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# Oman research update; documenting cetacean diversity and blue whale feeding habitat in Dhofar, southern Oman

Andrew Willson, Gianna Minton, Tim Collins, Suaad al Harthi, Maia Sarrouf Willson, Salvatore Cerchio, Gill Braulik and Robert Baldwin

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# Oman Research Update; documenting cetacean diversity and blue whale feeding habitat in Dhofar, southern Oman

A. Willson[1,2,3], G. Minton[4],T. Collins[5], S. Al-Harthi[6], M. Sarrouf Willson[6], S. Cerchio[7], G. Braulik[8] C. Curry[1] and R. Baldwin[1]

[1]*Five Oceans Environmental Services, PO Box 660, PC131, Ruwi, Sultanate of Oman*
[2] *Environment and Sustainability Institute, University of Exeter, Penryn Campus, Cornwall, UK*
[3]*Centre for Ecology and Conservation University of Exeter, Exeter, UK*
[4]*Megaptera Marine Conservation, Netherlands*
[5]*Wildlife Conservation Society, Ocean Giants Program, 2300 Southern Blvd, Bronx, NY 10460-1099, USA6*
[6]*Environment Society of Oman, PO Box 3955, PC 112, Ruwi, Sultanate of Oman*
[7]*New England Aquarium, USA*
[7]*Downstream Research & Conservation Ltd*

**ABSTRACT**

Cetacean research has been conducted in Dhofar, southern 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). The research has revealed the Hallaniyats Bay (including our study site measuring approximately 10,000km$^2$) to be a habitat of importance for reproductive and foraging related behaviours. Simultaneously the field surveys have revealed high cetacean diversity in the area, with over 18 species documented at the site, out of a total of 22 species known for the Arabian peninsula between 2003 and 2016. Short opportunistic surveys conducted March 2018 to April 2019 continue to provide evidence of the ecological importance of the area for a diverse array of species, including several species of large baleen whales (including humpback whales, Bryde's whales, and blue whales) as well as a range of large, medium and small odentocetes. Most recently, in April 2019, blue whales were observed over a three-day period, engaged in behaviour associated with feeding. As well as documenting this important ecological event the team was able to collect photographic, tissue and faecal samples that are expected to help resolve issues related to taxonomy and population structure of blue whales in the northern Indian Ocean. The high levels of cetacean diversity and the regular occurrence of species of scientific and conservation interest documented within a recent Important Marine Mammal Area workshop suggest that the area warrants conservation management attention to maintain its current 'near-wilderness' state.

**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.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, (Minton et al. 2011; Baldwin et al. 2011; Willson et al. 2012; Willson et al. 2013; Willson et al. 2014; Willson et al. 2015; ESO, 2018; Five Oceans Environmental Services, 2019; Cerchio et al. 2016).

Whilst a selected study site (Figure 2) has been targeted for ASHW research since 2001, incidental encounters of other species found within the area is of growing interest to the research community. To date a total of 18 species has been reported out of a total of 22 documented in the Arabian region. To date the list includes; ASHW, common dolphin (*Delphinus delphis)*, common bottlenose dolphin *(Tursiops truncatus)*, spinner dolphin (*Stenella longirostris)*, Indo-Pacific bottlenose dolphin (*Tursiops aduncus)*, rough-toothed dolphin (*Steno bredanensis)*, Indian Ocean humpback dolphin (*Sousa plumbea*), Risso's dolphin (*Grampus griseus*), false killer whale (*Pseudorca crassidens*), killer whale (*Orcinus orca*), dwarf sperm whale (*Kogia Sima*), melon-

headed whale (*Peponocephala electra*), short-finned pilot whale (*Globicephala macrorynchus*), Cuvier's beaked whale (*Ziphius cavirostris*), sperm whale(*Physeter macrocephalus*), Bryde's whale (*Balaenoptera edeni*), humpback whale ( *Megaptera novaeangliae*)and blue whale (*Balaenoptera musculus),* (Minton et al. 2011; Baldwin et al. 2011; Willson et al. 2012; Willson et al. 2013; Willson et al. 2014; Willson et al. 2015).

The documented species assemblagereflectsa diversity of habitat preferences (deep and shallow water), prey preferences and differing trophic levels (zooplankton through to mammal eating killer whales) and morphology (based on total length). The area surrounding the Hallaniyats Bay and islands is characterised by diverse bathymetric features and oceanographic features. The transition between the steep shelving area and the continental shelf are considered influential factors in supporting a high diversity of species. In the west of the study area the physical features are characterised by a narrow continental shelf and sandy dominated substrate fringed by continuous stretches of sandy beaches. This area is considered important humpback dolphin habitat (Minton et al. 2011) and breeding and foraging related area for Arabian Sea humpback whales (Willson et al; 2012;Willson et al. 2015; Willson et al. 2016; Cerchio et al. 2016). The coast from Mirbat to Hasik the coastline predominated by rocky shoreline punctuated with small sandy bays, and a narrow continental shelf which falls away to to depths greater than 1000m. This central sector of the area is associated with sightings of deep diving species (as documented in more detail below). Approaching the town of Hasik in the north of the Dhofar area the steep shelving bathymetry gives way to the broad continental shelf of the Hallaniyats Bay known to be an important area for humpback whales.

The habitats associated with these seafloor features are set within the oceanographic context of nutrient-rich temperate conditions found within a tropical climate (Banse,1987; Burkhill, 1999; Kindle and Arnone, 2001; Sheppard *et al.*, 1992). These conditions are generated by upwelling driven by the south west monsoon in the summer (peak between July and August) which drives sea-surface temperatures as low as 16-17 ˚C. Phytoplankton (chlorophyll) levels on the Arabian Sea coast can increase from 0.1g C m–2 d–1 during the inter-monsoonal period to above 1.1g C m–2 d–1 (Brock and McClain, 1992) during the summer season. It is these conditions that have been linked to providing the conditions for production of an abundance of cetacean prey (e.g. Papastavrou and Van Waerebeek, 1997) for species found in Oman.

Methods used during ASHW research surveys have also been applied to other encountered species. Biopsy sampling of Indian Ocean humpback dolphins (*Sousa plumbea*) from the area has contributed to a global review of taxonomy, population identity and status (Mendez et al. 2013, Braulik et al. 2015). The species is now listed as Endangered on the IUCN Red List of Threatened Species (Braulik et al., 2017). Similarly, regional samples of common and bottlenose dolphins are being used to address questions related to the biogeographic structure of populations of these species within the Indian Ocean (Gray et al. in prep). Blue whales have previously been documented in the area (Minton et al. 2011, Willson et al, 2012, Willson et al, 2013) and in 2018 a new blue whale 'song-type' was described from data collected with anchored passive acoustic monitoring units deployed during 2012 and 2013 (Cerchio et al 2018). This finding raises questions concerning the population identity of regional blue whales, which remains un-resolved (Branch et al. 2018).

Beyond the research potential, the marine mammal ecology in the area is considered a valuable component of Oman's natural heritage. In March 2019 a large extent of the Dhofar coastline was identified as a candidate Important Marine Mammal Area (cIMMA) (https://www.marinemammalhabitat.org/record-number-of-immas-awarded-in-west-indian-ocean-and-arabian-seas/) during a workshop for the Western Indian Ocean and Arabian Seas held in Salalah, Oman. The cIMMA proposal included several IMMA selection criteria, including population vulnerability, aggregations of several species, areas that are important to the lifecycle of some species, migration routes, distinctiveness and diversity.

Collecting data for endangered ASHWs has served as a primary objective for continued surveys in the area. However, a lack of funding since 2017 has precluded further dedicated fieldwork on the population, or in fact on any other cetacean taxon in Oman. As a result the research team has resorted to a more opportunistic survey approach that limits to data collection to short periods of time as funds allow. These constraints, and the nature of the platforms of opportunity, reduce the spatial extent of surveys and alter the prioritisation of field objectives from a focus on ASHW to maximising encounter time and data collection with all species encountered. Here we report on the results of a series of four short vessel-based field surveys conducted in the Hallaniyats Bay within a 13-month period, and discuss the implication for future research priorities with respect to baleen whales and conservation management in consideration of species diversity.

## METHODS

*Boat surveys*

Four short 3-5 day long boat-based surveys were conducted from a base camp at Ras Hasik in the Hallaniyats Bay between March 2018 and April 2019 (Figure 1). Surveys were conducted for the primary purposes of encountering ASHWs in the period between November and April coincident with the breeding season (Mikhalev 1997; Minton *et al.*, 2010; Corkeron *et al.*, 2012, Cerchio et al, 2016). The secondary objective was to document the distribution and diversity of other cetacean species in the area. Observers worked from a 6.5 m rigid hulled inflatables (RHIB) and searched for whales following saw-tooth transects. Survey methods were consistent with previously used protocols (Minton *et al.*, 2010; Corkeron *et al.*, 2012; SC/65a/SH06). Observers were also stationed on a cliff-top location above the base camp and conveyed sightings to the survey vessels via VHF.

During all surveys an omni-directional dipping hydrophone (High Tech Inc., HTI-96) was deployed at <10m depth to detect ASHWs and guide research vessels towards singing ASHW males. For the most recent survey in April 2019 a dual channel hydrophone was deployed at a depth of 50m (Cetacean Research Technology, C-56 and C75) with the objective of verifying vocalisations from sightings of baleen whales in close proximity to the research vessel. Biopsies were collected using a crossbow and modified dart (Lambertsen 1987). Sieves were used for opportunistic collection of sloughed skin and faecal material. For all sightings cetaceans were approached and followed with the primary objective of capturing photographic data that will support subsequent development of photo-ID catalogues. Sightings, sample and photographic records are now archived into an on-line 'Fluke-book Catalogue' (See document submitted to the SH subcommittee of this meeting for more detail). Processing of sighting and encounter records is also undertaken using this online platform.

## RESULTS

*Survey Effort*

During four separate survey periods a total of 1454.6 km was covered in almost 120 hours on the water resulting in 517 km and 8 hours and 42 minutes of effort (Table 1). Survey effort was focused around the Ras Hasik area based on proximity to the vessel anchorage. Acoustic effort resulted in recordings from 100 stations, each with a listening time of at least 5 minutes equating to a minimum of 8 hours and 20 minutes of acoustic recordings. The acoustic effort includes occasions when the hydrophone was purposefully placed in the water in close proximity to sightings of blue and Bryde's whales. These data have not yet been processed and spectrograms will be reviewed to identify vocalisations from these species.

Table 1 Summary of total and effort based distance and time at sea metrics for surveys between November 2018 and April 2019.

| Survey Period | Effort Time (hh:mm) | Effort Distance (km) | No. of Acoustic Stations | Acoustic Record Time (hh:mm) | Total Survey Time (hh:mm) | Total Survey Distance (km) |
|---|---|---|---|---|---|---|
| Nov 2018 | 06:10 | 119.33 | 20 | 01:40 | 40.45 | 563.53 |
| Mar 2018 | 12:51 | 232.36 | 44 | 03:40 | 31.15 | 303.32 |
| Mar 2019 | 07:15 | 43.08 | 18 | 01:30 | 29.19 | 424.36 |
| Apr 2019 | 06:26 | 122.46 | 18 | 01:30 | 19.17 | 163.39 |
| Total | 08:42 | 517.23 | 100 | 08:20 | 119.96 | 1454.60 |

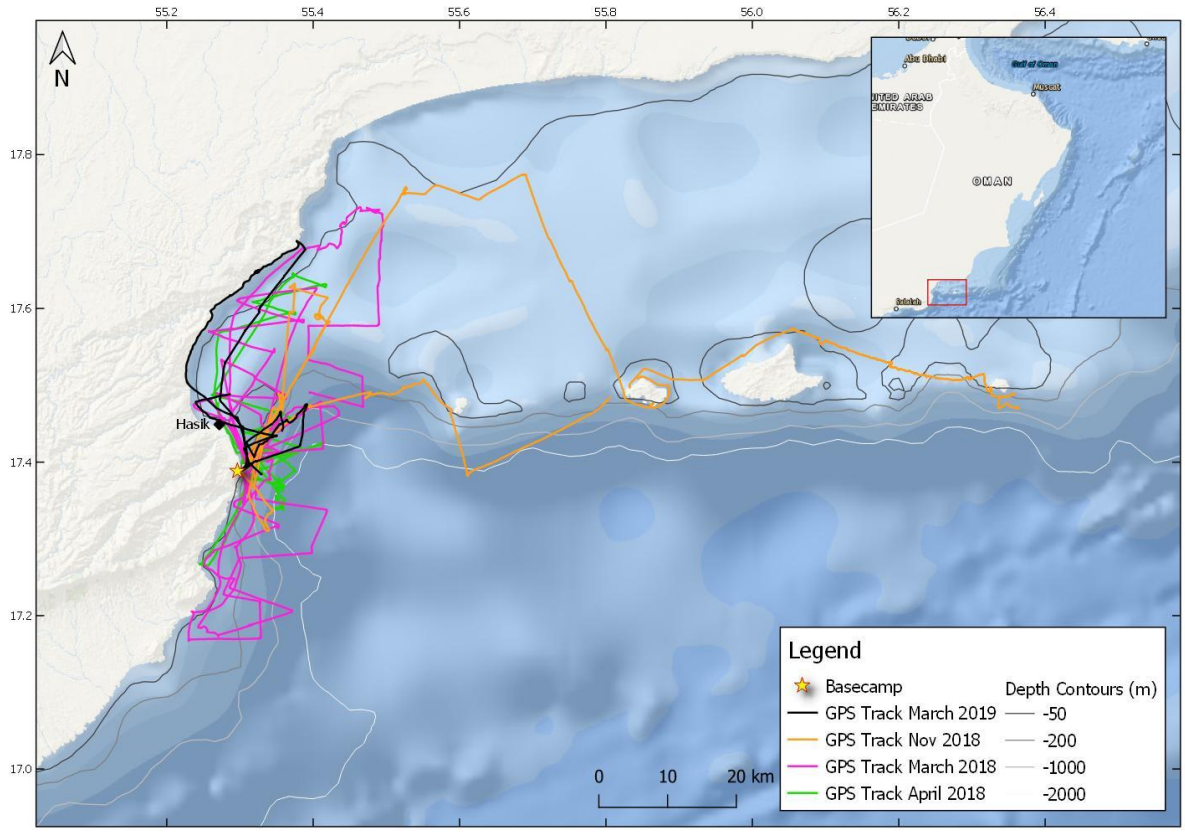



Figure 1. Vessel tracks of surveys conducted in the Halaniyats Bay area between March 2018 and April 2019

*Sightings and Sample Collection*

A total of 54 sightings were made during the course of the four surveys representing 11 species, (Table 2). Bryde's whales were the most frequently sighted species (n=18), with 11 of these sightings occurring during March 2018. Species which have been rarely documented at this site include dwarf sperm whales (two previous sightings), Cuvier's beaked whale (one previous sighting) and the sighting of blue whales (four previous sightings) (OMCD, 2019). A review of sighting locations (Figure 2) reveals a main cluster of sightings where effort was focused within 2km of the base camp, and includes Bryde's whales, humpback dolphins, bottlenose dolphins and another cluster within 10km of the north west of the camp positioned within the range of effort and along the shelf break including dwarf sperm whales, Cuvier's beaked whales, Bryde's whales and humpback whales.

Table 2 Summary of sightings records from surveys conducted between March 2018 and April 2019

| Species Encountered | Mar 2018 | Nov 2018 | Mar 2019 | April 2019 | Survey Total |
|---|---|---|---|---|---|
| *Balaenoptera edeni* - Bryde's whale (Small) | 11 | | 2 | 5 | 18 |
| *Megaptera novaeangliae* - Humpback whale | 3 | 5 | 1 | | 9 |
| *Delphinus delphinus* - Common dolphin | 5 | 2 | 1 | | 8 |
| Unknown | 2 | 1 | | 1 | 4 |
| *Balaenoptera musculus indica* - Blue whale | | | | 3 | 3 |
| *Sousa plumbea* - Humpback dolphin | | | 1 | 2 | 3 |
| *Balaenoptera* sp. - Baleen whale | 1 | | 1 | | 2 |
| *Kogia sima* - Dwarf sperm whale | | | | 2 | 2 |

| | | | | | |
|---|---|---|---|---|---|
| *Pseudorca crassidens* - False killer whale | | 1 | | 1 | 2 |
| *Tursiops aduncus* - Indian Ocean bottlenose dolphin | | | | 1 | 1 |
| *Ziphius cavirostris* - Cuvier's beaked whale | 1 | | | | 1 |
| *Tursiops truncatus* - Common bottlenose dolphin | | 1 | | | 1 |
| Grand Total | 23 | 10 | 6 | 15 | 54 |

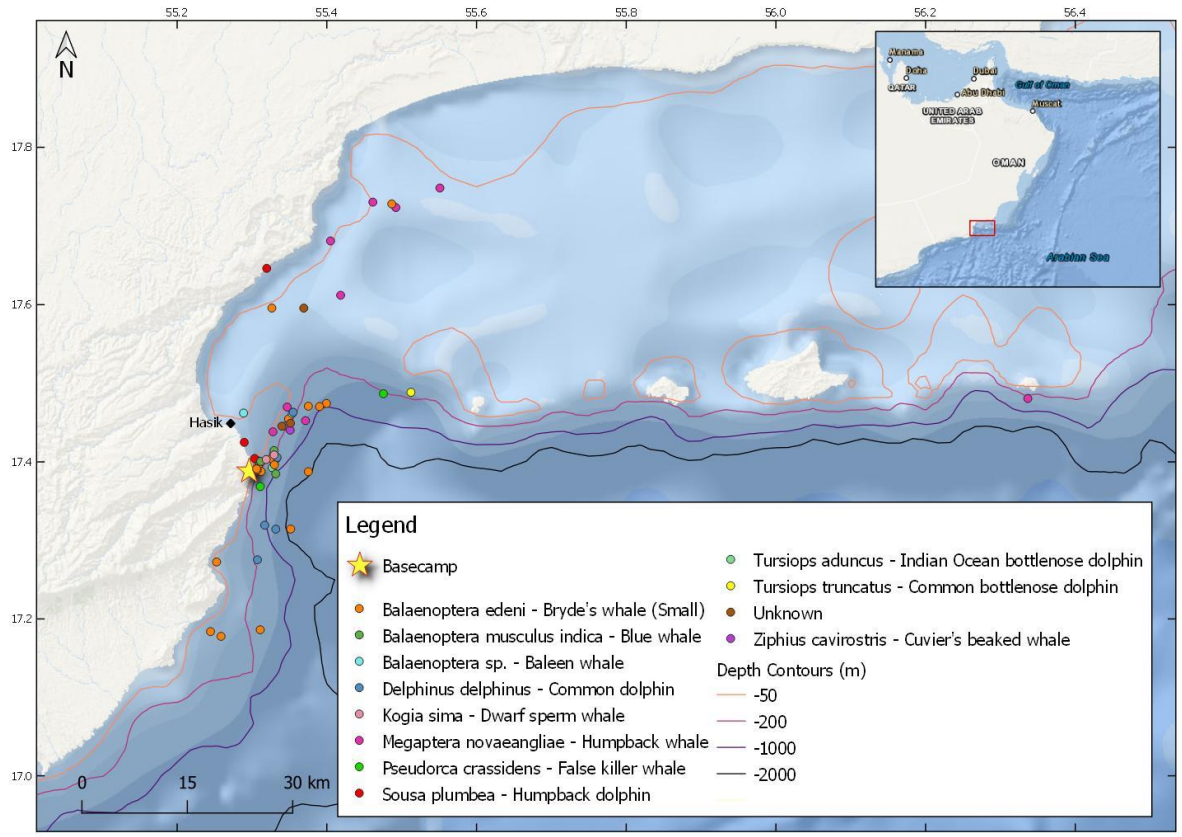



Figure 2. Species encountered in the Hallaniyats Bay region, southern Oman between March 2018 and April 2019.

Figure 3 Photos of deep diving species encountered in the study area, Kogiasima (left) encountered on 3-April 2019 and *Ziphius cavirostris* (right) encountered on 9-March 2018.

Humpback whales were observed in the area during three of the surveys, and all included encounters with animals previously identified in the Oman humpback whale Photo-ID database (Table 3). Three of the four individuals were some of the most frequently encountered whales in the catalogue, with the vast majority of sightings having been documented in the Dhofar study site, and within 10km of the Hasik base camp (for example O10-001 was encountered on 29 occasions since its first sighting in the area in 2010). Figure 4depicts the high site fidelity for these animals. ASHW song was detected on five occasions during the November 2018 survey and two faint detections in March 2018 and feeding was observed in the north of the study area in December 2018.

Table 3: Resighting frequency count of humpback whales observed in the Hallaniyats Bay area between March 2018 and April 2019.

| Individual | Nickname | Sex | Date | Latitude | Longitude | Date first observed | Number of previous observations |
|---|---|---|---|---|---|---|---|
| OM02-003 | Aswad | Male | 09/03/2018 | 17.7235 | 55.4923 | 24/02/2002 | 18 |
| OM02-003 | Aswad | Male | 30/11/2018 | 17.4384 | 55.3280 | | |
| OM02-003 | Aswad | Male | 01/12/2018 | 17.4698 | 55.34703 | | |
| OM03-004 | Quasimodo | Female | 01/12/2018 | 17.4698 | 55.3470 | 16/05/2003 | 10 |
| OM00-010 | Spitfire | Male | 01/12/2018 | 17.6120 | 55.4185 | 15/10/2000 | 3 |
| OM10-001 | Scooby | Male | 03/12/2018 | 17.4807 | 56.3367 | 04/03/2010 | 29 |
| OM00-010 | Spitfire | Male | 04/12/2018 | 17.7484 | 55.5511 | | |
| OM03-004 | Quasimodo | Female | 09/03/2019 | 17.4526 | 55.3715 | | |

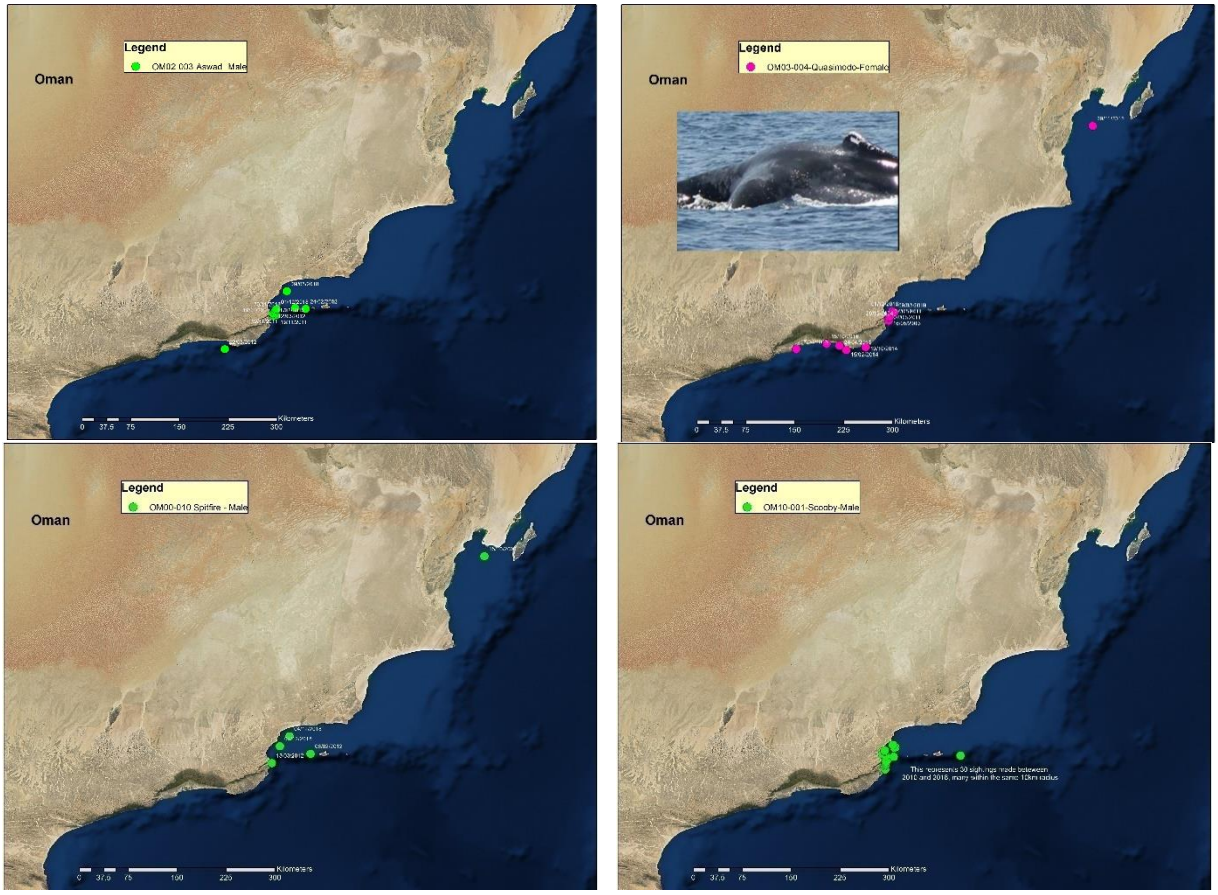
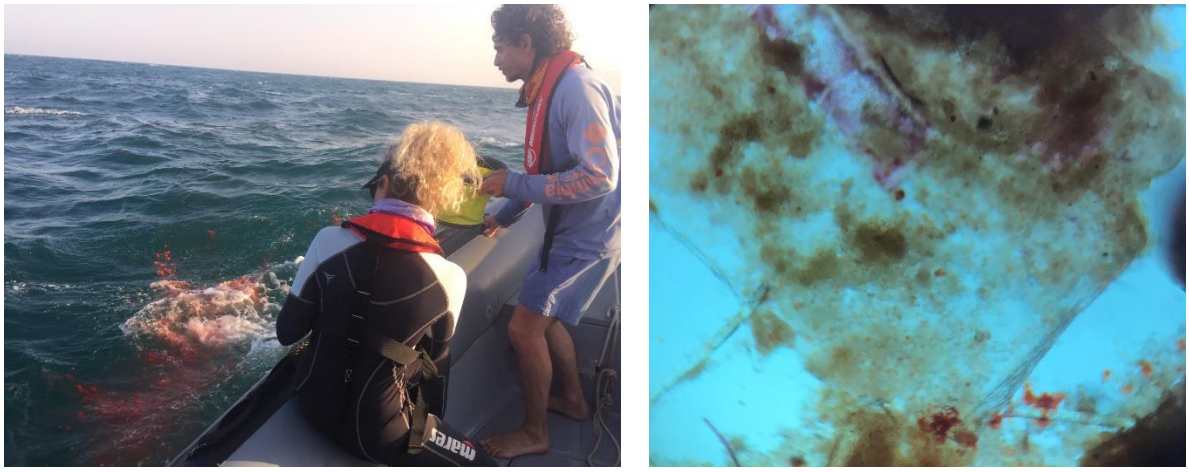


Figure 4 Maps of the sighting histories of the four ASHWs encountered during surveys conducted between March 2018 to April 2019:,OM02-003 (top left), OM03-004 (top right), OM00-010 (bottom left) and OM10-001 (bottom right).

Blue whales were observed on three consecutive days during the April 2019 survey. The whales were located by visual observations of tall blows initially made from the clifftop observation point above base camp. Photographs were taken of the flank, dorsal and flukes of blue whales. These images are yet to be processed for each sighting event. The intention is to prepare these for comparison to other archived datasets of blue whale images from the Oman and the wider Northern Indian Ocean.

Biopsy equipment was only used on two surveys. One *T. truncatus*, two *M.novaeangliae* and three *P. crassidens* tissue samples were obtained in November 2018. Five *B.musculus* tissue samples were obtained in April 2019 together with two faecal samples on separate days. Defecation was observed on three separate occasions and both faecal and biopsy samples await further analysis. During survey operations around blue whales the faecal material was obvious to the survey team given its bright orange pigmentation visible at the surface in the wake of the whale (Figure 5 (a)). No replicate (blank) sea water samples were taken at time of sampling faecal material. Preliminary observation of these Oman samples under a microscope reveals the presence of abdominal segments, antenna and/or pereipods that are expected to be associated with the zooplankton prey items of the super-order Eucarida.



a) b)

Figure 5 Faecal material observed in water immediately after defecation (a) and magnified image (x10) of faecal material from the sample (b)

Blue whales were predominantly observed fluking at the end of a bout (surface) period. During biopsy attempts observers kept a strict watch on time and GPS track of the boat in order to anticipate the best location to position the boat to attempt a close approach on the subsequent bout. During the three-day period of observations the time period between an individual leaving the surface and arriving back at the surface was noted to be between 11 and 15 minutes. Due to unfavourable sea states much of the time, and consideration of the potential influence of the boat on whale behaviour only a short opportunistic attempt was made to document whale dive behaviour whilst the boat remained static (Table 4). During the data collection process of dive behaviour a calm sea state prevailed (Beaufort Force 1) which allowed for the best opportunity to detecting the first surfacing of a single whale and considering no new whales would move in or out of the observation site. Records reveal bout durations of between one and three minutes, and dive times between three and fourteen minutes.

Table 4 Dive behaviour recorded for a blue whale during static observations from the survey vessel on 3/4/2019.

| First observed at surface (local time) | Last observed at surface (local time) | Surfacings per Bout | Bout Duration (min) | Dive Duration (min) |
|---|---|---|---|---|
| 14:03 | 14:06 | 13 | 00:03 | No Data |
| 14:09 | 14:10 | 5 | 00:01 | 00:03 |
| 14:23 | 14:27 | 15 | 00:04 | 00:13 |
| 14:37 | 14:40 | 9 | 00:03 | 00:10 |
| 14:44 | 14:47 | 9 | 00:03 | 00:04 |
| 15:01 | 15:04 | 9 | 00:03 | 00:14 |
| 15:15 | 15:17 | 4 | 00:02 | 00:11 |
| 15:25 | No Data | 3 | No Data | 00:08 |

**DISCUSSION**

The recent observations of ASHWs confirm their continued presence in the Dhofar study area, and confirm their site fidelity. The fact that relatively few ASHW observations were documented during the roughly 17 days of fieldwork, coupled with the fact that the four observed individuals had all been previously identified (most with 10 or more encounters over the past 19 years), provides further evidence that the population of ASHW off the coast of Oman is small, and of severe conservation concern. The population clearly merits ongoing monitoring, with an emphasis on health assessments and continued photo-identification to document health, reproductive status, and population size and trends.

In addition, these short opportunistic research trips act to allow the local field team to maintain skills and obtain baseline data that will inform more targeted and complex future research to investigate population health proposed within new research priorities for 2020. The change in field objectives during the 2018/2019 period forced by a lack of funding has also made the research team aware of the potential to focus on other species of conservation concern, particularly Bryde's whales, about which little is known but are frequently observed, and blue whales.

The regular 'fluke-up' dive behaviour of blue whales witnessed during April 2019 is consistent with that reported from a foraging aggregation site in southern Sri Lanka where animals observed during focal follows fluked-up 55% of the time (de Vos et al, 2013). Elsewhere 'fluke-up' dive behaviour is considered unusual for blue whales and considered a trait of specific individuals and observed only 15-20% of the time (COSEWIC, 2002). The same study in Sri Lanka also took a modelling approach to evaluating the dive characteristics, calculating the inter breath interval for deep dives of 640 seconds (SD=214). Our observations of whales engaged in deep diving behaviour (after fluking up) of between 10-14 minutes (600-840) fits within the upper range of the frequency distribution for this dive behaviour. Subsequent studies on the foraging site in southern Sri Lanka correlated presence of dense swarms of potential prey within the top 300m of the water column and above the deep scattering layer as detected by a hydroacoustic survey (de Vos et al. 2018). Genetic analysis of faecal samples collected from the same site found 87% of DNA amplicons of prey extracted from faecal material were sergistid shrimp with euphausids only representing 8% of sample material. Robust assessment of faecal material as performed by de Vos (2018) should also be performed on the samples from Oman to further understand of target prey for blue whales in the region.

Given the similarities in comparison with results of Sri Lankan studies, our observations of blue whales at the Hasik site in April 2019, includingthe evidence of defecation, fluke-up behaviour and dive times are indicative of foraging. At the time of writing (April 2019), further records of blue whales exhibiting the same foraging behaviour over a five day period have been reported from observers 100km to the east of the study site described here. Information presented in this manuscript is considered important in its contribution to understanding the occurrence and ecology of blue whales in the NIO. Soviet whaling records from two fleets operating in the Arabian Sea during the months of November and December between 1963 and 1965 report that

68% of blue whales from the Aden-Omani coasts had full to moderately full stomachs and that their level of blubber thickness was similar to that of pygmy blue whales from sub-Antarctic feeding grounds in the same season (Mikhalev, 1996b). To date the at-sea sightings of blue whales off the southern coast of Oman are all from the March and April period. Recent acoustic data recorded in the Hallaniyats Bay from 2012 indicated an undescribed baleen whale song that was attributed to a previously unrecognized population of blue whales; if this song type is verified to be a blue whale, it would indicate that blue whales are in the area between the end of November and beginning of April (Cerchio et al. 2018).The presence of animals feeding in the western Arabian Sea during this time fits with a hypothesis proposed by Anderson et al. (2012) that predicts blue whales are expected to feed in the most productive areas during the summer SW monsoon (in the west Arabian Sea) and may then disperse more widely across the ocean basin to during other months of the year. The sighting locations are also situated within 15-20% prediction contours of habitat distribution models described by Redfern et al (2017).

To date efforts to understand the status of blue whales in the Indian Ocean have been hindered by lack of a reliable method to determine stock structure (Branch et al 2018). The taxonomy remains unresolved and North Indian Ocean animals have been assigned as both *B.musculus brevicauda* and more recently *B.m.indica* (Anderson et al. 2012) and calls have been made for taxonomic investigations (Ilangakoon & Sathasivam, 2012). Branch et al. (2007) notes that elevating a population to subspecies requires evidence of geographic isolation and biological features. Song types have been used to describe population structure from at least four areas in the Indian and western Pacific Oceans including the NIO (Sri Lanka song type), south-western Indian Ocean (Madagascar song type), south-eastern Indian Ocean (East Australia song type) and south western Pacific (New Zealand song type) (Samaran et al. 2013, Branch et al. 2018). The recent findings of Cerchio et al. (2018) suggest that blue whales in the NIO may be represented by two different song types, inferring potentially different populations separated between Oman/Arabian Sea and Sri Lanka/central Indian Ocean. The Sri Lanka song type has been recorded widely in the central north and south Indian Ocean, with pervasive detections and clear seasonal variation betweenrecorder sites at Diego Garcia and the central south Indian Ocean (470km NE and 350km SW of Amsterdam Island),suggesting migratory movement (Samaranet al. 2013). The "new" song type, which we tentatively refer to as the "Oman song type" in keeping with other nomenclature, was heard during an extended period off Oman (November to April) in addition to sparse detections off Madagascar during April and May (Cerchio et al. 2018). Therefore, the putative population that sings the Oman song type does range into the southwestern Indian Ocean; however, this song has not been reported before, and is therefore not a pervasive or prominent feature of baleen whale detections at any of several sites with extensive effort on blue whale acoustic detections (Samaranet al. 2010, 2013; Stafford et al. 2011). Therefore it is possible that the blue whales found off Oman represent a population that ranges in the western Indian Ocean and may be found predominantly in the Arabian Sea.

Mikhalev (2000) grouped the NIO population to an area north of 5˚ south based on body length and distribution of catches processed on two factory vessel operation in the IO between 1963 and 1965. Branch et al. (2018) developed a new model for population structure based on separation of catches according song, satellite tag data and fetal lengths, and supported the assessment with the inclusion of 470 additional foetus sample lengths. The results suggest that south west Indian Ocean Blue whales extend to south of 2˚ north (with synchronised conception to austral summer), and those north of 9˚ north (and 4 degrees north off India) describing the NIO group demonstrate a seasonal reproduction. However, the distribution of different populations based on song-type described above indicates a more complex situation with a significant degree of overlap between NIO and SIO populations.

The recent faecal samples (n=2) biopsy samples collected in Oman (n=5) together with stranding samples collected in Oman (n=3) and UAE (n=1) (Environment Society of Oman, 2018) now presents a valuable dataset for further evaluating aspects of regional blue whale population structure. This investigation would also complement the recommendations to increase temporal and spatial acoustic surveillance within the NIO (Cerchio et al. 2018) and help provide increased resolution to the modelled population structure surface described by Branch et al (2018). So far this stock definition approach is reliant on data from just three acoustic recorders located within the southern extent of the north Indian Ocean. There is also an improved opportunity to compare photographic records of blue whales from Sri Lanka and southern hemisphere catalogues with those taken in Oman. These can be used to further investigate the Arabian Sea transits proposed by Anderson et al (2012). Results of the acoustic analysis described by Cerchio et al (2018) suggests that the 2019 season may not

be exceptional for the occurrence of blue whales along the southern coast of Oman and alternative approaches should be employed to work towards a future ambition of conducting a status review. Given difficulties in resourcing ASHW research these ambitions may only be achieved with considerable support from new funding sources that cover a multispecies approach.

The use of opportunistic platforms to continue cetacean research despite a lack of dedicated funding has produced results that continue to demonstrate the importance of southern Oman as habitat for a diverse assemblage of marine mammals. These efforts have contributed towards conservation management initiatives including defining the relative importance of areas based on the criteria driven IMMA process and defining areas for special planning zones as part of Oman's National Spatial Strategy (Supreme Council for Planning, 2019).The authors propose that this work is considered in supporting the development of conservation management plans for cetaceans in the Sultanate and the wider NIO.

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## REFERENCES

Anderson, C. Branch, T.A., Alagiyawadu, A.N.O.M.A., Baldwin, R. and Marsac, F., 2012. Seasonal distribution, movements and taxonomic status of blue whales (*Balaenoptera musculus*) in the northern Indian Ocean. *Journal of Cetacean Resources and Management*, *12*(2), pp.203-218.

Baldwin, R. M. 2000. Oman's humpback whales (*Megaptera novaeangliae*) The Journal of Oman Studies 11 11-18.

Baldwin, R., and R. V. Salm 1994. Whales and Dolphins Along the Coast of Oman. Muscat Printing Press, Muscat.

Ballance, L.T. et al., 2001. Cetacean sightings around the Republic of the Maldives, April 199. *Journal of Cetacean Research and Management*, 3(2), pp.213–218. Available at:papers3://publication/uuid/8160F260-4E63-4E7E-B56A-9F2310BAEB0C.

Branch, T.A. et al., 2007. Past and present distribution, densities and movements of blue whales Balaenoptera musculus in the Southern Hemisphere and northern Indian Ocean. *Mammal Review*, 37(2), pp.116–175.

Branch T.Monnahan, C.and Sirovic, A. 2018. Separating pygmy blue whale catches by population. *Paper* SC/67B/SH/23 *presented to IWC Scientific Committee*.

Braulik, G.T. et al., 2015. Assessment of the conservation status of the Indian Ocean Humpback Dolphin (Sousa plumbea) Using the IUCN red list criteria. *Advances in Marine Biology*, 72, pp.119–141.

Braulik, G.T., Findlay, K.P., Cerchio, S., Baldwin, R.M. 2017. Assessment of the conservation status of the Indian Ocean Humpback dolphin *Sousa plumbea* using the IUCN Red List Criteria, in: Humpback Dolphins (*Sousa* spp.): Current Status and Conservation. Eds T.A. Jefferson, B.E. Curry, Advances in Marine Biology.

Brown, S.G. 1957. Whales observed in the Indian Ocean. Notes on their distribution. Mar. Obs. 27(177): 157–65.

Cerchio S, Willson A, Muirhead C, Minton G, Collins T, Baldwin R, Sarrouf Willson M, Al Harthi S. 2016. Preliminary report on long-term detection of Arabian Sea humpback whale vocalizations off Oman. Paper SC/66b/SH32 presented to IWC Scientific Committee.

Cerchio S, Willson A, Muirhead C, Al Harthi S, Baldwin R, Cholewiak D, Collins T, Minton G, Rasoloarijao T, Sarrouf Willson M. 2018. A new baleen whale song type described for the Western Indian Ocean off Oman and northwest Madagascar. Paper SC/67B/SH24 presented to the IWC Scientific Committee.

Cooke, J.G. & Brownell Jr., R.L. 2018. *Balaenoptera edeni*. The IUCN Red List of Threatened Species 2018: e.T2476A50349178. http://dx.doi.org/10.2305/IUCN.UK.2018-1.RLTS.T2476A50349178.en.

Corkeron, P., Minton, G., Collins, T., Findlay, K., Willson, A., and Baldwin, R . 2011. Spatial models of sparse data to inform cetacean conservation planning: an example from Oman. Endangered Species Research Vol. 15:39-52.

COSEWIC, 2002. COSEWIC Assessment and Update Status Report on the Blue Whale *Balaenoptera musculus* in Canada. Committee on the Status of Endangered Wildlifein Canada, Ottawa 1–32.

de Vos, A., Pattiaratchi, C. and Harcourt, R., 2014. Inter-annual variability in blue whale distribution off southern Sri Lanka between 2011 and 2012. *Journal of Marine Science and Engineering*, *2*(3), pp.534-550.

de Vos, A., Christiansen, F., Harcourt, R.G. and Pattiaratchi, C.B., 2013. Surfacing characteristics and diving behaviour of blue whales in Sri Lankan waters. *Journal of experimental marine biology and ecology*, *449*, pp.149-153.

de Vos, A., Faux, C.E., Marthick, J., Dickinson, J. and Jarman, S.N., 2018. New determination of prey and parasite species for Northern Indian Ocean blue whales. *Frontiers in Marine Science*, *5*, p.104.

Environment Society of Oman. 2019. Oman Cetacean Database. OMCD Ver20160527. Data accessed 2019-03-01

Gheilani, A.L., 2015. Sighting of Whales and Dolphins in the Arabian Sea off Oman during 2007- Sighting of Whales and Dolphins in the Arabian Sea off Oman during 2007-2008. , 28(August), pp.2768–2776.

Ilangakoon, A.D. & Sathasivam, K., 2012. The need for taxonomic investigations on Northern Indian Ocean blue whales (Balaenoptera musculus): Implications of year-round occurrence off Sri Lanka and India. *Journal of Cetacean Research and Management*, 12(1), pp.195–202.

Kershaw F., Leslie M.S., Collins T., Mansur R.M., Smith B.D., Minton G., Baldwin R., LeDuc R.G., Anderson R.C., Brownell R.L., Rosenbaum H.C. 2013. Population differentiation of 2 forms of Bryde's whales in the Indian and Pacific Oceans. Journal of Heredity doi:10.1093/jhered/est057

Mendez, M., Jefferson, T.A., Kolokotronis, S.O., Krützen, M., Parra, G.J., Collins, T., Minton, G., Baldwin, R., Berggren, P., Särnblad, A. and Amir, O.A., 2013. Integrating multiple lines of evidence to better understand the evolutionary divergence of humpback dolphins along their entire distribution range: a new dolphin species in Australian waters?. *Molecular ecology*, *22*(23), pp.5936-5948.

Mikhalev, Y. A. 1996a. Bryde's whales of the Arabian Sea and adjacent waters. Paper SC/49/O35 presented to the IWC Scientific Committee, June 1996. Pages 1-10.

Mikhalev, Y. A. 1996b. Pygmy blue whales of the Northern-Western Indian Ocean. Document presented to the 48th meeting of the International Whaling Commission SC/48/SH30. Pages 1-30.

Mikhalev, Y. A. 1997. Humpback whales *Megaptera novaeangliae* in the Arabian Sea. Marine Ecology Progress Series 149:13-21.

Mikhalev, Y. A. 2000. Whaling in the Arabian Sea by the whaling fleets Slava and Sovetskaya Ukraina. In: Tormosov, D.D., Mikhalev, Y.A., Best, P.B., B., Zemsky, V.A., Sekiguchi, K., and Brownell Jr, R.L., editors. Soviet Whaling Data [1949-1979]. Moscow: Center for Russian Environmental Policy, Marine Mammal Council. p 141-181.

Minton, G. 2004. Ecology and conservation of cetaceans in Oman, with particular reference to humpback whales, Megaptera novaengliae (Borowski 1781). PhD Dissertation. University Marine Biological Station. University of London, Millport. 250pp.

Minton, G., Collins, T. J. Q., Pomilla, C., Findlay, K. P., Rosenbaum, H. C., Baldwin, R., and Brownell Jr, R. L. 2008. *Megaptera novaeangliae*, Araiban Sea subpopulation. IUCN Red List of Threatened Species http://www.iucnredlist.org/details/132835.

Minton, G., T. J. Q. Collins, K. P. Findlay & R. Baldwin. 2010. Cetacean distribution in the coastal waters of the Sultanate of Oman. Journal of Cetacean Research and Management, 11, 301-313.

Minton, G., T. J. Q. Collins, K. P. Findlay, P. J. Ersts, H. C. Rosenbaum, P. Berggren & R. M. Baldwin (2011) Seasonal distribution, abundance, habitat use and population identity of humpback whales in Oman. Journal of Cetacean Research and Management, Special Issue on Southern Hemisphere Humpback Whales, 185–198.

Pomilla, C. Amaral, A., Collins, T., Minton, G., Findlay, K., Leslie, M., Ponnampalam, L., Baldwin, R., Rosenbaum, H. 2014. The World's Most Isolated and Distinct Whale Population? Humpback Whales of the Arabian Sea. *PLoS ONE*, 9(12), p.e114162. Available at: http://dx.plos.org/10.1371/journal.pone.0114162

Redfern, J.V., Moore, T.J., Fiedler, P.C., de Vos, A., Brownell Jr, R.L., Forney, K.A., Becker, E.A. and Ballance, L.T., 2017. Predicting cetacean distributions in data-poor marine ecosystems. *Diversity and Distributions*, *23*(4), pp.394-408.

Salm, R. V., R. A. C. Jensen, and V. Papastavrou. 1993. Marine fauna of Oman: Cetaceans, turtles, seabirds and shallow water corals. Pages 1-66. IUCN, Gland, Switzerland.

Samaran F, Adam O, Guinet C (2010) Discovery of a mid-latitude sympatric area for two Southern Hemisphere blue whale subspecies. Endanger Species Res 12: 157–165.

Samaran, F., Stafford, K. M., Branch, R. A., Gedamke, J., Royer, J.-Y., Dziak, R. P., and Guinet, D. (2013). Seasonal and geographic variation of southern blue whale subspecies in the Indian Ocean, PLoS One 8(8), e71561.

Stafford, K. M., Chapp, E., Bohnenstiehl, D. R., and Tolstoy, M. (2011). Seasonal detection of three types of 'pygmy' blue whale calls in the Indian Ocean, Marine Mammal Science 27(4), 828–840.

Supreme Council for Planning. 2019. Marine and Coastal Resource Mapping Project. Mapping Portfolio. Produced by Five Oceans Environmental Services for the Oman National Spatial Strategy.

Willson, A., Baldwin, R., Minton, G. and Collins, T. 2012. Arabian Sea humpback whale research update for 2011/2012. Paper SC/64/SH30 presented to the International Whaling Commission Scientific Committee, Panama June 2012, (available from the IWC Office).

Willson, A., Baldwin, R., Minton, G., Gray, H., Findlay, K., Collins, T. 2013. Arabian Sea humpback whale research update for 2012/13. Paper SC/65a/SH06 presented to the International Whaling Commission Scientific Committee, Jeju, South Korea, June 2013. 08pp, (available from the IWC Office).

Willson, A., Baldwin, R., Cerchio, S., Geyer, Y., Godley B., Gray, H., Al-Harthi, S., Minton, Al-Zehlawi, N., M.Witt., Rosenbaum, H., Zerbini, A. 2014. Preliminary results and first insights from satellite tracking studies of male Arabian Sea humpback whales. Paper SC/65b/SH19 presented to the International Whaling Commission Scientific Committee, Slovenia, May 2014. (Available from the IWC Office).

Willson, A., Baldwin, R., Cerchio, S., Collins, T. Findlay, K., Gray, H., Godley B., Al-Harthi, S., Kennedy, A., Minton, G., Zerbini, A and Witt, M. 2015. Research update of satellite tracking studies of male Arabian Sea humpback whales; Oman. Paper SC/66a/SH22 presented to the International Whaling Commission Scientific Committee, San Diego, May 2015. (Available from the IWC Office).

Willson, A., Baldwin, R., Cerchio, S., Collins, T. Findlay, K., Gray, H., Godley B., Gray, H., Al-Harthi, S., Kennedy, A., Minton, Sucunza, F., Zerbini, A., Witt, M. 2016a. Research update on satellite tagging studies of the Arabian Sea humpback whale in the Sultanate of Oman. Paper SC/66b/SH28 presented to the International Whaling Commission Scientific Committee, Slovenia, June 2016. (Available from the IWC Office).

Willson, A., Kowalik, J., Godley, J., Baldwin, R., Struck, A., Struck, L., Nawaz, R. and Witt, M. 2016b. Priorities for addressing whale and ship strike co-occurence off the coast of Oman and the wider North Indian Ocean. Paper SC/66b/HIM/10 presented to the International Whaling Commission Scientific Committee, Slovenia, June 2016. Available from the IWC Office).

Willson, A., Baldwin, R., Collins, T., Godley, B., Minton, G., Al Harthi, S., Pikesley, S., Witt. 2017. Preliminary ensemble ecological niche modelling of Arabian Sea humpback whale vessel sightings and satellite telemetry data. Paper presented to the International Whaling Commission Scientific Committee, Slovenia, May 2017. (Available from the IWC)