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Oman Research Update: Preliminary survey results and update on deep water acoustic deployments

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ABSTRACT

Cetacean research has been conducted in Dhofar, the southern region of Oman, since 2000. During this time, efforts have been primarily focused on documenting the distribution, abundance, and ecology of an Endangered population of Arabian Sea humpback whales (ASHWs, *Megaptera novaeangliae*). The research has revealed the Hallaniyats Bay to be a habitat of importance for reproductive and foraging related behaviours. Following three years of shorter opportunistic surveys between 2018 and 2020, a 2 week-long survey was conducted in March 2021 with the main objectives of recovering and redeploying a moored passive acoustic monitoring unit deployed in March 2020 for the purpose of detecting blue whale song and assessing the body condition of humpback whales using Unmanned Aerial Vehicles (UAVs/drones). The passive acoustic monitoring unit was recovered, and data successfully retrieved, although an equipment malfunction resulted in the recorder stopping after 7 months of successful data collection. Equipment has been sent for repair prior to a planned redeployment in late April 2021. Thirteen consecutive days of small vessel-based survey effort yielded multiple sightings of common dolphins (*Delphinus delphis tropicalis*), Bryde's whales (*Balaenoptera edeni*), Risso's dolphins (*Grampus griseus*), Indian Ocean humpback dolphins (*Sousa plumbea*), Indo-Pacific bottlenose dolphins (*Tursiops aduncus*), and false killer whales (*Pseudorca crassidens*), as well as a single sighting of dwarf sperm whales (*Kogia sima*). However, neither humpback whales nor blue whales were detected during the survey, either visually or acoustically during the multiple hydrophone deployments conducted daily for humpback whale song throughout the survey area. Reasons for the absence of ASHWs in the study area is currently unknown, but could be related to warmer water temperatures potentially influencing their prey species and hence distribution.

INTRODUCTION

The marine waters of the Governorate of Dhofar in southern Oman have been the subject of dedicated cetacean surveys since 2000. Survey methods and effort in this region have focused principally on the Arabian Sea humpback whale (*Megaptera novaeangliae*, ASHW). This population is listed as 'Endangered' on the International Union for the Conservation of Nature (IUCN) Red-list based on a mark-recapture population estimate of 82 individuals (95% CI 60-111) (Minton et al., 2008) and evidence of the populations' isolation (Pomilla et al., 2014). The area of the Hallaniyats Bay within Dhofar is considered critical habitat for this population based on the results of behavioural observations, genetic work, photo-identification, satellite tracking and passive acoustic monitoring studies (Baldwin et al., 2011; Minton et al., 2011; Willson et al., 2015; Cerchio et al., 2016; Willson et al., 2019). The study area is also presumed feeding habitat for Endangered blue whales, which have been sighted in previous years although at a much lower sighting frequency than ASHW (Willson et al. 2019). The blue whales that utilize this area are thought to belong to a population that was recently described as potentially distinct from those found off Sri Lanka, based upon the discovery of a novel Northwest Indian Ocean (NWIO) song-type off the Dhofar region during acoustic monitoring in 2011/2012 (Cerchio et al. 2020).

Following three years of shorter, opportunistic surveys conducted in March and April 2018-2020, funding was secured through the IWC Scientific Committee and other sources to conduct a longer survey in March 2021 with two main objectives:

1) to recover a SoundTrap 500STD unit that was deployed at 266m depth in March 2020. This unit was deployed with the principle aim of recording blue whale (*Balaenoptera musculus*) vocalisations following the documentation of a new NWIO blue whale song (Cerchio et al., 2020). Funding was obtained through an IWC Scientific Committee approved research project entitled 'Passive Acoustic Monitoring for blue whales and other baleen whales off Oman. Funds helped to cover the costs of fieldwork mobilisation, equipment recovery, extraction of recorded data, replacement of batteries, and redeployment of the unit at the same location.

2) to assess ASHW body condition using Unmanned Aerial Vehicles (UAVs/drones) in accordance with the methods described in Christiansen *et al.* 2020 (IWC/SC/68B/CMP23_Rev1.2). Funding for this objective was obtained through an IWC Scientific Committee approved research project entitled 'Assessment of Arabian Sea humpback whale body condition and co-occurrence with human activities in Oman'. In November 2019 measurements from nine ASHW collected in the Gulf of Masirah provided some preliminary insight into ASWH body condition at a time of year (November) that follows the period of highest productivity associated with strong upwelling during the southwest summer monsoon. The timing of the March 2021 survey was intended to collect body condition data prior to the summer monsoon, in order to investigate potential seasonal patterns in body condition of ASHWs. The selected location for the work is strongly linked to reproductive behaviours rather than feeding (e.g. Mikhalev, 1997; Minton et al., 2010; Corkeron et al., 2011; Minton et al., 2011; Cerchio et al., 2016).

METHODS

Vessel surveys

Thirteen days of surveys were conducted from a base camp at Ras Hasik in the Hallaniyats Bay from March 10th-22nd, 2021. Observers worked from a 6.5 m rigid hulled inflatable (RHIB) and searched for whales following parallel transects running perpendicular to the coast and separated by 4kms (See Figure 1). Survey methods were consistent with previously described protocols (Minton *et al.*, 2010; Corkeron *et al.*, 2012; Willson et al., 2013), using a minimum of 3 observers scanning a 180-degree arc centred on the bow of the vessel.

An omni-directional dipping hydrophone (High Tech Inc., HTI-96) was deployed at <10m depth at the start and end of every transect leg for a minimum of five minutes in order to detect ASHW song/vocalisations. All cetacean species encountered were approached and followed to confirm species identification, group size and behaviour. Several species were photographed with the additional objective of obtaining photographs of dorsal fins or other features that can be used in the development of photo-ID catalogues. Records of sightings (all species), samples (all species) and photo-identification data (humpback whales) are now archived into the Fluke Book online database (Blount et al., 2020).

Had humpback whales or blue whales been encountered, they would have been biopsied, and aerial footage would have been obtained to assess body condition following Christiansen *et al.* (2018). For this purpose, a DJI Phantom 4 Pro (diameter = 350 mm, weight = 1388 g, 1'' CMOS sensor, 20MP, 5472x3078 pixels, 8.8mm focal length) multirotor UAV was carried on board the research vessel at all times. By photographing the dorsal side of whales as they surface to breathe, their body length and width (at 5% increments along the body) can be measured from the photographs, in pixels, using a custom-made script in R (Christiansen *et al.* 2016). The relative (pixels) measurements can then be converted to absolute (meters) measurements using the image resolution, camera sensor size, focal length and altitude above sea level (measured using the build in barometric altimeter of the UAV, corrected for the launch altitude above water) (for details, see Christiansen *et al.* 2018). The body length and width measurements are used to estimate the body volume of the whale (by modelling the body of the whales as a series of infinitesimal ellipses, Christiansen *et al.* 2020 (IWC/SC/68B/CMP23_Rev1.2)), and ultimately body condition (from the residual of the log-log relationship between body volume and body length, Christiansen *et al.* 2018). When possible, opportunistic measurements of body length and condition of non-target species, e.g. Bryde's whales, were also made with the UAV.

SoundTrap Passive Acoustic Recorder

An Ocean Instruments SoundTrap unit ST500STD was deployed at a depth of approximately 250m on 6th March 2020, suspended approximately 10 m above the seafloor with an 11" deep water trawl float and tethered to an acoustic release (Vemco Ascent AR) for subsequent recovery. The ST500 was configured to record at a sample rate of 24 kHz with a duty cycle of 50% (half an hour recording every hour). Recovery of the unit was made by using a GPS to station the survey vessel over the previous deployment location, and communicate with and trigger the release of the Vemco Ascent AR using a Vemco VR100 deck unit and transponding hydrophone. The initial intention was to recover, refurbish and redeploy the unit in September 2020, and thus conduct two ca. 6-month deployments between March 2020 and March 2021; however, travel restrictions resulting from the COVID-19 pandemic precluded an autumn/winter field trip. Thus, the recorder was deployed for a complete 1 year period.

RESULTS

Vessel Surveys

The 13 days of survey comprised a total of 1642 km and 105 hours on the vessel, with 396 kms and 38 hours dedicated search effort (see figure 1). A total of 63 sightings were made during the survey representing 7 species (Table 1). Common dolphins (*Delphinus delphis tropicalis*) were the most frequently sighted species (n=22). Bryde's whales (*Balaenoptera edeni*) were observed on every day of the survey and accounted for 21 sightings. Of these, 16 sightings were of single animals, three were pairs, including one mother and calf, and one group comprised a trio. Indian Ocean humpback dolphin (*Sousa plumbea*) sightings (n=3) were made within 5 km of each other on three separate days. The boat-based dipping hydrophone was deployed at 126 stations throughout the entire survey area on every day that surveys were conducted. No humpback whale song or vocalisations were detected at any of these stations.

Table 1: Species sighted during the March 2021 Survey in Dhofar, Oman.

Species Encountered	Number of sightings recorded
Delphinus delphis tropicalis - Common dolphin	22
Balaenoptera edeni - Bryde's whale	21
Grampus griseus – Rissos dolphins	5
Unknown whale	4
Unknown cetacean	4
Sousa plumbea – Indian Ocean humpback dolphin	3
Tursiops aduncus – Indian Ocean bottlenose dolphin	2
Kogia sima – Dwarf sperm whale	1
Pseudorca crassidens – False killer whale	1
Total	63

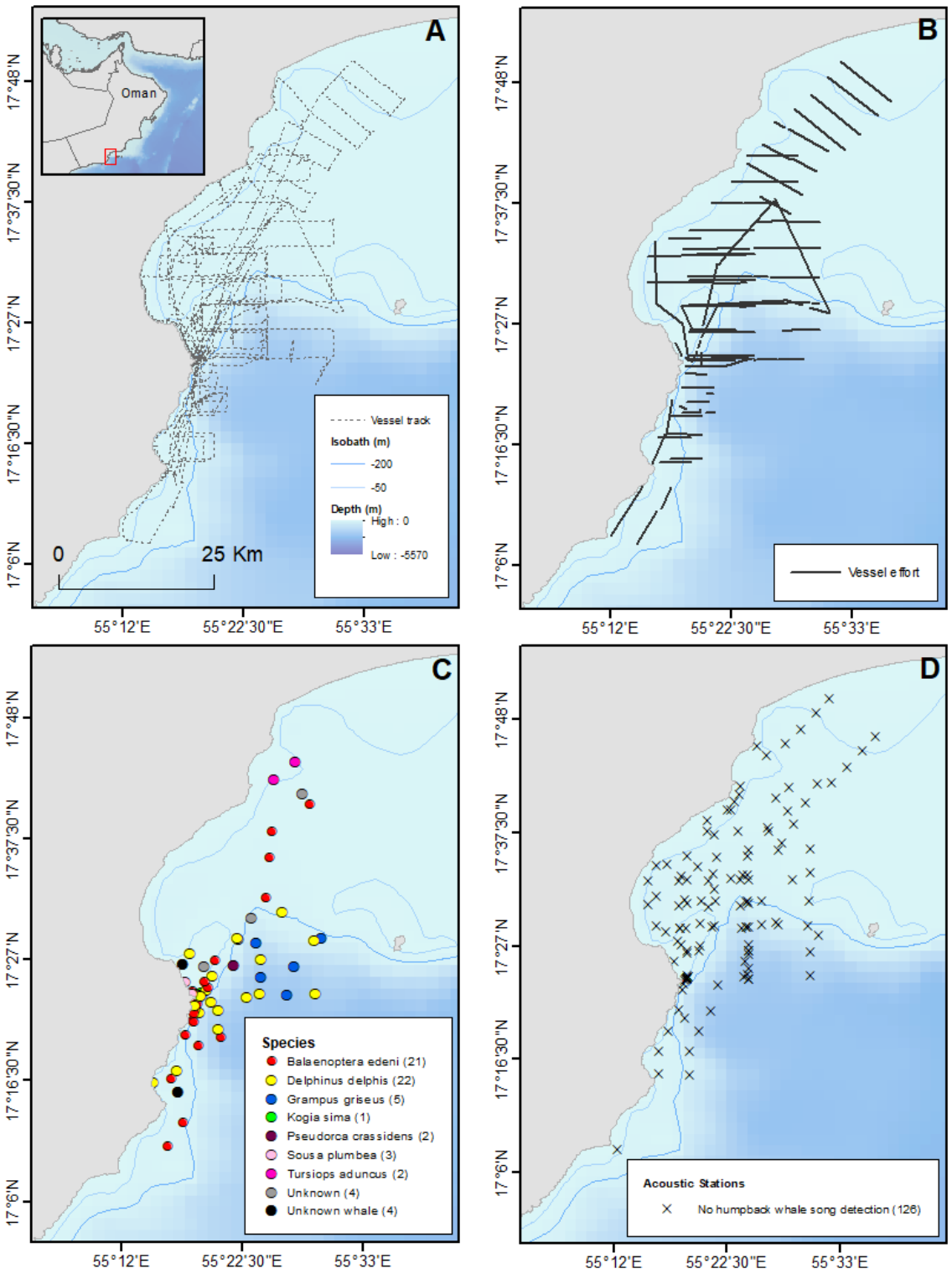

Figure 1. A) Vessel tracks of surveys conducted in the Hallaniyats Bay area between March 10-22nd, 2021. B) On-effort portions of track. C) cetacean sightings documented during the survey. D) locations of 5-minute-long hydrophone drops to listen for humpback whale song (which was never detected during the survey).

On the 11th of March, a Bryde's whale mother-calf pair was encountered and their body length and condition measured using the UAV. The mother was measured to be 11.44m in body length and the calf 4.96m (43.4% of maternal length), (Figure 2). Both animals were widest around 40-45% body lengths from the rostrum, which equalled 1.31m (11.5% of body length) and 0.67m (13.5% of body length) in absolute width for the mother and calf, respectively. Since no baseline information on body condition of Bryde's whales exists, the relative body condition of the animals could not be estimated.

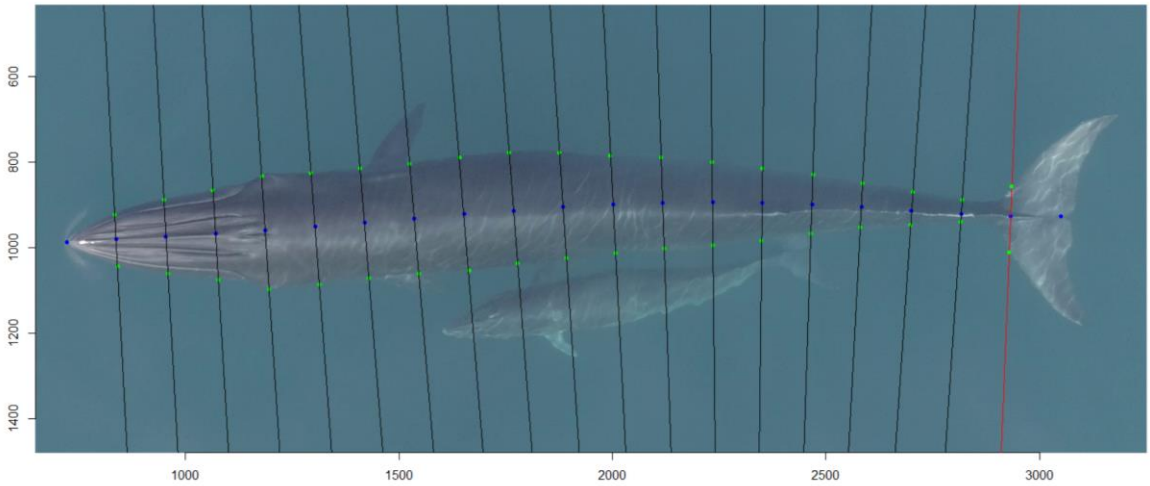

Figure 2. Still image of Bryde's whale mother and calf, used to measure the body length of the animals (i.e. the mother) using the custom written script in R (Christiansen et al. 2016). The blue dots indicate the centre of the body axis from the tip of the rostrum to the notch of the tail fluke, used to measure body length, whereas the green points indicate the body widths at the different width measurement sites (black lines). Image supplied courtesy of In Focus Oman and Obsessively Creative.

SoundTrap Passive Acoustic Recorder

The Sound Trap ST500 unit was successfully recovered on 14th March 2021 after 373 days in the water. The acoustic release functioned properly without exception and the unit floated to the surface emerging near to the deployment waypoint. Fouling was minimal, and there were no signs of abrasion or damage to the unit. Preliminary screening of the recovered data indicated that the hydrophone on the ST500 failed on 6th October 2020 after a period of 214 days of data collection. Due to field constraints, only a limited number of samples were able to be reviewed to assess and validate the acoustic data that was recorded during the first 214 days of the deployment. The review indicated that one month before the failure on 6th September, the recorder appeared to be functioning normally; at midnight on 6th October, there was some static observed likely related to the impending hydrophone failure, but the data still appeared useable; at 13:00 on 6th October, the recording was saturated with static and at 14:08 the hydrophone failed but the recorder continued to sample blank data. Starting on 24th December 2020 performance of the unit deteriorated indicating battery drain below the power threshold needed and the recorder stopped working due to power loss by 9th January 2021. The deployment nevertheless is expected to provide 2562 hours of useable acoustic data collected at a 50% duty cycle over 214 days.

DISCUSSION

Combining funds from the IWC-supported ASHW health assessment study and blue whale acoustics project with additional logistical and financial support from a local company (In Focus Oman), provided support for a total of 21 operational days for this survey (including mobilisation). Despite initial pandemic-related logistical problems with

mobilisation, the team was able to document 63 sightings of seven species, conduct 126 hydrophone drops and recover and acoustic gear during the 13 days it was possible to be on the water.

Arabian Sea Humpback Whales

The March 2021 survey is the first time that a field survey conducted in the Hallaniyats bay in March has failed to visually or acoustically detect humpback whales, (Minton et al. 2011; Baldwin et al. 2011; Willson et al. 2012; Willson et al. 2013; Willson et al. 2014; Willson et al. 2015; Cerchio et al. 2016). The failure to encounter and sample humpback whales meant that many of the objectives proposed in the IWC-funded ASWH health assessment project could not be met. The change in distribution for 2021 is a also a concern given prior evidence that indicates it is critical habitat (Minton et al. 2011; Corkeron et al. 2011; Willson et al. 2015; Willson et al. 2018). At the same time, the apparent 2021 anomaly also offers an opportunity to explore new questions about the primary drivers of the distribution and movements of ASHW.

Distribution of other populations of humpback whales are thought to be driven primarily by feeding opportunities when they are at high latitudes and by habitats suitable for activities associated with reproduction when at low latitudes (e.g. Clapham, 2000; Friedlaender et al., 2006; Santora et al., 2010; Bejder et al., 2019). The ASHW breeding season is thought to occur between early January and to late May based on foetal length data collected during Soviet whaling operations (Mikhalev, 1997; Minton et al., 2011). Prior acoustic monitoring supports these observations, with singing activity documented from November through May during the 2011/2012 and 2012/2013 seasons (Cerchio et al. 2016). Therefore, March should fall well within the period that activities related to reproduction (singing, mating, calving and nursing), would be expected to be driving humpback whale distribution in Oman.

Aggregation at major breeding grounds has also been documented as a possible factor influencing shifts in humpback whale distribution away from previously important breeding grounds after population depletion (e.g. Clapham and Zerbini, 2015). The Hallaniyats bay area was previously characterised as an area with a higher proportion of males (Minton et al . 2011) and an area subject to consistent detection of song detection between years during the breeding season (Minton et al. 2011; Willson et al. 2012; Willson et al; 2013; Cerchio et al. 2016). However, important ASHW habitat documented to the north in the Gulf of Masirah is also an area well documented for song detection, although with near parity of males and females (Minton et al. 2011). As such, it is possible that larger aggregations of whales engaged in song in other parts of the population's range are a driver behind relocation of whales away from the Hallaniyats Bay area.

However, in a population that does not undertake migrations between high latitude feeding grounds and low latitude breeding grounds, multiple factors other than breeding may be driving distribution at the same time. Humpback whales are known to take advantage of feeding opportunities when on migration or breeding grounds, and certain cohorts of populations may forgo migrations to breeding grounds in favour of feeding opportunities (e.g. Best et al., 1995; Barendse et al., 2010). Feeding has also been observed in previous years in the Hallaniyats Bay, sometimes concurrent with breeding related displays such as singing and competitive behaviour (Baldwin et al. 2011). Satellite telemetry data has also revealed that ASHWs switch between nearshore coastal areas and offshore areas (for suspected foraging) during the winter period. As such it is possible that foraging opportunities outside of the study area took precedence over the historical fidelity to the area during breeding season.

Changes in humpback whale distribution may also be linked to other oceanographic drivers. For example, a study of breeding habitat around New Caledonia found an inverse relationship between encounter rates and sea surface temperature. Preliminary review of sea surface temperature data for March 2021 shows water temperatures off Dhofar (and much of Oman's EEZ) were between 1.5o C and 3o C warmer than the average from previous years[1] .

[1] (https://earth.nullschool.net/#2021/03/16/1200Z/ocean/surface/currents/overlay=sea_surface_temp_anomaly/orthographic=-305.32,12.92,1667).

On March 21st, 2021 data from this archive documents sea surface temperature in the bay at >27oC. This is close to the upper limit of 28oC documented for breeding grounds (Rasmussen et al., 2007; Derville et al., 2019).

The 2021 temperature anomalies could also be linked to prey availability. As such we believe it will be valuable to look in more detail at the oceanographic conditions that may be driving ASHW distribution. This will be imperative to understanding the implications of climate change and rapid ecosystem state change currently occurring in the North Indian Ocean (Goes et al. 2020). These changes are related to the weakening of the winter monsoon with stratification of the ocean resulting in the expansion of the oxygen minimum zone, denitrification above the oxygen minimum zone and increased occurrence of algal blooms that drive oxygen depletion and threaten the productivity of fish resources.

Bryde's Whales

The morphometric measurements of the Bryde's whale mother-calf pair were the first obtained in the Arabian Sea and demonstrate the potential of using this technique to study the bioenergetics of this species. It should however, be noted that during 21 Bryde's whale encounters during the survey, we were only able to obtain good quality measurement on one of these occasions. Whilst poor weather conditions prevented UAV data collection on some of these occasions, even when weather conditions were favourable, the evasive behaviour of the whales made UAV measurements very challenging. Still, given the value of obtaining data on Bryde's whale body condition, especially in relation to calf size and growth, we recommend that UAV body condition measurements are collected for this species on an opportunistic basis in the future, using a Phantom 4 or similar model that can be quickly deployed (e.g DJI. Phantom 4) to maximize the chances of success.

Acoustic Monitoring

The funding provided by the IWC allowed the recovery of acoustic data from the first deep-water acoustic monitoring to take place off the coast of Oman. Despite the early cessation of recording, the unit successfully collected seven complete months of acoustic data that will provide valuable insights into the presence of blue whales and other baleen whales in the Dhofar area between March and October. Based on previous recording effort from 2011/2012, blue whales were present and singing in this area from December until the end of May, but no detections were made from June to October (Cerchio et al. 2020). The 2012 recording effort was conducted from a very shallow deployment on the shelf just above the slope drop-off, where sound propagation loss would have severely limited the detection range of the recorder for whales singing off the shelf in deep water. Therefore, we expect to have a far more complete and accurate record of blue whale presence and singing activity during this period from March to May, as well as higher confidence of detecting presence from May to October if they are present and singing. Furthermore, based on the 2012 data, it is expected that humpback whales were present and singing within detection range of the recorder until mid-May; therefore, this will allow a comparison between years of late season humpback whale singing activity, and assess any differences between the 2020 breeding season and previous years.

Initial plans to recover the acoustic unit in September/October 2020 had to be abandoned due to pandemic travel restrictions which were not lifted until early 2021. Had a recovery been achieved in September or October, it is likely that the fault that caused the cessation of recording would have been discovered and ameliorated, and redeployment at that time would have strongly increased the likelihood of collecting an acoustic record through the Boreal winter and a complete year sample. This travel constraint therefore has compromised the data we were able to obtain for the 2020/21 winter season and can be considered an impact of the COVID-19 pandemic on this research. The Ocean Instrument hydrophone element (which is detachable from the ST500 unit) that failed during this deployment, along with a second hydrophone that was manufactured at the same time and therefore may have the same suspected fault, have been returned to the manufacturer for a rebuild. It is anticipated these will be returned to Oman by the end of

April to provide an opportunity to redeploy at least one of the units prior to the start of poor sea conditions during the south west monsoon (starting at the beginning of May).

We consider that the use of moored acoustic recorders to detect inter-annual and distributional shifts in humpback whale song/presence remains as important for this imperilled population during the breeding season, as it does for further discovery on the ecology of blue whales. As such it seems imperative to ensure greater redundancy in the Dhofar area through the deployment of two units in April/May 2021, and plan for units to be recovered and redeployed in October 2021 to ensure deep water acoustic records can be acquired for the winter season. Given the uncertainty of reasons behind distributional shifts of ASHWs and the potential link to climate change we also recommend additional efforts to find funding for the concurrent deployment of recorders in the Gulf of Masirah, given this area is considered to be as important as a potential breeding site for ASHWs in the western Arabian Sea.

Recommendations

In summary we recommend that the following is considered for research and conservation management planning for large whales in the western Arabian Sea:

- continued support for deployment of passive acoustic recording units in the Dhofar for the monitoring of blue whales and ASHWs;
- simultaneous deployment of passive acoustic recorders in multiple known or predicted 'hotspots' in ASWH range including the Gulf of Masirah, the southwest coast of India and Gulf of Kutch;
- systematic analysis of ASWH range and tracking data together with oceanographic variables to develop a dynamic modelling approach to ASHW distribution, as well as forecasting the implications of climate change on distribution and prey availability; and
- continued UAV body condition work to understand whether there is seasonal and/or annual variation in body condition indicative of fluctuations in feeding opportunities/prey availability.

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