. Combined, our three deployments yielded 548 days of acoustic data from Site 1, and 162 days from Site 2.

The software Avisoft-SASLab Pro was used to down-sample the 48 kHz SR files to a SR of 2 kHz, using the Sampling Frequency Conversion function. For each deployment, data were analyzed for temporal occurrence by loading the entire acoustic file stream in Raven Pro using the 2 kHz SR acoustic data. We visually and aurally reviewed spectrograms over the frequency range 0 - 500 Hz (FFT 8192, Hann window, 50% overlap) and logged hourly presence of humpback song.

Song structure was qualitatively assessed to facilitate comparison to song from other breeding regions. Phrases were identified using the general guidelines suggested by Cholewiak et al. (2013) to ensure reliable and consistent delineations. We classified all distinct phrase-types and labeled each numerically based on their order of presentation within the song. Song structure was compared to one sample recorded in the Gulf of Guinea, an established SH breeding stock area (IWC 2007, Figure 1). This SH song recorded off the coast of Conkouati, Republic of Congo was opportunistically collected on 9 August 2022 with a GO PRO video recorder over the side of a vessel at anchor, when a singing humpback whale was observed near the vessel (Godefroy De Bruyne, unpublished data). With these additional data, we conducted a qualitative analysis of song

content at the phrase level to assess hemispherical population identity of singers off the coast of Dakar.

Results

Humpback song was detected in both deployments covering the austral winter (Deployments 1 and 3), but no song was detected during the boreal winter (Deployment 2). During the first deployment in the austral winter of 2021, song was present in early September, commencing on 6 September 2021 at Site 1 (Figure 3a) and 8 September 2021 at Site 2 (Figure 3b). Humpback song was present for six days total at Site 1 (ending on 13 September 2021,) and for five days total at Site 2 (ending on 22 September 2021, Figure 3b).

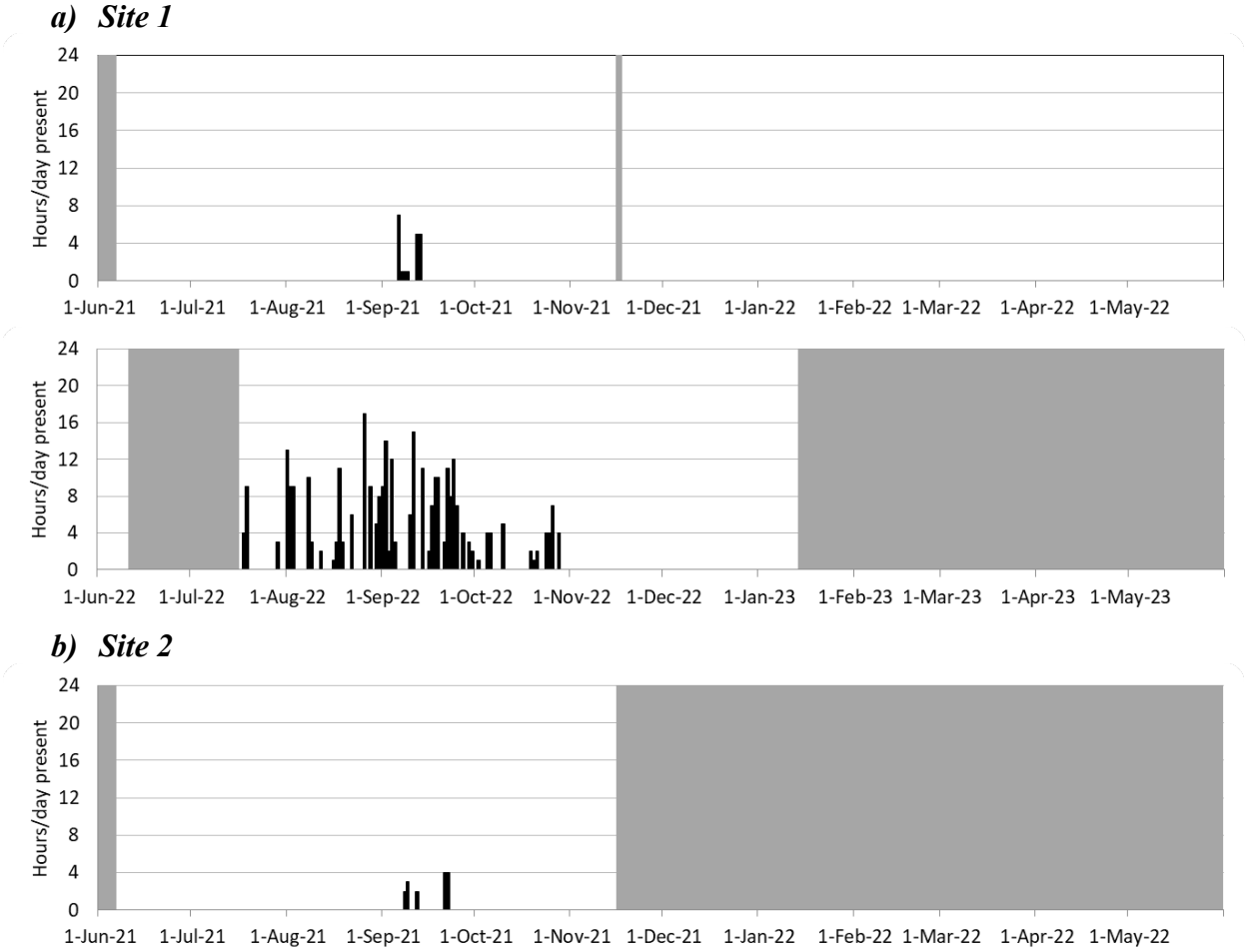

Figure 3. Hourly occurrence of humpback whale song detected off Dakar, Senegal. Data represent three deployments combined effort, for: **a)** Site 1 from 6 June 2021 to 14 January 2023; and **b)** Site 2 from 6 June 2021 to 11 November 2021. Each panel represents one year of data commencing from 1 June, with gray areas indicating hours and days of no data. For each day, bars represent the number of hours in which humpback whale song was detected based upon a manual browse of spectrographic data from 0-500 Hz.

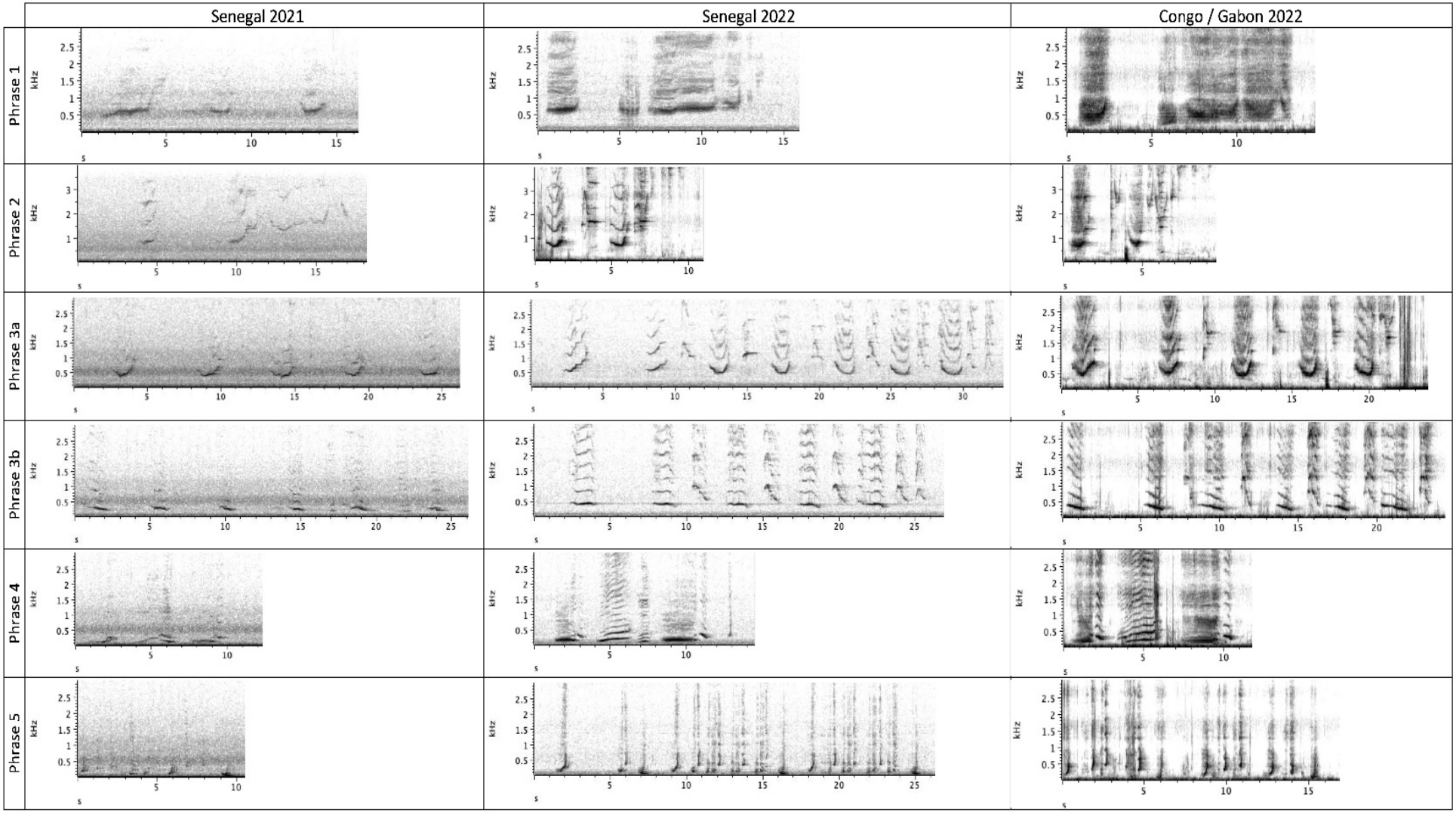
Senegal 2021
Senegal 2022
Congo / Gabon 2022
Phrase 1
Phrase 2
Phrase 3a
Phrase 3b
Phrase 4
Phrase 5
kHz
s

Figure 4. (previous page) Spectrograms of song comparison analysis results depicting phrase components identified in humpback song recorded in the 2021 austral winter in Senegal (9 September) and the 2022 austral winter in Senegal (26 August) and near the Republic of Congo (9 August).

In contrast, during Deployment 3 in the austral winter of 2022, humpback song was detected almost immediately upon deployment of the recorder, with the first song being recorded on 18 July 2022 (Figure 3a). Song was consistently recorded on a near daily basis until 28 October 2022, and was found for a total of 49 days, peaking in hourly presence at 17 hrs/day on 26 August 2022 (Figure 3a).

Our analysis of song structure revealed a complete overlap of all phrases that could be defined in the Senegal samples from 2021 and 2022, and in the Congo sample from 2022. The same five phrases were present in the high SNR recordings from Senegal and Congo 2022, without any ambiguity, conclusively linking the singers in Senegal in 2022 to the SH population (Figure 4). Furthermore, these same five phrase lineages could be diagnosed in the lower SNR samples from Senegal 2021, with some qualitative variation that is expected due to the progressive cultural evolution that would occur between 2021 and 2022 (Figure 4). Therefore, both the timing of occurrence and the link in song structure with Congo, indicates that the singers recorded off Dakar between July and November likely came from the SH population.

Discussion

Between June 2021 and January 2023, we collected PAM data off the coast of Dakar, Senegal to systematically document the spatiotemporal presence of humpback whale song and designate hemispherical population identity based on song structure analysis. Humpback song was absent during the single deployment period covering the boreal winter months (December 2021 to April 2022). However, song was detected during both the austral winters of 2021 (in September) and 2022 (from July through October). Song structure analysis and comparison with song from the Gulf of Guinea confirmed that the song we recorded in Senegal during the 2021 and 2022 austral winters matched the phrase content and song structure of the recording of a singer off Congo in 2022, indicating that the singers recorded off Dakar were migrants from the eastern South Atlantic Ocean population. These findings have relevance to our understanding of both the eastern North Atlantic, and eastern South Atlantic.

North Atlantic Population

It is noteworthy that we found no evidence of humpback whale singing activity off Dakar during the boreal winter of 2021/2022. The Cape Verde Islands are less than 600 km from our study site, at approximately the same latitude. This is a similar distance as in other regions where humpback populations range between island and mainland breeding areas (e.g., mainland Mexico and the Revillagigedo Archipelago, Urbán & Aguayo 1987). This proximity, combined with a suggested "missing breeding ground", has given rise to the conjecture that humpback whales from the eastern North Atlantic may be utilizing parts of the West African coast as breeding habitat (Bettridge et al. 2015). Although there has to date been little evidence to support this supposition, it is important to recognize that there is little effort off West Africa and more recent studies are beginning to provide some support. In Senegal, nine humpback whale strandings documented by Mullié et al. (in prep) between 2016 and 2021 include eight animals found between the months of January to May. Strandings for which total length measurements were made appeared to be entirely immature

(likely yearling) animals (n=6, 890 cm to 1070 cm), including one whale that stranded alive in January 2017, and seven that were found in states of decomposition that suggested they were dead for several weeks (in February 2021, March 2016, March 2019, April 2016, and May 2019). Based on the timing, these strandings most likely correspond to animals from the North Atlantic population.

Therefore, we find it surprising that no song was detected at any point during the boreal winter. It is possible that the eastern North Atlantic population that breeds around the Cape Verde Islands visits the mainland coast of West Africa, but farther north, perhaps in northern Senegal or off Mauritania, and does not heavily utilize coastal habitat off Dakar. It is also important to recognize that the lack of humpback song presence during the boreal winters does not necessarily indicate a lack of animal presence; only males sing and it is possible that our study site is, for instance, a boreal winter female-calf area. It is also important to consider seasonal fluctuations in breeding area attendance, and it is possible that there may be greater use of these waters by the eastern North Atlantic population in other years, but monitoring across multiple boreal winters is required to determine if this is the case.

South Atlantic Population

The humpback whale song documented at our study site during both austral winters unambiguously shared composition and phrase content with song captured in the Gulf of Guinea indicating a SH origin of these singers. There was a marked difference in occurrence of SH song between the 2021 and 2022 austral seasons. In the first year, the few detections of song could be considered indicative of vagrant whales, similar to what was observed in the Arabian Sea, where Southwest Indian Ocean (SWIO) songs were detected on several days in August 2012 (Cerchio et al. 2018). However, the preponderance of SH song off Senegal in 2022 has more of the character of an active breeding ground, with consistent presence from mid-July to late October (Figure 3). Given the gap in recording effort from mid-June to mid-July 2022, it is conceivable that whales arrived even earlier. It is noteworthy that this was concurrent with an exceptional year for humpback whales in the SWIO, with higher than average absolute numbers and mother-calf pairs in four of six sites surveyed in six different countries between the East African mainland and the Mascarene Islands (V. Dulau and T. Collins, pers. comm. https://indocet.org/en/where-are-the-whales/).

These results reinforce previous reports of Southern Hemisphere humpback whales occurring in the North Atlantic, off West Africa (Van Waerebeek et al. 2013) and the Cape Verde Islands (Ryan et al. 2019). Also, in addition to the eight stranded animals documented off Senegal mentioned above, there was a stranding in October 2020 of a small whale, likely a calf (although not measured) that was almost certainly a SH calf of the year, and possibly born off West Africa (Mullié et al, in prep). There are several other examples globally of SH breeding populations that move into the Northern Hemisphere during their Austral winter: in the southeast Pacific Ocean, Costa Rica at 11°N is documented as a breeding area for both SH and NH populations in opposing winter seasons (Rasmussen et al. 2007); in the southeast Atlantic Ocean, a whale satellite tagged in Gabon moved to 4.7°N off the coast of Ghana (Rosenbaum et al. 2014); in the southwest Indian Ocean, a whale satellite tagged in Madagascar moved to at least 3°N off the coast of Somalia, and was moving directionally covering ~100 km/day when the tag stopped transmitting (Cerchio et al 2016), and singers from the SWIO population have been documented in the Arabian Sea at 17.4°N

(Cerchio et al 2018). Therefore, it is possible that the coast of Dakar represents the most northern range of the B1 breeding sub-stock; as SH populations grow, they may move into lesser occupied habitats like the current study area. This would substantiate the possibility that dispersal of humpbacks to lower density breeding waters may occur (Mackay et al. 2019).

Implications and Recommendations

These findings contribute to our understanding of spatiotemporal dynamics of humpback whale habitat usage in breeding grounds around the southern end of Macaronesia and West Africa. The lack of recordings of NH humpback whale song off Senegal does not necessarily indicate the absence of a NH population, but rather when combined with the recent stranding data suggests that our understanding of how the North Atlantic populations uses these waters is incomplete. In documenting SH humpback whales ~1,000 km northwest of their traditionally established breeding grounds in the Gulf of Guinea, it is clear that the B1 sub-stock exhibits plasticity in breeding ground usage and attendance. Long-term PAM research is needed to determine if usage of Senegalese waters by SH whales is occasional and episodic, or a consistent phenomenon across years. Similarly, it also remains unclear if NH humpback whales that breed in the Cape Verde Islands, ~600 km almost due east of Dakar, may exhibit a plasticity in seasonal movement behavior, or if breeding activity there is geospatially restricted to a locally concentrated range. Additional monitoring is also needed to better understand possible shifts in distribution due to climate change. Moreover, our findings raise intriguing questions about the potential mixing of NH and SH populations, that might be detected through the introgression of genetic haplotypes, or cultural diffusion of songs, highlighting the utility of continued monitoring across multiple boreal and austral winters. Our research sheds new light on the behavioral ecology of humpback whales on the northwest coast of Africa and underscores the importance of continued long-term research and monitoring to effectively inform conservation efforts.

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