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Cetacean surveys in Oman November 2019- November 2022

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ABSTRACT

Arabian Sea humpback whales (ASHW) comprise an Endangered sub-population that does not undertake seasonal migrations between low-latitude breeding grounds and high latitude feeding grounds. The population has been the subject of discussions at IWC Scientific Committee meetings since the late 1990s when the unique nature of the population was first revealed by scientists working on illegal Soviet whaling vessels. Continuing over 20 years of research efforts in Oman, four vessel-based surveys were conducted in two areas of documented humpback whale abundance off the coast of Oman between November 2019 and November 2022. ASWH encounter rates varied significantly from no encounters over two weeks of surveys in March 2021, to 40 encounters during two weeks of survey effort in November 2021. Over the course of all four surveys 57 ASHW sightings were documented, comprising 38 unique individuals, all of which were photo-identified, and 30 of which were filmed by UAV to assess body condition. Re-sightings rates were high, with 29 of the 38 identified whales representing whales that were already present in the Oman humpback whale Photo-ID catalogue, including 9 individuals that were first identified in 2001 or 2002. The body condition of sampled ASHWs ranged from -0.08 to +0.51%, with a mean of 0.12 (SD=0.126). There was a significant difference in body condition between sexes, with females on average having a 16.1 percentage units higher body condition than males. Bryde's whale encounter rates were inversely proportional to humpback whale encounter rates, and appeared to be correlated with warmer sea surface temperatures in the study area. Body condition was also opportunistically assessed for 12 Bryde's whales, including five mother-calf pairs. Bryde's whale body condition ranged from -0.13 to +0.17%, with a mean of 0.00 (SD=0.092). These findings reinforce the need for continued monitoring of both species of whales' relative abundance, distribution and health in relation to changing oceanographic conditions in the Arabian Sea that are likely to impact their preferred prey and foraging strategies.

INTRODUCTION

The Arabian Sea humpback whale (ASHW) sub-population is the only known humpback whale (Megaptera novaeangliae) population that does not undertake long seasonal migrations between low latitude breeding grounds and high latitude feeding grounds (e.g. Minton et al. 2011). Assessed as Endangered by the IUCN Red List of Threatened Species, the last published abundance estimate based on mark recapture models and photo-identification off the coast of Oman between 2000 and 2004 was 82 animals (95% CI 60-111) (Minton et al. 2008). The population is genetically distinct and isolated from other populations in the Indian Ocean (Pomilla and Amaral et al., 2014), and faces multiple threats from fisheries, shipping, disease, and coastal development, including activities related to oil and gas exploration and development (Minton et al. 2008; Baldwin et al. 2010; Van Bressem et al. 2014; Minton et al. 2022). The Scientific Committee of the International Whaling Commission (IWC) has emphasized the importance of research and conservation of this unique population since the late 1990s when Russian scientists working on Soviet whaling vessels first published evidence of its existence and its unique biology and ecology (Mikhalev 1997). The IWC SC has repeatedly recommended that a regional Conservation Management Plan (CMP) be implemented, involving as many ASHW range countries as possible (e.g. IWC 1998; IWC 2016; IWC 2018), and in recent years discussions with the Convention on the Conservation of Migratory Species of Wild Animals (CMS), which hosts a Concerted Action for ASHW (CMS 2017) have concluded that a joint IWC-CMS regional CMP would maximise the potential for effective ASHW range country collaboration.

While many ASHW range countries are engaged in research and conservation activities, to date the Sultanate of Oman has hosted more dedicated research on this population than any other range country, with small boat surveys focusing on humpback whales conducted on an almost annual basis from 2000 onward (e.g. Minton et al. 2011; Willson et al. 2015; Willson et al. 2018; Willson et al. 2019). This report presents the broad-scale results of boat-based research conducted off the coast of Oman between November 2019 and November 2022, with a focus on findings relevant to ASHWs. While surveys documented all cetaceans encountered, these boat-based surveys were designed predominantly with the objective to document the (seasonal) distribution of ASHWs in Oman's documented 'hotspots' as well as to continue photo-identification, genetic sampling, and drone-based assessment of body condition activities that were partially funded through the IWC SC. Surveys detailed in this document also provided the platform from which to undertake occurrence mapping of artisanal fisheries, and the results of this work is also detailed in a bycatch risk assessment methodology presented to HIM subcommittee if SC69A

Note that the results of passive acoustic monitoring for humpback whales and blue whales (Balaenoptera musculus) are presented in two separate reports presented the CMP and SH subcommittees of SC69A. More detailed information on a formal field survey capacity building programme also linked to IWC SC funded projects and stakeholder engagement to progress national and regional conservation planning in Oman are reviewed in the Arabian Sea Whale Network update, presented to the CMP subcommittee, and a workshop report submitted as a For Info document.

METHODS

Distribution and photo-identification

Data collection and processing

Boat-based surveys were conducted in two locations previously identified as areas of seasonal concentration for ASHW off the Arabian Sea coast of Oman – the Gulf of Masirah (19.67ºN, 58.19ºE), and the Halaniyats Bay (17.40ºN, 55.30ºE) (Fig. 1). Vessels were open-decked vessels ranging from 6.5m to 10m, with outboard engines ranging up to 2 x 150hp.

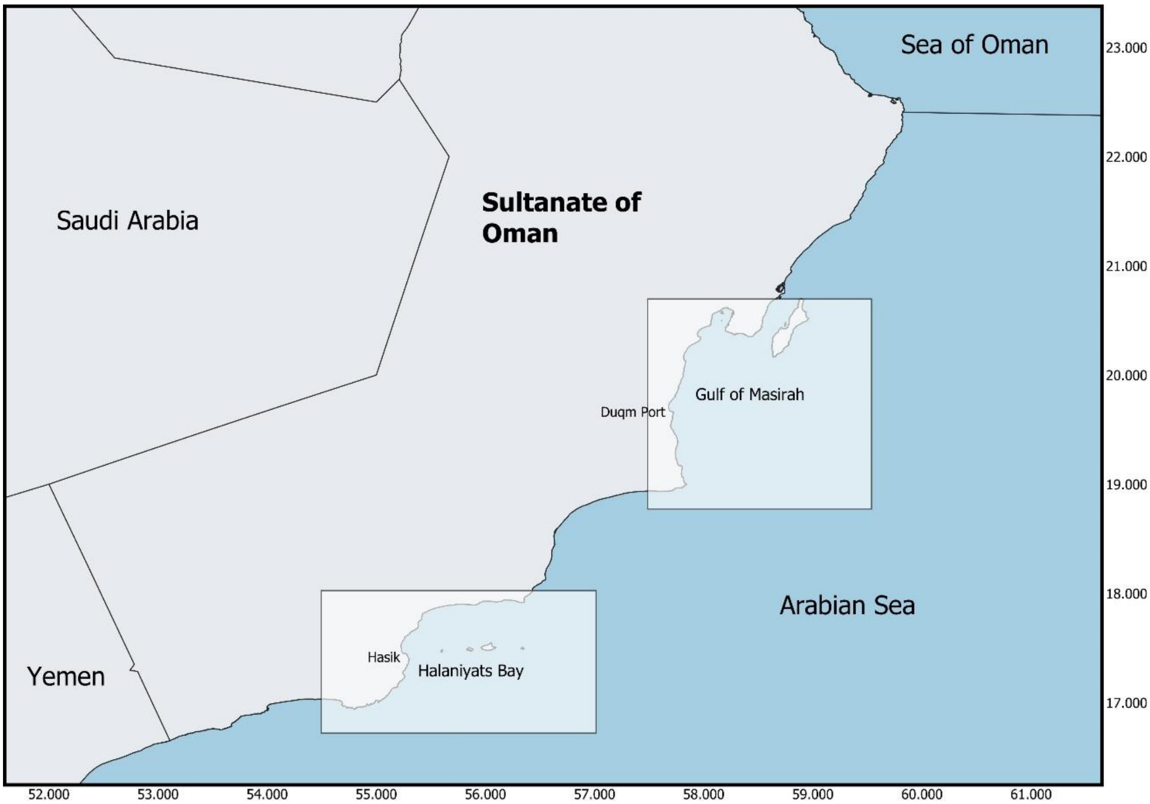


Figure 1. *Map depicting the two study areas on the Arabian Sea coast of Oman, the Gulf of Masirah in the north (location of surveys in November 2019, 2021 and 2022) and the Halaniyats Bay in the South (location of the March, 2021 survey).*

Survey methods were consistent with previously described protocols (e.g. Minton et al. 2010; Corkeron et al. 2011; Willson et al. 2019). Vessels navigated pre-determined survey transects at a speed of 20 km/h with a minimum of two experienced cetacean researchers scanning a 180-degree arc centred on the bow of the vessel. An omni-directional dipping hydrophone (High Tech Inc., HTI-96 and Aquarian Scientific, AS-1) were deployed at <10m depth at the start and end of every transect leg, usually at roughly 10km intervals, for a minimum of five minutes in order to detect ASHW song/vocalisations. Five-minute long recordings were made at every station. When humpback whale song was detected at close range with little interference, longer recordings were made to attempt to capture entire song samples for qualitative analysis (see IWC/SC69A/CMPXXX for a full report of methods and results related to ASHW song analysis).

During November 2021 and 2022 all identifiable fishing vessels were counted at the stations marking start and end points of each transect. Two or more observers scanned at a height of 2.5m either clockwise or counter-clockwise and classified the counts as either dhows (multiday fishing vessels <15 m length) or skiffs (day-boats <9 m length). Results were conferred until agreement was reached on the number of vessels.

All cetacean species encountered were approached and followed to confirm species identification, group size and behaviour. Digital SLR cameras with 70-300mm or 100-400mm zoom lenses were used to photograph the left and right sides of the dorsal fins, caudal peduncle, and the ventral surface of the tail flukes of humpback whales. A printed or PDF version of the existing Oman humpback Whale Photo-Identification catalogue (Curated by GM on behalf of the Environment Society of Oman) was used to attempt to identify individual whales in the field and determine whether they had been biopsied or satellite tagged in the past. Whales that had not yet been biopsied during a particular survey were approached and biopsies were attempted using a crossbow and modified dart (Larsen 1998).

Data analysis and processing

GPS tracks and meta-data related to survey effort and cetacean sightings were downloaded, transcribed, and checked for inconsistencies at the end of each survey day. These were compiled in an Excel spreadsheet that was used for mapping and analysis of sightings in relation to survey tracks. Photographs were also downloaded and archived at the end of each survey day, and assigned to individual whales where relevant, to ensure that the correct whales could be linked to drone footage (see below) and genetic samples. Trainee researchers were guided through this work on a daily basis during the fieldwork.

Photographs of the left and right sides of humpback dorsal fins and tail flukes, as well as caudal peduncles and satellite tag healing sites, were sorted cropped, enhanced and labelled and entered into the Oman humpback Whale Photo-Identification database. Individuals were either assigned pre-existing IDs if they matched photographs already in the catalogue, or assigned new IDs. All photographs were scored for quality and distinctiveness (e.g. Friday et al. 2000; Urian et al. 2015).

Because many humpbacks whale sightings were documented outside of dedicated survey effort (e.g. while speeding to and from transect start or end points, or while working with another group of cetaceans), crude encounter rates were calculated for humpback whales and Bryde's whales (Balaenoptera edeni) by dividing the total number of sightings of each species documented during a survey by the total number of hours spent navigating on the survey vessel each day.

Use of unmanned aerial systems/drones to assess body condition

Data collection and processing

Unmanned aerial vehicles (UAVs) were used to record zenithal videos of ASHWs in the Gulf of Masirah, Oman, in November 2019, 2021 and 2022 and the Hallaniyat Bay in March 2021. Opportunistic footage of Bryde's whales was also obtained. A variety of drone models were used, including a DJI Inspire 1 Pro (56.0 cm diameter, 3.4 kg) with a Zenmuse X5 camera and 25mm lens (2019 and 2021), a DJI Phantom 4 Pro Plus (35.0 cm diameter, 1.4kg) with a built-in 8.8mm camera (2021), a DJI Mavic 1 Pro Platinum (33.5cm diameter, 0.7 kg) with a built-in 5.5mm camera (2021), and a DJI Inspire 2 (60.5 cm diameter, 4.0 kg) with a Zenmuse X5 camera (2022). The UAVs were flown above the whales at altitudes ranging from 18 to 66 m (mean=33, SD=10,0) and recorded videos of the whales as they surfaced to breathe. During post-processing, a still frame photograph of each whale was extracted from the videos. An ideal photograph represented a whale lying flat at the surface with its dorsal side visible with its body non-arching and the body contour (both length and width) clearly visible (Christiansen et al. 2016, 2018) (Fig. 1A). Each photograph was quality graded (based on posture, clarity and contrast) following the protocol of Christiansen et al. (2018), and only photographs of adequate quality were included in analyses. Each whale was individually identified using the unique shape and pattern of the whale's fluke and/or dorsal fin, which was photographed by one of the researchers on board the research vessel.

Body morphometrics and condition

A custom written script (available from Christiansen et al. 2016) in R 4.0.3. (R Core Team 2020) was used to measure body lengths and widths from the best aerial photographs (video still frames) at 5% increments along the entire body axis of the whale (Fig. 2A), following the method developed by (Christiansen et al. 2016, 2020b). If the whale rolled over to its side, the dorso-ventral distance (height) was also measured at the same measurements sites (Fig. 2B). All measurements were scaled (converted from pixels to meters) using the known altitude of the UAV, the camera sensor size, focal length and image resolution (for details, see Christiansen et al., 2018). The altitude of the UAV was measured using either the built-in barometric altimeter of the UAV (for the Phantom 4 and Mavic 1) or by a laser range finder (a LightWare SF11/C) attached to the drone (Inspire 1 and Inspire 2). Juveniles and adults were separated based on a body length threshold of 11.2 m (Chittleborough 1955a b, Christiansen et al. 2016), although it is possible that ASHWs reach sexual maturity at a larger (>11.6m) body size (Mikhalev 2000).

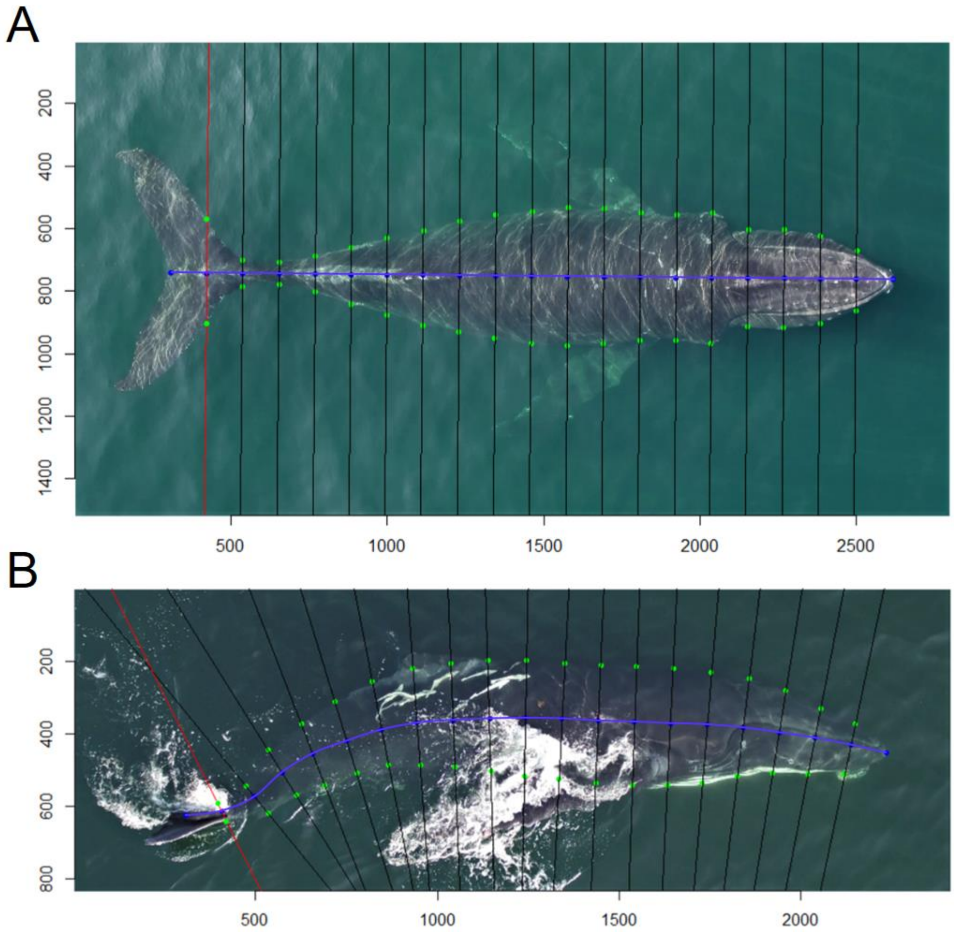


Figure 2. *Aerial photograph (video still frame) of an adult ASHW, showing the (A) dorsal and (B) lateral side and the location of the body length (blue line), body width (green points, top-figure) and body height (green points, bottom-figure) measurement sites. The pictures were extracted from the custom written R script by Christiansen et al. (2016).*

The body condition of individual whales was calculated from the residual of the relationship between body volume and body length (Christiansen et al. 2018). First, we used the body length, width and height data to estimate the body volume of the whales. To account for the elliptical cross-sectional body shape of the whales (Lockyer et al. 1985, Christiansen et al. 2019, 2020b), we first calculated the corresponding height (dorso-ventral distance) of the whales at each width measurement site, using the known height-width (HW) ratios of humpback whales provided by Christiansen et al. (2020b). The total body volume (BVTotal) of each whale (i) was then estimated from the sum of the volumes of all body segments (s), the section of the body between two adjacent width/height measurement sites, S=20 in total):

$$BV_{Total,i} = \sum_{s=1}^{20} V_{s,i} \tag{1}$$

where the volume of each segment (V_s) was modelled as a series of infinitesimal ellipses, following the methods of Christiansen et al. (2019):

$$V_{S,i} = BL_i \times 0.05 \times \int_0^1 \pi \times \frac{W_{A,s,i}+(W_{P,s,i}-W_{A,s,i})\times x}{2} \times \frac{H_{A,s,i}+(H_{P,s,i}-H_{A,s,i})\times x}{2} dx \tag{2}$$

where BLi is the body length of whale i, WA,s,i and HA,s,i are the anterior width and height measurements of body segment s for individual i, and WP,s,i and HP,s,i are the posterior width and height measurements of segment s for individual i, respectively. To account for the gradual decrease in height and width towards the end points of the animal, the segments closest to the rostrum (0-5% BL from the rostrum) and the end of the tail region (85-100%BL from rostrum) were modelled as elliptical cones (Christiansen et al. 2019).

From the body volume estimates, the body condition (BC) of individual whales was calculated following the methods of Christiansen et al. (2018):

$$BCI_i = \frac{BV_{obs,i} - BV_{exp,i}}{BV_{exp,i}} \quad (3)$$

where BVobs,i is the observed body volume of whale i, in m3, and BVexp,i is the expected (or predicted) body volume of whale i, in m3, from the linear relationship between body volume and length on the log-log scale, based on breeding stock D humpback whales from Western Australia averaged over the entire breeding season (Christiansen et al. 2020b):

$$\log\left(BV_{exp,i}\right) = -3.70 + 2.77 \times \log\left(BL_i\right) \quad (4)$$

We used the volume-length relationship of breeding stock D because it was based on a healthy (growing) population and covered the full-size range of whales from calves to adults. The body condition of ASHWs was compared between years and sexes, using linear models in R v.3.5.3 (R Core Team 2020). We tested the effect of year, expressed both as a continuous variable and as a factor. For each model, model validation tests were performed to test for homogeneity and normality of residuals, as well as influential data points and outliers. All model assumptions were fulfilled.

RESULTS

Seasonal distribution and photo-identification of ASHW

Boat based surveys were conducted in the Gulf of Masirah in November 2019, November 2021, and November 2022. An additional survey was conducted in the Dhofar Region in March 2021 (note that the results of this survey were reported in detail in SC/68C/CMP/04).

Table 1 provides a summary of the dates, total number of hours of survey effort and ASHW encounter rates per hour for each of these four surveys. In total, over 550 hours were spent across all four surveys either speeding to and from transect start points, on search effort, or filming and sampling cetaceans. Encounter rates varied considerably from one survey to the next, with relatively high humpback whale encounter rates (both sightings per hour, and number of identified individuals per hour) in November 2019 and November 2021, but no humpback whale sightings at all in March 2021 and a very low encounter rate in November 2022. Interestingly, Bryde's whale encounter rates were inversely proportional to humpback whale encounter rates, with high encounter rates recorded in both March 2021 and November 2022 (Fig. 3). Figure 3a-d provides an overview of survey tracks, and humpback whale sightings from each of the four surveys.

Table 1: *Survey dates, locations, and cumulative time spent on the survey vessels, along with the cumulative number of humpback and Bryde's whale sightings and encounter rates per hour.*

Survey dates	Survey location	Cum. vessel hours	# ASHW stgs.	# Bryde's stgs.	# photo-ID'd ASWH indivs.	# of new ASHW indivs.	ASHW stgs/hour	ASHW whale indivs/hr	Bryde's stgs/hr
15-26 November, 2019	Gulf of Masirah	132.33	13	2	13	1	0.098	0.098	0.015
11-22 March, 2021	Halaniyats Bay	105.39	0	24	0	0	0.000	0.000	0.228
5-22 November, 2021	Gulf of Masirah	210.86	40	3	30	8	0.190	0.142	0.014
9-22 November, 2022	Gulf of Masirah	111.14	4	18	3	1	0.036	0.027	0.162
Total/Average		559.72	57	47	38	10	0.081	0.067	0.105

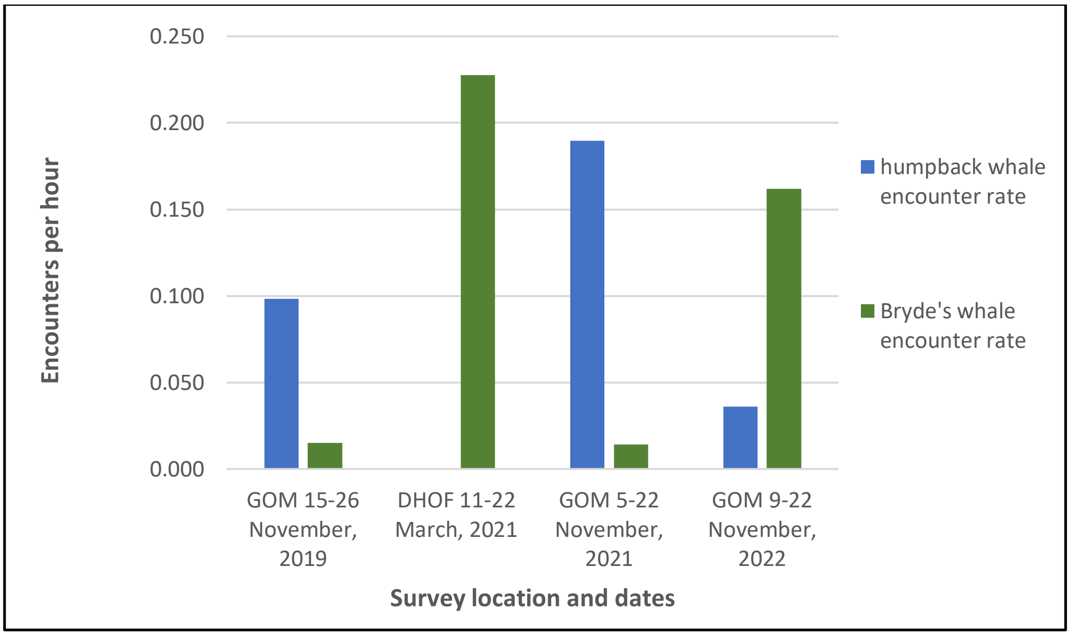
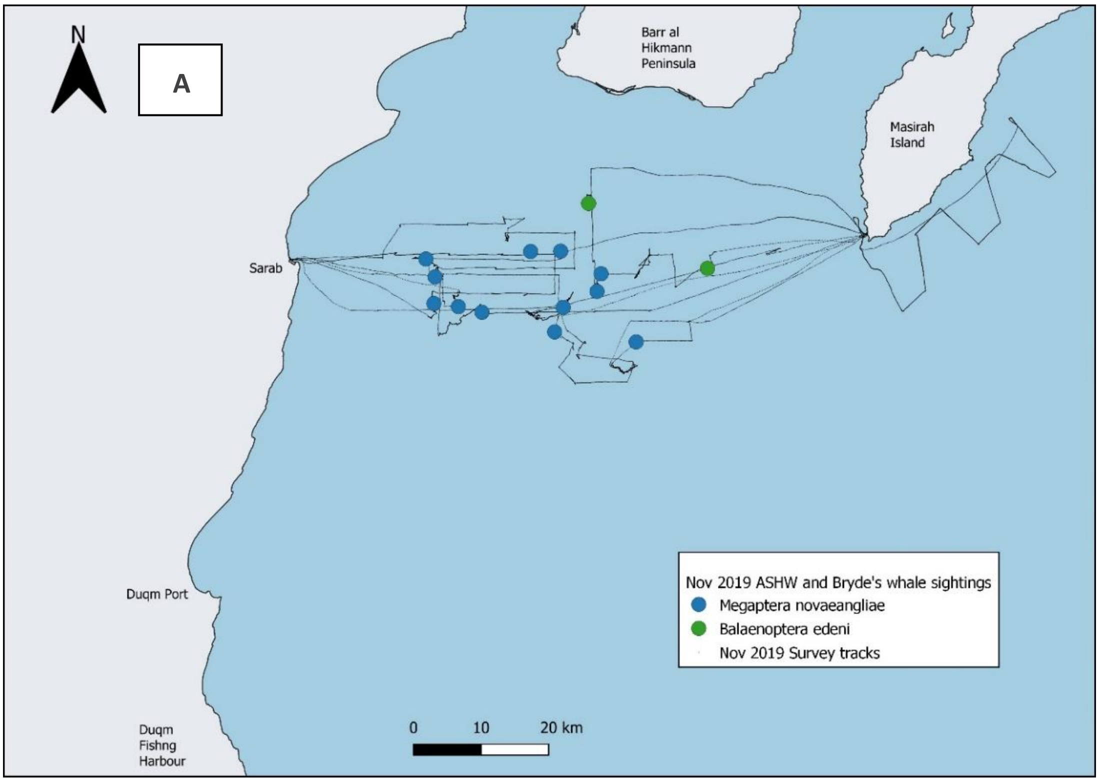


Figure 3. *Humpback whale vs. Bryde's whale encounter rates, during four surveys conducted off the coast of Oman between November 2019 and November 2022. GOM = Gulf of Masirah, and DHOF = Halaniyats Bay in Dhofar. Encounter rates were calculated as the total number of sightings divided by the cumulative number of hours spent navigating.*



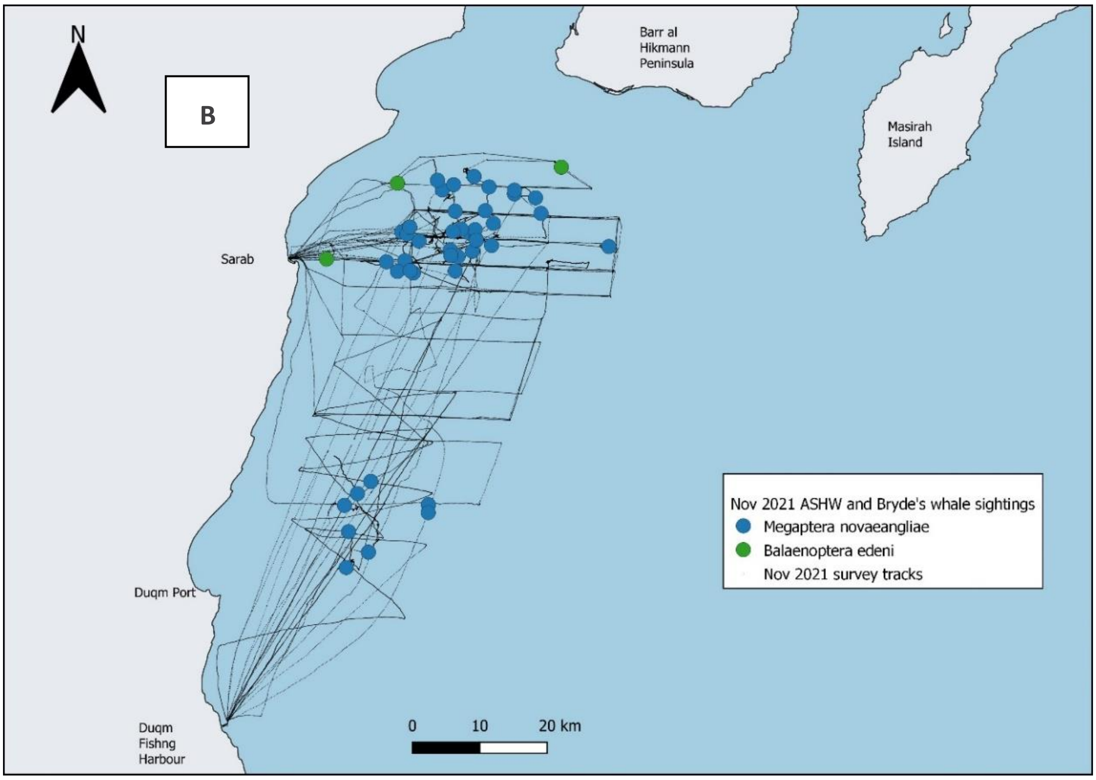
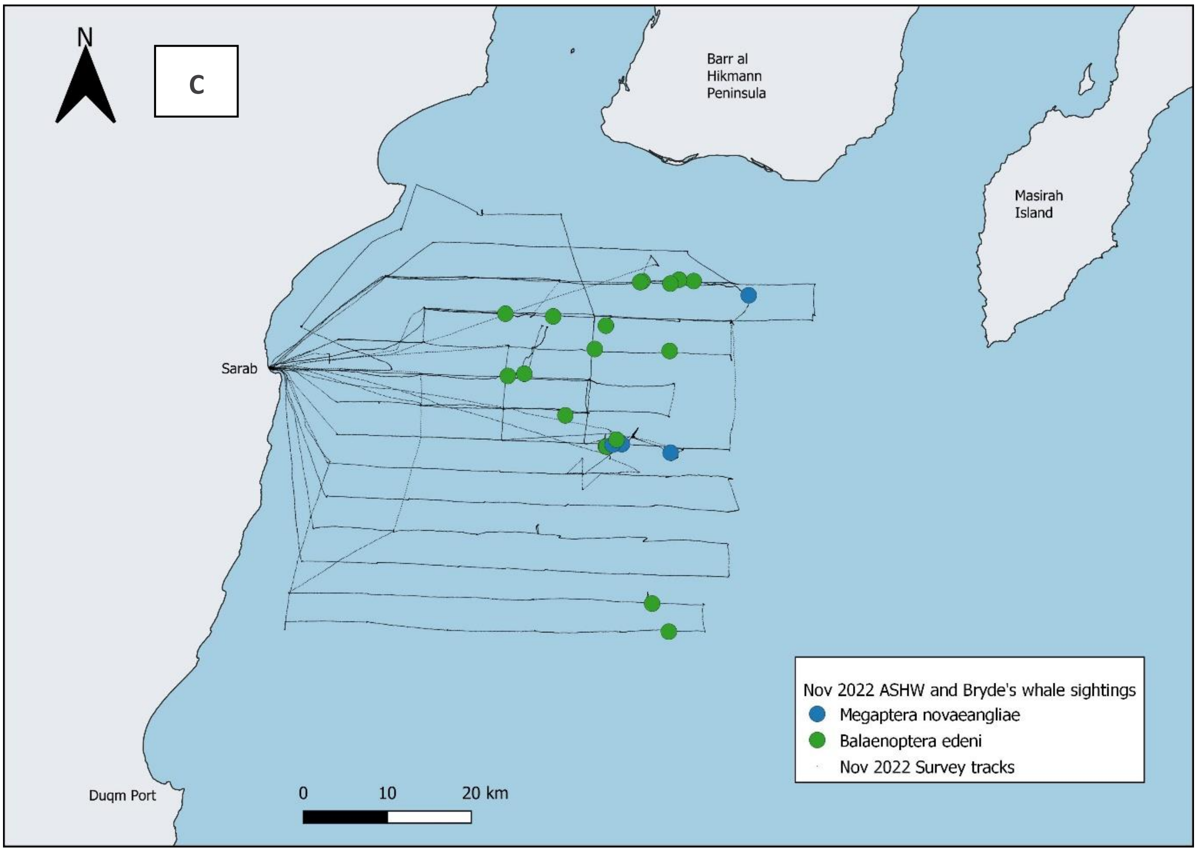


Figure 4a-d (including following pages). *Survey tracks (including on- and off-effort portions of navigation), and humpback whale sighting locations documented during four recent surveys off the coast of Oman a) Gulf of Masirah, November 2019; b) Gulf of Masirah, November 2021; c) Gulf of Masirah, November, 2022; c) Dhofar, March 2021.*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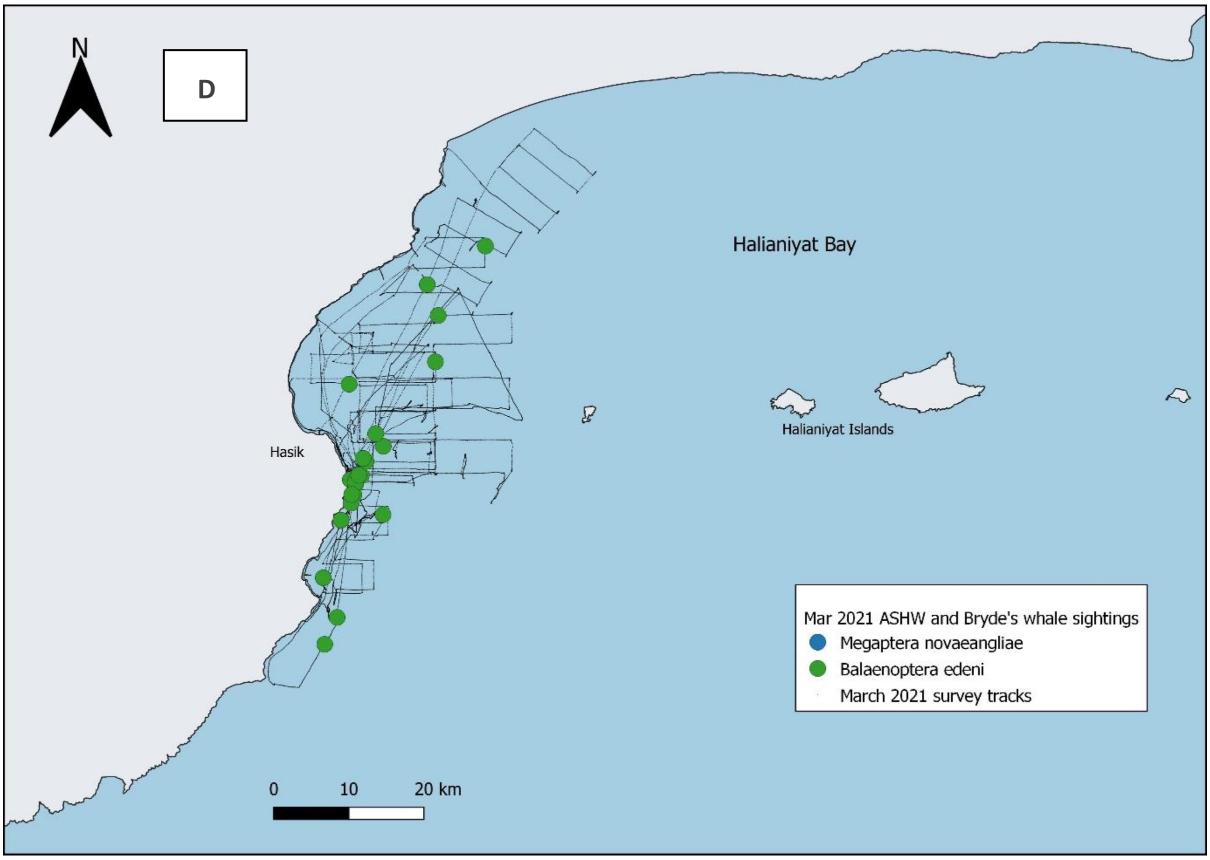
Balaenoptera edeni
Nov 2022 Survey tracks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Mar 2021 ASHW and Bryde's whale sightings
Megaptera novaeangliae
Balaenoptera edeni
March 2021 survey tracks
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Over the course of all four surveys a total of 57 ASHW and 47 Bryde's whale encounters were documented. This entailed a total of 38 photo-identified ASHW individuals. As during past surveys, re-sighting rates of previously photo-identified individual humpback whales were high. Re-sighed whales included individuals identified for the first time in 2001 (5 individuals) and 2002 (4 individuals). Individual OM02-008, known as 'Luban', the female that was satellite tagged in December 2017 in the Gulf of Masirah and then crossed the Arabian Sea to the southern tip of India and back, was observed in both November 2021 and November 2022. She appeared to be in good condition (see Table 2 below), and photographs of her right flank indicate that the tag insertion site was well healed. However, a more systematic evaluation of all the photos collected between 2019 and 2022 is still required to qualitatively and quantitatively assess external signs of disease, anthropogenic scarring, and tag healing, using the same protocols that were used by Minton et al. (2022).

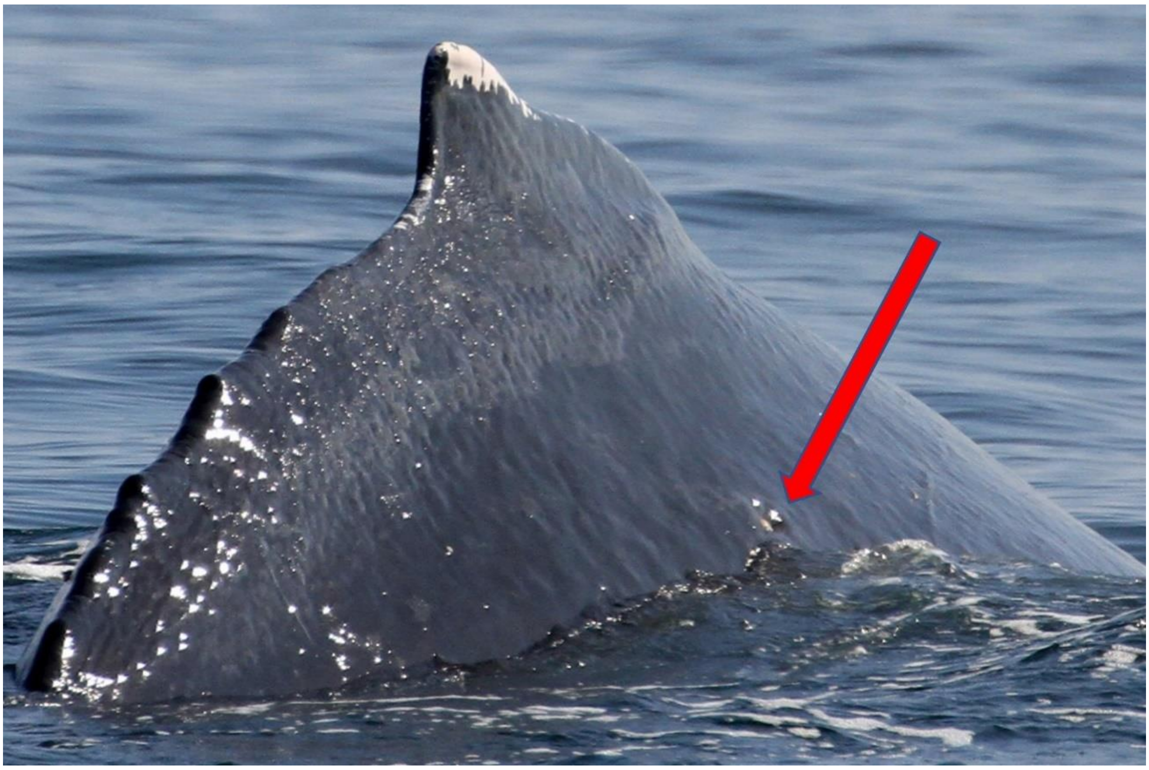

Figure 5. *Humpback whale female, known as OM02-008, or 'Luban'. This whale was tagged in December 2017 off the coast of Oman and crossed the Arabian Sea to the southern tip of India and back. This photo shows the tag insertion site low on her right flank near the water line. Healing appears to be normal without complications.*

Acoustic detections and recordings

Acoustic detections were proportional to the visual sightings documented during all four surveys. Acoustic detections were made regularly during November 2019, and longer recordings were included in the analysis presented in IWC/SC69A/CMPXXX. As reported by Willson et al. (2021), no acoustic detections of humpback whale song were made during March 2021 when no ASHW sightings were made. Regular detections were made in November 2021, and only two detections were made despite regular sampling throughout November 2022.

Use of unmanned aerial systems/drones to assess body condition

Humpback whale data

Between 2019 and 2022, a total of 77 body condition measurements were obtained from 30 individual ASHWs (Table 2). Of these, 11 were sampled in 2019, 22 in 2021, and 3 in 2022. Six of the whales measured in 2019 were also measured in 2021. Previous biopsy sampling and genetic analysis of known individuals from the Oman humpback whale photo-identification catalogue confirmed that measured individuals included 8 females, 9 males and 13 animals of unknown sex (biopsy samples collected between 2019 and 2022 will allow sexing of 7 of these individuals) (Table 2). All the measured ASHWs were adults, ranging in body length from 12.0 to 16.8 m (mean=14.5 m, SD=1.2, n=30) (Table 2).

Table 2 *Summary table of individual ASHWs sampled in Oman between 2019 and 2022. The body condition (BC) score includes all quality grades.*

ID	Body length (m)	Sex	BC 2019	BC 2021	BC 2022
OM02-019	14.3	M	0.09	0.06	-
OM14-023	15.0	F	0.28	0.18	-
OM19-001	14.5	-	0.17	-	-
OM02-001	14.0	M	0.09	-	-
OM17-010	14.0	-	-0.08	-	-
OM01-004	14.2	F	0.08	0.21	-
OM16-001	14.4	-	-0.11	0.39	-
OM01-013	16.0	M	0.03	0.10	-
OM01-017	14.2	F	0.12	-	-
OM01-001	14.8	M	0.16	0.02	-
OM15-006	16.8	F	0.13	-	-
OM17-009	15.4	-	-	0.15	-
OM11-004	13.1	F	-	0.37	-
OM01-012	15.3	F	-	0.23	-
OM02-020	13.8	M	-	0.09	-
OM21-002	15.2	-	-	0.34	-
OM04-011	15.2	M	-	0.11	-
OM21-004	15.2	-	-	0.26	-
OM21-005	14.8	-	-	0.18	-
OM03-004	12.4	F	-	0.47	-
OM21-006	12.0	-	-	0.19	-
OM17-008	15.0	M	-	0.02	-
OM14-013	12.2	M	-	-0.05	-
OM17-005	12.2	M	-	0.01	-
OM11-014	15.2	-	-	0.05	-
OM11-012	16.0	-	-	0.07	-
OM21-007	15.2	-	-	0.07	-
OM16-002	15.0	-	-	-	-0.01
OM02-008	13.6	F	-	-	0.11
OM22-001	15.8	-	-	-	0.14

Based on high quality images only, the body condition of ASHWs ranged from -0.08 to +0.51%, with a mean of 0.12 (SD=0.126) (Table 2). There was a significant difference in body condition between sexes ($F_{2,51}$=9.55, P<0.001, R^2=0.273), with females on average having a 16.1 percentage units higher body condition than males (t-value=-4.296, p<0.001) and 12.4 percentage points above individuals of unknown sex (t-value=-3.172, p=0.003) (Fig. 6A). There was no difference in the average body condition of ASHWs between years (Continuous: $F_{1,52}$=0.24, P=0.626, R^2=0.005, Factor: $F_{2,51}$=0.39, P=0.681, R^2=0.015) (Fig. 6B). From the 6 individuals that were sampled in both 2019 and 2021, 3 had high quality measurements in both years. These 3 whales all declined in body condition from 2019 and 2021, from 0.22-0.12, 0.34-0.18 and 0.16-0.02. This corresponds to a decline in body volume of 8.2, 11.9 and 12.1%, respectively.

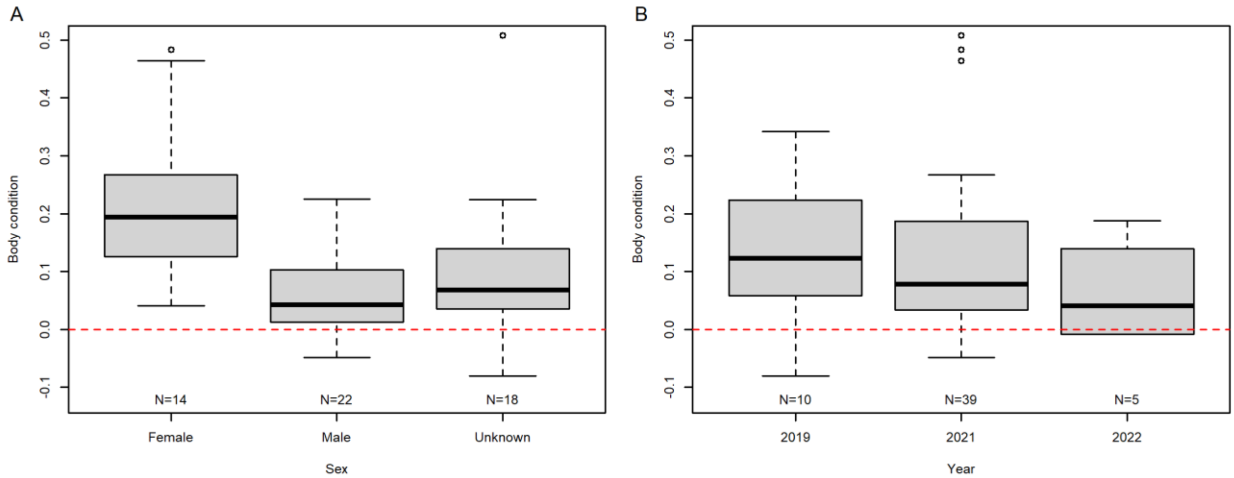

Figure 6. *Boxplots of ASHW body condition for different (A) sex and (B) years. The dashed red horizontal line represents the average body condition of humpback whales based on breeding stock D sampled throughout the breeding season in Western Australia. The sample size for each reproductive class and year is given below each boxplot.*

Bryde's whale data

We opportunistically obtained 16 measurements from 12 Bryde's whales in 2021 (n=4 individuals) and 2022 (n=8 individuals) (Fig. 7). This comprised 5 calves (5.6-7.6m), 2 juveniles (11.6-11.9m), 3 adults (12.0-12.2m) and 6 lactating females (12.8-15.7m). Designation of stages of maturity was based on Mikhalev (2000), who determined that sexual maturity was reached at a threshold of 12.0m. In 2022, we also obtained one lateral photograph of an adult Bryde's whale. From this, we calculated the HW ratio of the whales and then used equations 1 and 2 to calculate their body volume (Fig. 8). The resulting volume-to-length relationship for Bryde's whales was ($F_{1,14}$=1843, P<0.001, R^2=0.993):

$$\log\left(BV_{BE,exp,i}\right) = -4.14 + 2.70 \times \log\left(BL_i\right) \qquad (5)$$

Using equations 3 and 5, we calculated the body condition of the Bryde's whales, which ranged from -0.13 to +0.17%, with a mean of 0.00 (SD=0.092).

Figure 7. *Example photograph of a Bryde's whale mother and calf that were used to measure body morphometrics and condition.*

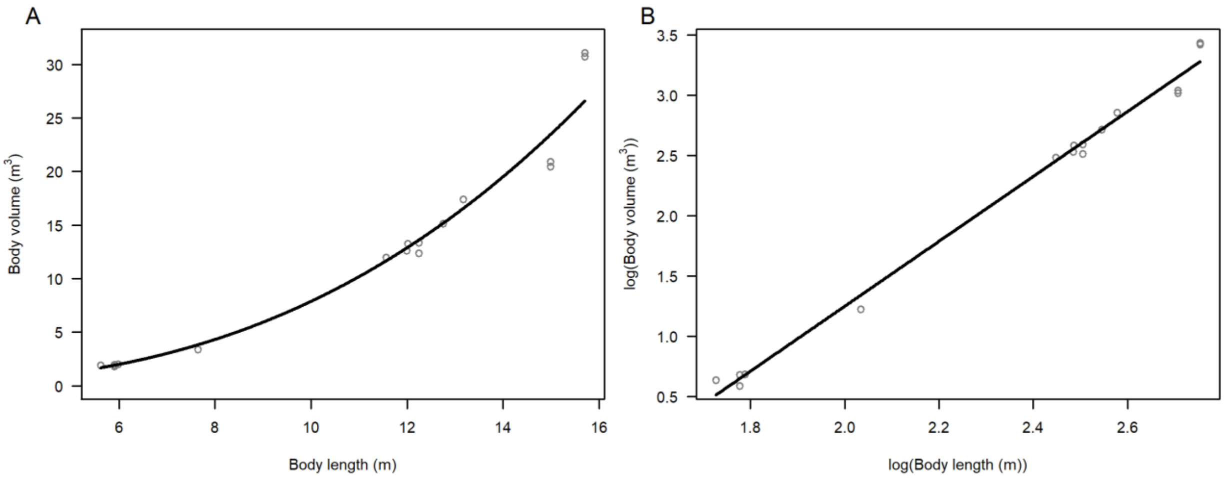

Figure 8. *(A) Bryde's whale body volume as a function of body length. The solid line represents the back-transformed fitted values of the linear model. (B) The log-log relationship between body volume and body length for the same data set, with the solid line representing the fitted values of the linear model. N=16 measurements.*

DISCUSSION

Distribution and relative abundance

The 2019-2022 surveys followed from a series of surveys conducted in Oman from 2014-2017 during which there was a strong emphasis on satellite tagging of ASHWs (i.e. Willson et al. 2015; Willson et al. 2016; Willson et al. 2018). The results of these tagging studies yielded highly valuable insights into the apparent site fidelity, habitat use and ecology of the tagged individuals, as well as the long-range movement of one individual across the Arabian Sea (e.g. Willson et al. 2017). However, for various reasons, these surveys were slightly less suitable for assessing relative abundance and distribution of ASHW and other cetacean species.

The results of the four surveys described here are useful to view together, as they highlight the extreme inter-annual variability in both ASHW and Bryde's whale encounter rates. Following the survey in March 2021 during which humpback whales were not detected at all, Willson et al. in SC/68C/CMP/04 (2021) speculate that their absence was linked to a period of sea surface temperatures that were 1.5° – 3°C warmer than average, which may have been linked to reduced prey availability. Conditions during the November 2022 survey were similar to those in March 2021, with warmer, clearer waters and air temperatures than usual. Temperatures throughout the November 2022 survey period were roughly 1°C warmer than average (see, for example https://earth.nullschool.net/#2022/11/12/0100Z/ocean/surface/currents/overlay=sea_surface_temp_anomaly/orthographic=-301.05,20.14,3117/loc=63.296,18.239). Previous ecological niche ensemble modelling based on both boat-based observations and satellite telemetry indicated that ASHW were most likely to be found in waters between 24°C and 26°C (Willson et al. 2017, Willson, 2021). Sea surface temperatures in the Gulf of Masirah in October and November 2022 averaged 27.5°C. Local small-scale artisanal fishermen complained that sardine catches were so low that many boats suspended fishing effort for several days during the survey period.

However, over the same period in November 2022 industrial trawlers targeting sardines were observed operating in areas where ASHW encounter rates had been high in 2019 and 2021. CPUE of sardines has increased by a factor of 12 in the waters of Al-Wusta area that includes the Gulf of Masirah (Jufaili and Piontkovski 2020). The demands on this resource are worthy of further attention given that sardines are known to comprise a major component of ASHW diet off the coast of Oman (Mikhalev 1997; Mikhalev 2000). The issue provides continued justification for continued tracking of ASHWs through the body condition assessment work.

The inverse relationship between the relative abundance of ASHW and Bryde's whales may also be linked to oceanographic drivers and prey availability. While humpback whales are known to specialise in prey species that occur in seasonally variable high concentrations, and to undertake long seasonal migrations in order to access these prey concentrations (e.g. Clapham 2009), Bryde's whales, also informally known as 'tropical whales' are known to remain at tropical latitudes year-round and considered more 'opportunistic feeders' (Kato and Perrin 2009), able take advantage of more limited and diffuse prey. While the data from Soviet whaling catches indicated that both ASHW and Bryde's whales were feeding on *Sardinella spp*. in the Arabian Sea, Bryde's whales appeared to also feed on larger fish like lantern fishes (family Myctophidae), spotted mackerels (*Scomber tapeincocephalus*) and horse mackerels (*Trachurus spp*.) (Mikhalev 2000). The catch positions reported from the Soviet whaling data showed minimal overlap between the distribution of ASHW and Bryde's whales (data held by the IWC Secretariat), indicating that there is little direct overlap between preferred prey and foraging strategies of both species. The results of our surveys to date indicate that this niche partitioning is likely to be temporal, rather than solely geographical, as the same areas were surveyed at the same time of year with highly variable encounter rates for both species. Further studies will be required to better understand exactly what drives this partitioning.

Given the potential impacts of climate change, which is already affecting the unique seasonal upwelling systems in the Arabian Sea (e.g. Goes et al. 2020), and increased fishing effort on sardine species known to comprise important prey for both ASHWs and Bryde's whales (Jufaili and Pointkovski, 2020), it will be important to continue monitoring both species' relative abundance, distribution, and body condition in relation to oceanographic trends and fishing effort in the region.

Body condition

We found that ASHW females were in overall better body condition than males. Similar patterns can be found on the breeding grounds for migratory baleen whale populations, where late pregnant/early lactating females are in their best body condition state compared to other reproductive classes (Miller et al. 2012, Christiansen et al. 2016, 2020a, 2021, Soledade Lemos et al. 2020), since they need to carry sufficient fat reserves to grow their calf for the first 3-4 months while fasting. Based on foetal lengths obtained from pregnant females caught in Soviet whaling operations, ASHWs should begin calving in December, with a peak in February (Mikhalev 1997). It is thus possible that the females measured in this study could be pregnant (Mikhalev 1997 reported foetuses measured in November to be 340-375 cm in length), or at least in sufficiently good condition to reproduce.

Photo-identification and visual health assessment

This report only briefly summarises the results of the 2019-2022 surveys with respect to the number of ASHW individuals that were observed and catalogued. While we provide some insight into the continuing trend toward high resighting rates of known individuals, many of which have sighting histories that span up to 20 years, it is important that the photographic data are used to undertake more thorough and systematic analyses of external signs of disease, epi-bionts, anthropogenic scarring and tag site healing using the same methodology used for the visual health assessment that was conducted on data collected through 2018 (Minton et al. 2022). These data should also be used to generate updated mark-recapture abundance estimates for ASHW off the coast of Oman, an effort which is already underway using data collected through 2018. Funding and/or additional human resources (i.e., through the identification of range-country graduate students who could undertake analyses as part of an academic degree) are required to progress this work.

Capacity building during surveys

The November 2021 and November 2022 surveys both included a strong element of capacity building for Omani scientists, an element that was partially funded by the IWC SC. An Omani employee of Future Seas participated in the full November 2021 survey, and became proficient in all aspects of data collection, entry, and mapping during the survey. Two Omani graduates working with the Environment Society of Oman (ESO) also joined the November 2021 survey and became familiar with basic field techniques during that time.

In 2022, the Environment Society of Oman received funding to host a longer-term programme to build capacity for cetacean research and conservation among Omani scientists. This programme involved five half-day long classroom-based modules that were delivered in a hybrid format (online and in-person), followed by day-long monthly vessel-based training surveys in the Muscat area. Participants included employees of Future Seas, interns working with the ESO, recent graduates, and a staff member of the Oman Environment Authority (EA). Three of the six trainees participating in this programme also participated in the November 2022 survey in the Gulf of Masirah for a minimum of three days, with one participating in the full survey. An additional two EA employees joined the survey for 2 days. Trainees were fully involved in all aspects of boat-based data collection, data downloading and entry, and basic mapping of survey results. They will use the survey results in final projects that will be completed in June 2023.

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