Original Articles

Population estimate and distribution pattern of Indian Ocean humpback dolphin (*Sousa plumbea*) in an industrialised bay, northwestern Persian Gulf

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ABSTRACT

Monitoring and assessing marine biodiversity relies upon adequate and accurate knowledge of population and distribution patterns of ecologically important species. Cetaceans are recognised both as functionally important and as flagship species and have been the target of monitoring and conservation programs. The habitat specialist Indian Ocean humpback dolphin (*Sousa plumbea*) is the second most common cetacean in the Persian Gulf. Mousa Bay in the northwestern Persian Gulf is an important, but highly industrialised habitat for this species. We developed a systematic and comprehensive distance sampling survey carried out from 2014 to 2016 to estimate abundance and population density of humpback dolphin in this bay. To evaluate distribution pattern of the species, eight environmental variables were measured and employed in a zero-inflated generalised additive model (ZINB GAM). With an estimated abundance of 92 animals (64–131, 95% CI) and density of 0.123 animal/km^2 (0.086–0.176, 95% CI), our results revealed Mousa Bay as one of the largest population of humpback dolphin in northern latitudes of its global range. Based on ZINB GAM findings, distance to coastlines, depth, EC, and chlorophyll *a* concentration significantly influence the distribution of the species. Our results highlighted that physiographic parameters and resource availability are the most important motivators of the species distribution in shallow nearshore waters. Biotic (e.g. water quality) factors due to strongly being affected by the variability of time and space ranked after physiographic variables. The high tendency of humpback dolphins to enter in highly developed foreshore of Mousa Bay raise the need for conservation-oriented studies to inform conservation planning. This study provides a basis for monitoring humpback dolphin and assessing ecosystem health of northern Persian Gulf.

1. Introduction

Despite the importance of ocean-marine ecosystems, the quality of these natural habitats are rapidly declining particularly due to habitat destruction, over-exploitation, introduction of alien species, water pollution and climatic fluctuations (Pompa et al., 2011; Worm et al., 2006). Additionally, close to 60% of the world's human population is settled at a range of 100 km from shorelines (Pompa et al., 2011). Anthropogenic disturbances in these areas have led to the fact that of the 89 cetacean species, 22% are assigned to threatened (i.e. CR, EN, VU) or near threatened (NT) categories and the conservation status of 50% of them is data deficient (DD) due to the insufficient data of their population trend and geographic distribution (IUCN, 2017). Consequently, planning monitoring programs is indispensable for filling conservation gaps and developing management strategies for marine mammals. Nevertheless, despite successful conservation activities and improved population status of some of the marine mammals in recent decades (e.g. whales), those occurring in coastal areas or inland waters (mainly dolphins and porpoises), have constantly been facing threats from human activities (Lotze et al., 2011; Pompa et al., 2011). Ships and boats traffic, habitat destruction, and entanglement in fishing gears are among the most serious threats to marine mammals in these areas (Komoroske and Lewison, 2015).

Cetaceans are recognised as functionally important species by the EU Marine Strategy Framework Directive (Azzellino et al., 2014). They are also considered as flagship (Hoyt, 2012), keystone (Bănaru et al., 2013), and umbrella (di Sciara and Agardy, 2016) species and hence are the target of conservation efforts.

The Persian Gulf is a relatively small, shallow and semi-enclosed marginal sea of the Indian Ocean bordered by Iran and the Arabian

Fig. 1. Location of Mousa Bay in the northeast of the Persian Gulf, where distance sampling efforts were implemented to estimate abundance of humpback dolphins.

Peninsula. This area harbours diverse marine and coastal habitats and a great diversity of plant and animal species adapted to its unique condition of extreme salinity and high temperature (Hume et al., 2013). The Persian Gulf is the world's largest source of crude oil and gas through which about 60% of the world's sea transport of crude oil passes (Reynolds, 1993) making it one of the most impacted ocean areas in the world. The main anthropogenic pressures to the Persian Gulf's environment includes oil and waste contamination, high maritime traffic, overfishing, rapid coastal development and industrialisation, sedimentation and dredging, introducing nonindigenous organisms through ships' ballast water discharge, and destruction of habitats (Bayani, 2016). During the Gulf War in early 1991, an estimated four to eight million barrels of crude oil were directly released into the Persian Gulf made it the largest oil spill in history.

At least 98 marine mammals have been identified from the Persian Gulf (Owfi et al., 2016), though, most of them are vagrant or seasonal visitors. Persian Gulf is also known as the most important stronghold for dugongs (*Dugong dugon*) in western half of their range outside the Australia, and is home to resident populations of Indo-pacific bottlenose dolphins (*Tursiops aduncus*) and Indian Ocean humpback dolphins (*Sousa plumbea*; hereafter called humpback dolphins) all year round (Owfi et al., 2016; Preen, 2004).

Humpback dolphins are obligate shallow-water species usually found within a narrow strip of nearshore waters and estuarine areas from South Africa northward around the rim of the Indian Ocean to the Arabian Peninsula from the Red Sea into the Persian Gulf and east to Pakistan and the southwestern coast of India. The geographic distribution of the species is discontinuous across most of the range, with probably discrete local subpopulations (Braulik et al., 2015). Preference of *S. plumbea* to disperse within coastal areas with high anthropogenic footprints and ongoing environmental degradation is further fragmenting the aggregate population of the species making it exceedingly vulnerable. *Sousa chinensis* and *S. plumbea*, formerly considered as two morphological forms of a single species (*S. chinensis*) and were assessed together by IUCN as Near Threatened. However, based on the last assessment on the status of *S. plumbea*, the species meets the IUCN Red List requirements for Endangered category (Braulik et al., 2017).

Humpback dolphin is one of the most common marine mammal species seen in coastal areas and shallow waters of Persian Gulf (Preen, 2004). Both humpback dolphins and fishermen of the gulf concentrate in nearshore or estuarine areas, where large schools of fishes with high density are available. Although human attitudes toward humpback dolphin in Mousa Bay has not been assessed negative (Khatibzadeh, 2017), they have been killed intentionally or accidentally as a result of human fishing activities. On the other hand, increasing water pollution as a result of industrial development in coastal areas of the Persian Gulf has been threatening marine biodiversity particularly in semi-enclosed basins, where are important biodiversity and economic areas. Biodiversity conservation in such important areas has been hampered by the scarcity of information on the abundance and habitat suitability of representative target species.

Knowledge of cetacean abundance and distribution is a prerequisite to inform conservation planning of marine ecosystems. Hence, monitoring cetacean populations is of global importance for marine ecosystem conservation (Parsons et al., 2015). Albeit, several studies have been conducted on the abundance and spatial ecology of humpback dolphin from South China Sea (Chen et al., 2010; Xu et al., 2015) to Goa Gulf in India (Sutaria and Jefferson, 2004) and eastern coast of Africa and South Africa (Guissamulo and Cockcroft, 2004; Karczmarski, 2000; Meyler et al., 2011; Stensland et al., 2006), little is known about the ecology, abundance and distribution pattern of the species in the Persian Gulf. We only found two publications on the distribution and population estimation of the Indian Ocean humpback dolphin in the southern coast of the Persian Gulf; Preen (2004) and (Díaz López et al., 2017).

In the current study, we developed a systematic and comprehensive field survey to estimate abundance and evaluate distribution pattern of humpback dolphin in Mousa Bay, a semi-enclosed harbour in the