Priorities for addressing whale and ship co-occurrence off the coast of Oman and the wider North Indian Ocean.

Andrew Willson, Jonathan Kowalik, Brendan Godley, Robert Baldwin, Andreas Struck, Lioba Struck, Rab Nawaz and Matthew Witt

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A.Willson[1,2,3], J. Kowalik[4], B.J. Godley[1,2], R. Baldwin[3], A. Struck[4], L. Struck[4], R. Nawaz[5] and M.J. Witt[1]

[1] *Environment and Sustainability Institute, University of Exeter, Penryn Campus, Cornwall, UK.*
[2] *Centre for Ecology and Conservation University of Exeter, Exeter, UK.*
[3] *Five Oceans Environmental Services, PO Box 660, PC131, Ruwi, Sultanate of Oman*
[4] *Navama GmbH, München, Deutschland*
[5] *WWF Pakistan P.O Box 5180, Lahore, Pakistan*

Abstract

Satellite telemetry studies and habitat density mapping of the endangered Arabian Sea humpback whale (*Megaptera novaeangliae*) has revealed overlap with shipping off the coast of Oman. To date the only other Northern Indian Ocean (NIO) study to determine the risk of mortality to whales (*Baleanoptera musculus*) from shipping was completed in Sri Lanka. A demonstration exercise reviewing vessel traffic (from AIS data) passing through coarsely defined habitat reveals that container vessels may provide the highest risk to whales based on speed of vessels, and given a three fold increase in container traffic in the NIO region between 2004 and 2014. Traffic density heat maps show shipping routes are predominantly distributed around the periphery of the NIO area in close proximity to the continental shelf showing overlap with historical records of takes of blue, humpback, sperm (*Physester macrocephalus*) and Bryde's whales (*Baleanoptridae edeni*) during Soviet whaling between 1964 and 1966. The review presents a case for immediately commencing risk assessment work on humpback and ship co-occurrence in Oman whilst undertaking a wider spatial assessment of the region to at least determine priority areas for study. Given overlapping habitat use between species in certain areas, a multi-species approach to reviewing mitigation options is recommended.

Introduction

The vulnerability of all large species of whales to ship strikes has been well documented over the last 15 years, including identification of clear linkages between whale mortality, vessel speed and traffic density (Laist et al., 2001; Jensen and Sibler 2003; Van Waerebeek and Leaper, 2008). The issue is of recognised global importance and has motivated the implementation of mitigation measures by the International Maritime Organisation (IMO), including a guidance document for minimizing the risk of ship strikes (International Maritime Organisation, 2009). Measures include the introduction of speed restrictions, rerouting of vessels and demarcation of areas to be avoided (Silber et al., 2009). Silber (2012) notes that the uptake of successful schemes has been facilitated by '*a strong statement of needs, accompanied by relevant documentation including an assessment of impact to maritime industries and a robust risk reduction analysis*'.

In January 2015, a workshop of regional scientists referred to as the 'Arabian Sea Whale Network,' (ASWN) recognised the importance of work being undertaken by a consortium of scientists to investigate solutions for the mitigation of ship strikes within blue whale habitat off the Southern Coast of Sri Lanka (De Vos et al., 2015; Priyadarashana et al. 2015). Participants supported recommendations to undertake further studies of the interaction of shipping with the Arabian Sea Humpback Whale (ASHW) (Minton et al., 2015). These recommendations were based variously on the documented use of habitats by satellite tagged whales that are traversed by shipping routes and the commissioning of a new port facility (Duqm) in Oman adjacent to important ASHW habitat (Willson et al., 2014; Willson et al., 2015). The importance of this work was underscored by the workshop participants given the current Endangered status of the ASHW population (Minton *et al.* 2008) and that globally humpback whales are the species second most at risk from ship strike (Vanderlaan & Taggert, 2007).

Industry-led whale mitigation efforts were initiated in Oman during 2014 as a partnership between Port of Duqm and Five Oceans Environmental Services (5OES). At present a Mitigation Plan currently in operation draws from previous studies on the distribution of important whale habitat along the central and southern coast of Oman (Corkeron et al., 2011, Baldwin et al. 2015) and applies practical measures to reduce the risk collision, including approach channel alignment, reducing vessel speed and an active ship to port control whale reporting system (Baldwin et al., 2015).

Automatic Identification System (AIS) data transmitted from ships is used as a tool to quatativly map shipping patterns for the purpose of assessing ship strike risk from ships, with a veriety of methods available to generate density plots (Leaper and Panigada, 2010). In 2015, 5OES were connected with a team of vessel traffic mapping experts at Navama[1] through WWF's *Smart Fishing Programme* to investigate the application of their global AIS dataset to evaluate the co-occurrence of shipping in whale habitat in Oman. Here we present a qualitative co-occurrence exercise to evaluate the requirements for developing multi-species whale strike risk assessment for Oman and the wider Northern Indian Ocean (NIO) within the context of shipping traffic trends in the region.

Method

Previous studies evaluating interactions between whales and ships have implemented a cross-taxa approach to ensure that proffered management solutions do not shift high density traffic from the habitat of one species into another (e.g. Redfern et al., 2013). To guide this study a rapid gap analysis and literature search was initially undertaken to understand availability of whale habitat density maps and vessel traffic data within the NIO. Aside from on-going modelling work of blue whale habitat and ship strike risk assessment in Sri Lanka, the only other published information is for humpback whales along the coast of Oman (Minton et al., 2011, Corkeron et al., 2012; Willson et al., 2015). To make a composite and coarse spatial definition of important humpback whale habitat in Oman, whale encounters and satellite tagging track data (Willson et al. 2014) was projected within ARC GIS (v. 10.2) and a polygon drawn around overlapping areas defined by these studies.

As a preliminary exersize vessel movement and metadata in the AIS format was compiled from the Navama 2014 AIS database within predetermined geographic extent defined for the NIO. This data was originally sourced through the Orbcomm[2] AIS satellite receiving network. Class A and B AIS data was used to construct traffic density heat maps allocating data into grid cell sizes of 0.1° by 0.1°. AIS data associated with vessels was filtered according to predetermined speed thresholds of <15 knots and <10 knots. The cell density was determined by counts of each vessels' AIS signal within a cell if the temporal separation was more than one hour or if the vessel had shown up in another cell meanwhile, (Navama GmbH, 2015). Speed characteristics were extracted for vessels passing through the whale habitat polygon and processed to calculate the mean and median of all speeds records, and filtered to include only the 95%-quartile to eliminate outliers.

The potential economic consequences for shipping based on scenario testing of mitigation options was evaluated through the application of a vessel-fuel consumption model adapted from Notteboom and Carriou (2009), Figure 1. Comparisons of transit time and oil consumption differences were modelled under two test scenarios including 1) speed reductions within whale habitat and 2) re-rerouting of vessels around habitats for comparison.
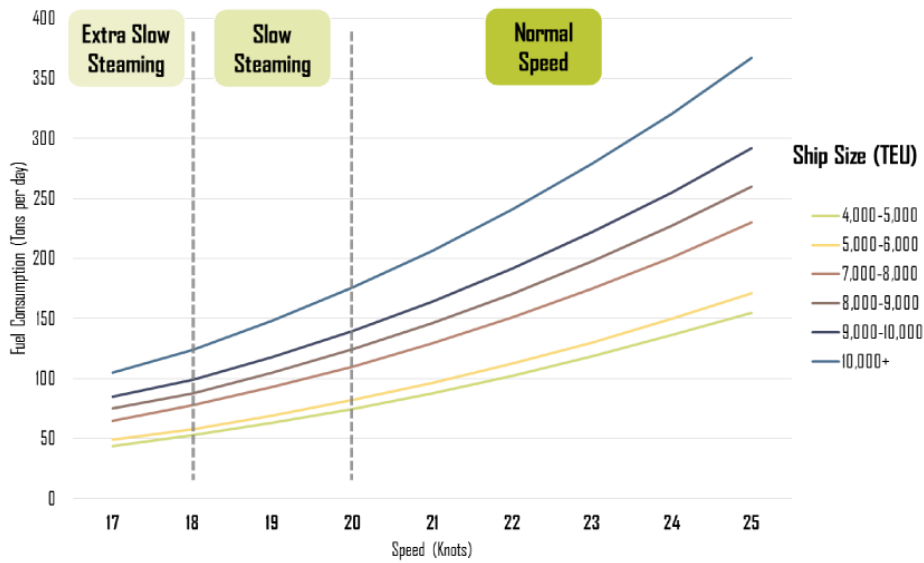

Figure 1 Fuel Consumption over Speed for different ship sizes.
Source: https://people.hofstra.edu/geotrans/eng/ch8en/conc8en/fuel_consumption_containerships.html
Note: TEU related to standardised container unit "Twenty-foot Equivalent Unit". Vessel size can be attributed to the number of these units carried.

Results

Traffic density heat maps generated from AIS data reveal that transiting vessels are predominantly distributed at the peripheries of the North Indian Ocean basin, with the highest levels of traffic found between the southern coast of India and Sri Lanka. The density of vessels travelling at speeds greater than 15 knots is greatest in the areas of Southern Sri Lanka, the Straits of Hormuz and the Gulf of Aden (**Figure 2**). Vessels passing through the coarsely defined humpback whale habitat off the southern coast of Oman follow a predominant route between the Gulf of Aden to the straits of Hormuz via the most eastern tip of Arabia, (Ra's al Hadd).
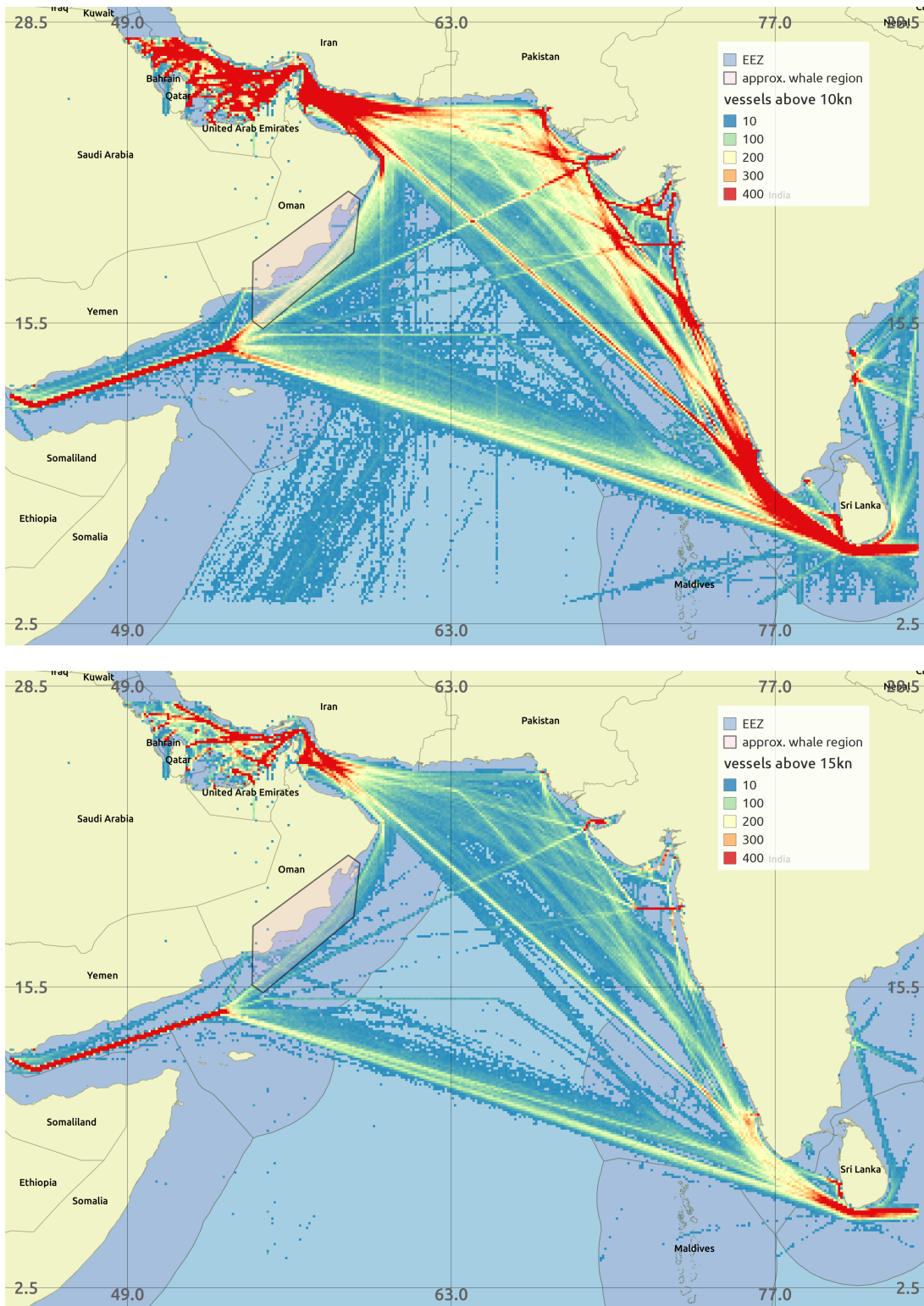
Figure 2 Heat-map of AIS data from vessels with speeds >10 knots (top n=2726 vessels) and >15 knots (bottom n=949 vessels). Density determined by the number of non repetitive AIS signals per vessel per cell (0.1° by 0.1°) within a 1 hour period, (NAVAMA GmbH (2015).

A review of the speed characteristics of vessels passing through known whale habitats shows that approximately 20% of vessels have a median speed below 10 knots and 80% of all vessels have a median below 15 knots, (Figure 3). Extraction of AIS metadata evaluating the fastest vessels in the study area (Table 1), indicates that container vessels represent the majority of commercial vessels and are operating at maximum speeds above 22 knots.

Speed Characteristics Distribution for the Western Whale Area (2014)

- average
- median
- 95% maximum

100% = 3062 vessels

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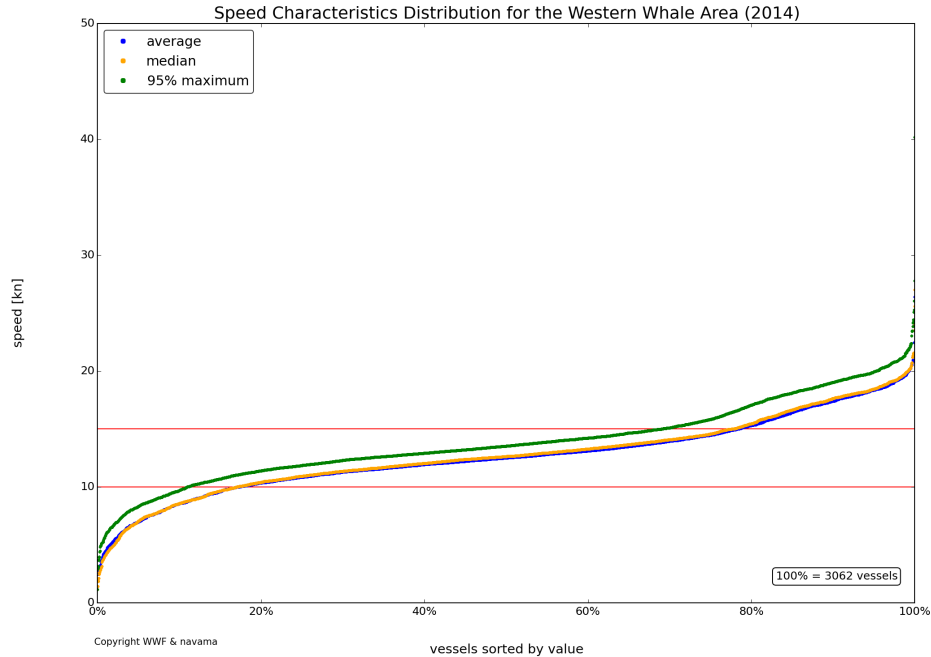
vessels sorted by value

Figure 3 Average, Median and 95%-Maximum (see above) of all vessels in the whale habitat defined off Oman, sorted by value and depicted as percent (100% = 3062 vessels). The red lines indicate the suggested speed thresholds of 10 and 15 knots respectively.

Table 1 Speed of 15 fastest vessels in the identified 'western whale habitat' extracted from 2014 Navama AIS dataset.

Rank by 95% Maximum Speed	MMSI Number	Average speed (knots)	Median Speed (knots)	Maximum Speed (knots)	95% Maximum Speed (knots)	Vessel Classification	No of relevant AIS points	Length (m)
1	319524000	26	27	41	40	yacht	7	73
2	538001809	15	14	30	28	general cargo	19	192
3	220596000	24	26	27	26	container	16	194
4	538002150	20	20	28	25	tanker	11	274
5	211906000	22	24	28	25	military	30	143
6	310627000	24	24	32	24	cruiseliner	13	345
7	220005000	17	17	25	24	container	116	266
8	228032900	21	21	35	24	container	91	241
9	636091082	21	20	24	24	container	18	294
10	219229000	21	22	23	23	container	4	334
11	211362460	19	19	25	23	container	88	320
12	211387390	19	18	26	23	container	59	321
13	253075000	18	18	34	23	container	73	294
14	235267000	17	18	24	22	container	64	300
15	249851000	19.09	18.63	25.80	22.37	container	219	304

For evaluation of the economic constraints, container vessels were selected as the target vessel type for this assessment given their predominance in the review of the fastest 15 vessels. We assumed that vessels had an average TEU of 8000 together with a conservative upper value for 'normal' speed of 20 knots. Based on these assumptions, fuel consumption rates were extracted from a fuel consumption model (Notteboom, T. and P. Carriou 2009) for speeds of 10, 15 and 20 knots.

In reviewing the mitigation options, the calculated distance of the direct route through whale habitat off Oman from north to south was measured at 380nm, with an additional 60nm required to go around this habitat. A speed reduction to 15 knots for vessels passing through this region provided the lowest fuel consumption, with a 33% reduction from an assumed maximum speed of 20 knots. A further reduction to 10 knots results in an 18% fuel reduction. Simulating the diversion of vessels around the whale area at 20 knots resulted in an increase in just over half an hour of transit time and an additional 1.67 tonnes of fuel.

Table 2 Time and fuel consumption for different mitigation scenarios.

Vessel Route	Speed (knots)	Time (h)	Fuel (t)
	10	38.0	79.2
Through whale habitat	15	25.3	63.3
	20	19.0	95.0
Rerouting around whale habitat	20	19.3	96.7
Difference in rerouting around whale habitat	20	0.3	1.7

Discussion

As a scoping exercise the study demonstrates that there is sufficient cause for concern to justify the further evaluation of ship and whale co-occurrence in the Arabian Region given a demonstrated overlap within the coarsely defined whale habitat off the coast of Oman (**Figure 2**). Results showed that 80% of vessels in the study area travel at a speed above 10 knots and 20% at a speed above 15 knots, with the top 15 vessels transiting above 22 knots. These preliminary results suggest that if struck the probability of whale mortality would be high; Vanderlan and Taggart (2007) demonstrated that the chance of lethal injury increased significantly from 0.21 at 8.6 knots, to 0.79 at 15 knots if a whale is struck by a vessel. The probability of lethal injury falls below a threshold of 0.5 at <11.8 knots. Ships classified as container and cargo vessels are perhaps of most concern given they account for 12 of the 15 fastest vessels in the study, although their associated risk is also dependent on their total proportion, something that isn't assessed here.

The simplistic evaluations of fuel and time costs associated with speed reductions or route alterations demonstrates that these mitigation measures may be realistic for the shipping industry and result in fuel costs savings by as much as 33%. For open sea areas the trade off between speed restrictions and vessel diversions through shipping lanes, traffic separation schemes or 'areas to be avoided' will become apparent once whale habitats have been more accurately delineated. For localised areas close to vessel destinations and where whale occurrence is either known or suspected, voluntary speed reductions could be encouraged given the evidence supporting reduced encounter rates (of >91.5%) below 12.5 of speed (Currie et al., 2015) and the reduction of hydrodynamic forces that draw whales towards vessels resulting in strikes (Silber et al., 2010). Connections between existing conservation efforts in Oman and the shipping industry (Baldwin et al., 2015) and between the IMO and IWC (IWC/65/CCRep01) at the international level, indicate future studies have an opportunity to influence policy and, as such, should be pursued.

The initial scoping work for this study is limited by the paucity of ASHW occurrence data in areas beyond Oman. Similarly data for other whale species known to occur in the NIO is very sparse. Redfern (2013) presented a multi species ecological niche modelling approach for evaluating routes of least risk for vessels crossing whale habitat for three species off the southern coast of California. At least four species of large whales are known to occur off the coast of Oman (Mikhalev., 2000), with a fifth being a possibility based on a beach cast record of Omura's whale (*Balaenoptera omurai*) on Qesham Island, Iran (Ranjbar et al. 2016). Efforts to improve the available data for these species would prudent prior to proceeding further with mitigation advice for offshore areas.

Although temporally distant, comparison of historical data of whale encounters (Figure 4) with regional shipping traffic density (**Figure 5**) provides an opportunity to consider gaps in spatial data and where future efforts should be applied to investigate if these habitats are still important. In addition to the humpback whale habitat off the coast of Oman, and existing studies being undertaken on blue whales off the coast of Sri Lanka areas of co-occurrence annotated in **Figure 5** include:

1. Bryde's, blue, pygmy blue and humpback whale habitat in the Gulf of Aden.
2. Humpback and blue whale habitat between Sindh province Pakistan and Gujurat India in the Ram of Kutch.
3. Bryde's, pygmy blue and sperm whale habitat extending west for 1000km from the south of India past the northern Maldives.

The encounter data sourced from Soviet whaling catch records between 1962 and 1966 (Mikhalev, 2000; IWC Catch Database) has the associated caveat that whaling only occurred in these years between late October and mid December. Furthermore counts of pygmy blue whales and blue whales were tallied as two separate forms in the NIO, however Branch (2007) notes they are most likely to belong to all belong to the same species (*Balaenoptera musculus brevicauda*). Another taxonomic issue of note is the bryde's whale complex, where Kershaw (2013) identified two genetically recognised subspecies occurring within the NIO; the offshore form (*Balaenoptera edeni brydei*) and coastal form (*Balaenoptera edeni edeni*).

Other studies also reflect the potential for identifying important whale habitat within the North Indian Ocean. Whitehead (1985) detected humpback whale song in the Gulf of Mannar, Sri Lanka in February and March 1982, similar to that recorded off Oman in January 1982. Autonomous seafloor hydrophones deployed off the south west coast of India near Cochin (Kerala State) detected humpback song between January and March 2011 (Mahanty et al. 2015), indicating that this could be an important area. Opportunistic surveys and interviews with fishers along the west coast of India between Gujarat, Maharashtra and Kerela (Sutaria, 2015) in 2014 and 2015 revealed the presence of humpback whales, blue whales and Bryde's whales. These encounters occur in areas with high density of shipping traffic (**Figure 5**). Recent discussions with fishermen active off the east coast of the UAE together with documented strandings along the southern shores of the Sea of Oman (Oman Cetacean Stranding Database, 2016) suggest that sperm whales may rely on habitats in the approaches to the Straits of Hormuz, one of the highest traffic density areas in the world (**Figure 5**).
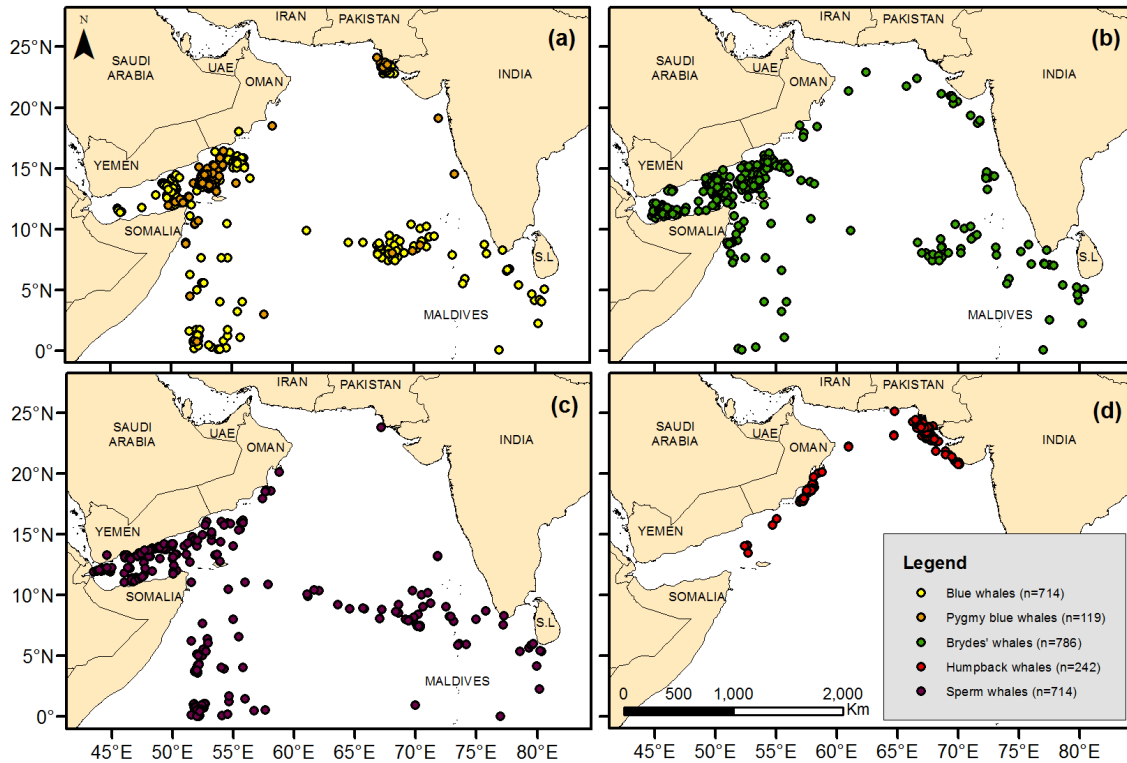
Figure 4 Historical takes of pygmy blue, sperm, humpback and Bryde's whales takes in the Northern Indian Ocean as documented in Soviet whaling records between 1962 and 1966 ,(Mikhalev, 2000; IWC Catch Database, extracted 25 October 2013).
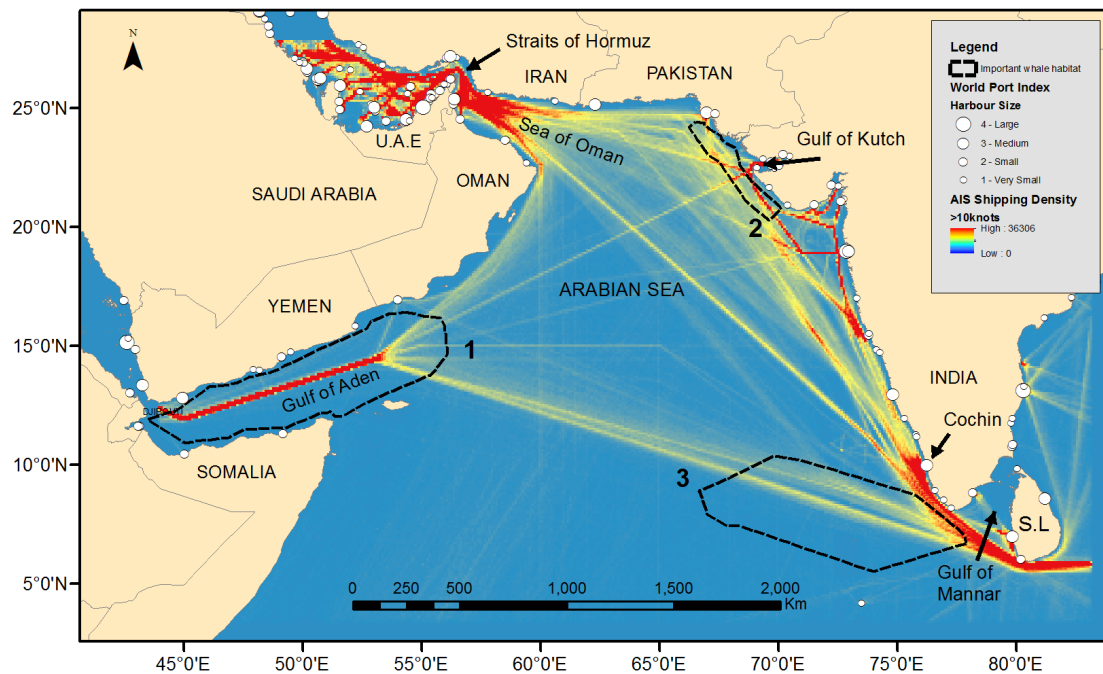

Figure 5 Class A and B AIS data (2014) annotated with polygones outlining important whale habitat areas as defined by historical records of Soviet whaling records plotted in Figure 4 **(AIS Source data: Navama, 2014).**

Other studies that quantify risk for specific areas and associated mitigation recommendations (e.g. Peel et al., 2015; Redfern et al., 2013; Smith et al., 2012) are of use for devising an approach for further work in Oman and the wider NIO. Redfern (2013) developed whale habitat density models to predict the number of whales in the Californian Channel Islands using 2 x 2 km grid cells for three species based on dedicated line transect surveys conducted over an 18 year period. AIS data was used to define ship routes and traffic density. The relative risk for each route traffic density was defined by multiplying the number of whales predicted within each channel by the traffic density. This multi species approach enabled a route-based risk assessment on a scale that could be considered analogous to the central coastline or southern coastline of Oman.

Work by Peel (2015) focused on risk assessment evaluating relative ship and humpback whale co-occurrence across a larger extent along the Great Barrier Reef (GBR) using predicted whale densities from modelling of two years of aerial survey data together with AIS data. Expanding on the approach by Redfern (2013) the study also developed an index for predicting expected number of whale mortalities through inclusion of vessel speeds in the model and evaluated future risk by considering increases of projected traffic and whale population 10 years ahead. Shipping trends are important in considering future risk scenarios, especially for the ASHW population, given limited population size (Minton et al., 2008) and the location of important ASHW habitat within developing industrial area (Willson et al., 2015; Baldwin et al 2015). Using the flow of containers from land to sea port modes in the last 10 years as an index of containerised shipping traffic trends (Table 1), activity has increased 3.16 times between 2004 and 2010 across North Indian Ocean countries (n=7), and reflects the increasing regional trend. This compares to an increase of 2.01 globally (The World Bank, 2016) and is of concern given the higher risk associated with speeds of container vessels highlighted in this study.

Table 3 Container port traffic of countries surrounding the North Indian Ocean region including Arabian Gulf and Rese Sea, (The World Bank, 2016. Source: http://data.worldbank.org/indicator/IS.SHP.GOOD.TU?page=2)

Country Name	Container Port Traffic in TEU (20ft equivelent units)							Increase	
	2004	2009	2010	2011	2012	2013	2014	2009-13	2004-2014
Bahrain	N/A	279,799	289,956	306,483	329,470	355,498	373,628	1.27	N/A
Djibouti	N/A	519,500	600,000	634,200	681,765	735,624	773,141	1.42	N/A
Egypt, Arab Rep.	2,959,895	6,250,443	6,709,053	7,737,183	8,140,950	8,248,115	8,810,990	1.32	2.98
Jordan		674,525	619,000	654,283	703,354	758,919	797,624	1.13	N/A
India	4,332,863	8,014,487	9,752,908	10,284,885	10,279,265	10,883,343	11,655,635	1.36	2.69
Iran, Islamic Rep.	1,177,265	2,206,476	2,592,522	2,740,296	2,945,818	3,178,538		1.44	N/A
Iraq	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Kuwait	N/A	854,044	991,545	1,048,063	1,126,668	1,215,675	1,277,674	1.42	
Maldives	N/A	56,000	65,016	68,722	73,876	79,712	83,778	1.42	N/A
Oman	2,515,546	3,768,045	3,893,198	3,632,940	4,167,044	3,930,261	3,620,364	1.04	1.44
Pakistan	1,269,373	2,058,056	2,149,000	2,193,403	2,375,158	2,485,086	2,597,395	1.21	2.05
Qatar	N/A	410,000	346,000	365,722	393,151	424,210	445,845	1.03	N/A
Saudi Arabia	759,769	4,430,676	5,313,141	5,694,538	6,563,844	6,742,697	6,326,861	1.52	8.33
Somalia	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
South Sudan	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sri Lanka	2,220,525	3,464,297	4,000,000	4,262,887	4,321,000	4,306,200	4,907,900	1.24	2.21
Sudan	N/A	431,232	439,100	464,129	498,938	538,354	565,811	1.25	N/A
United Arab Emirates	8,661,636	14,425,039	15,176,524	17,548,086	18,120,915	19,336,427	20,900,567	1.34	2.41
Yemen, Rep.	N/A	639,671	669,021	707,155	760,192	820,247	862,079	1.28	N/A
NIO Region	2,987,109	3,030,143	3,350,374	3,646,436	3,842,588	4,002,432	4,266,620	1.29	3.16
World	338,433,750	472,175,125	542,248,030	587,483,461	622,313,936	649,453,845	679,264,658	1.38	2.01

Approach for future studies
Future studies that assess risks and identify suitable mitigation actions for the region will need to be implemented in a stepwise manner according to availability of data and prioritisation of specific areas for evaluation according to studies predicting co-occurrence risks to whales. The primary constraints are presented by availability of whale data, with the limitations of shipping traffic data constrained by that available through global AIS datasets.

The availability of vessel encounter and telemetry data for the ASHW in Oman (Willson et al., 2015) make this a suitable candidate area and species for initial evaluation of whale and shipping co-occurrence. The dataset has sufficient sampling points to support a similar approach to the study presented by Peel (2015), with the potential to predict the relative risk of co-occurrence and fatalities and consider risk adjustments based on projected traffic densities over the next decade.

Generation of habitat density maps can be attempted through ecological niche modelling techniques for other species encountered off the coast of Oman by drawing from records contained within the (Oman Cetacean Database). Use of these in evaluating co-occurrence will be dependent on strength of selected environmental covariates. If the models are considered sufficiently robust for a multispecies approach, evaluation of risk along different route options can be tested according to the approach adopted by Redfern, (2013).

On completion of a multispecies approach, mitigation options can subsequently be evaluated according to economic implications on time and fuel cost considerations. AIS data should be further interrogated to classify vessel types and identify specific shipping lines (especially faster vessels operating >20 knots) as a step towards facilitating further dialogue with industry.

A region-wide assessment is a more ambitious undertaking, given limited encounter data to test habitat density models from range states other than Oman. However ecological niche models developed for Oman could be used to predict habitat region wide, and used to coarsely quantify relative risk of co-occurrence as a means of providing a more accurate and up-to-date evaluation of priority areas than that presented in this document. Whale risk and economic assessments can then be attempted at a finer scale within each state at a local level as research capacity evolves.

Conclusion

Significant resources are required to generate datasets sufficiently robust both in producing habitat density models used in evaluating risks, mitigation options and economic implications. Traffic in the region has shown a three-fold growth in the last 10 years and operating at speeds with greater than 50% probability of causing mortality if whales are struck. The spatial distribution of vessel traffic is concentrated around the periphery of the NIO revealing potential co-occurrence issues with four species of whales. As with Sri Lanka immediate work on risk assessment can begin in Oman. Beyond these efforts it is apparent that investigating mitigation through a robust IMO supported approach will be out of the reach of other states until sufficient effort is invested in dedicated habitat density assessments. Given the lead-in time required for obtaining data, options for encouraging voluntary speed restrictions on approaches to ports with known occurrence of whales should be encouraged. With vessel strikes being just one of a host of threats facing ASHWs in the region further resources and coordinated regulatory support are required to gain government and industry support for further work.

References

Baldwin R.M., Gallagher M., and Van Waerebeek K. 1999 A review of cetaceans from waters off the Arabian Peninsula. Pp. 161-189. In: M. Fisher, S.A. Ghazanfar and J.A. Spalton (eds). The Natural History of Oman: A Festschrift for Michael Gallagher. Backhuys Publishers, Leiden.

Baldwin, R. M. 2003. Whales and Dolphins of Arabia. Mazoon Printing Press, Muscat, Oman. 116pp.

Baldwin, R., Willson, A. and Collins, T. 2015. Watching out for whales: industry responsibility to address threats to Arabian Sea humpback whales in the Gulf of Masirah, Oman. Paper SC/66a/SH23 presented to the International Whaling Commission Scientific Committee, San Diego, May 2015. (Available from the IWC Office).

de Vos A, Wu, T., Brownell Jr. R.L. 2013. Recent blue whale deaths due to ship strike around Sri Lanka. SC/65a/HIM03. Paper presented to the scientific committee of the IWC. (Available from the IWC Office).

de Vos, A., Redfern, J., Brownell, R., Fielder, P., Moore, T., Balance, L., Tershy, B. and Croll, D. 2015. Assessing risk to endangered blue whales in the Northern Indian Ocean. SC/66a/HIM13. Paper presented to the scientific committee of the IWC. (Available from the IWC Office).

International Maritime Organization. Measures for minimizing the risks of collisions with cetaceans. MEPC 59/18, 2009.

Jensen, A.S. and Silber, G.K., 2003. *Large Whale Ship Strike Database. US Department of Commerce. National Oceanic and Atmospheric Administration*. Technical Memorandum NMFS-OPR.

Kite-Powell, H.L., Knowlton, A. and Brown, M., 2007. Modeling the effect of vessel speed on right whale ship strike risk. *Project report for NOAA/NMFS Project NA04NMF47202394*.

Laist, D. W., Knowlton, A. R., Mead, J. G., Collet, A. S., & Podesta, M. (2001). Collisions between ships and whales. Marine Mammal Science, 17(1), 35-75.

Leaper, R. and Panigada, S. 2010 Some considerations on the use of AIS data to estimate shipping density for ship strike assessment. SC/63/BC4. Paper presented to the scientific committee of the IWC. (Available from the IWC Office).

Mahanty, M.M., Latha, G. and Thirunavukkarasu, A., 2015. Analysis of humpback whale sounds in shallow waters of the Southeastern Arabian Sea: An indication of breeding habitat. *Journal of biosciences*, *40*(2), pp.407-417.

Mikhalev, Y.A. 2000. Whaling in the Arabian Sea by the whaling fleets *Slava* and *Sovetskaya Ukraina*. pp.141–81. *In*: Yablokov, A.V., Zemsky, V.A. and Tormosov, D.D. (eds). *Soviet Whaling Data (1949–1979)*. Centre for Russian Environmental Policy, Moscow. 408pp.

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., Reeves, R., Collins, T. and Willson, A. 2015. Report on the Arabian Sea Humpback Whale Workshop: Developing a collaborative research and conservation strategy. Dubai, 27-29 January 2015

Notteboom, T. and Cariou, P., 2009, June. Fuel surcharge practices of container shipping lines: Is it about cost recovery or revenue making. In *Proceedings of the 2009 International Association of Maritime Economists (IAME) Conference* (pp. 24-26). IAME.

Peel, D., Kelly, N., Smith, J. and Childerhouse, S. Quantative assessment of the risk of ship strike to humpback whales in the Great Barrier Reef. SC/66a/HIM/16. Presented to the International Whaling Commission Scientific Committee, Slovenia, May 2014. (Available from the IWC Office).

Priyadarshana, T., Randage, A.M., Alling, A., Calderan, S., Gordon, J., Gordon, T., Leaper, R., Lewis, T., Porter, T. and Thillo, M. 2015.An update on work related to ship strike risk to blue whales off southern Sri Lanka. SC/66a/HIM/9. Presented to the International Whaling Commission Scientific Committee, Slovenia, May 2014. (Available from the IWC Office).

Ranjbar, S., Dakhteh, M.S. and Van Waerebeek, K., 2016. Omura's whale (Balaenoptera omurai) stranding on Qeshm Island, Iran: further evidence for a wide (sub) tropical distribution, including the Persian Gulf. *bioRxiv*, p.042614.

Redfern, J. V., Mckenna, M., Moore, T., Calambokidis, J., Deangelis, M. L., Becker, E. A., Barlow, J., Forney, K., Fiedler, P., & Chivers, S. (2013). Assessing the risk of ships striking large whales in Marine Spatial Planning. Conservation Biology, 27, 292-302.

Silber, G.K., S. Bettridge, and D. Cottingham. 2009. Report of a workshop to identify and assess technologies to reduce ship strikes of large whales, 8-10 July, 2008, Providence, Rhode Island. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-OPR-42. 55 p.

Silber, G.K., Slutsky, J., and Bettridge, S. (2010). Hydrodynamics of a ship/whale collision. Journal of Experimental Marine Biology and Ecology, 391: 10-19.

Silber GK, Vanderlaan ASM, Tejedor Arceredillo A, Johnson L , Taggart, C.T., Brown, M.W., Bettridge, S., Sagarminaga, R. (2012) The role of the International Maritime Organization in reducing vessel threat to whales: process, options, action and effectiveness. Mar Policy 36: 1221−1233

Sutaria, D., Sule, M., Jog, K., Bopardikar, I. and Panicker, D. Recent baleen whale records from the Arabian Sea, India. Paper SC/66a/SH17 presented to the International Whaling Commission Scientific Committee, San Diego, May 2015. (Available from the IWC Office).

The World Bank, World Development Indicators (2016). Container port traffic (TEU: 20foot equivalent units). Retrieved from
http://data.worldbank.org/indicator/IS.SHP.GOOD.TU?page=2

Van der Hoop, J.M., Vanderlaan, A.S.M., Taggart, C.T. (2012) Absolute probability estimates of lethal vessel strikes to North Atlantic right whales in Roseway Basin, Scotian Shelf. Ecol Appl 22:2021−2033

Vanderlaan, A.S. and Taggart, C.T., 2007. Vessel collisions with whales: the probability of lethal injury based on vessel speed. *Marine mammal science*, *23*(1), pp.144-156.

Van Waerebeek, K., Baker, A. N., Félix, F., Gedamke, J., Iñiguez, M., Sanino, G.P., Secchi, E., Sutaria, D., Van Helden, A., and Wang, Y. (2007). Vessel collisions with small cetaceans worldwide and with large whales in the Southern Hemisphere, an initial assessment. Latin American Journal of Aquatic Mammals, 6: 43–69.

Whitehead, H., 1985. Humpback whale songs from the North Indian Ocean. *Investigations on Cetacea*, *17*, pp.157-162.