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Reconstructing historical baselines for the Persian/Arabian Gulf Dugong, *Dugong dugon* (Mammalia: Sirenia)

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Retrospective estimates of historic abundances and distributions of marine organisms are crucial to understanding the anthropogenic impacts on the structure and species of coastal ecosystems, especially in the case of vulnerable species such as the Dugong (*Dugong dugon*). The Persian/Arabian Gulf is home to the second largest Dugong population in the world, yet little is known about their current or past abundance, distribution, and ecological role. Here, we examine historical changes in dugong distribution and estimate perceived changes in their abundance. We create a ‘dugong discovery curve’ and compile global density estimates as proxies for the overall health of the population in the Gulf. We find that since 1950 dugong range may have contracted by one quarter, and despite their large population, their overall densities in the Gulf are far lower than in other areas within their range. Basic understanding of historical trajectories for Dugongs is needed in order to develop appropriate management plans and conservation targets, particularly in light of large and wide-spread coastal development projects in the region.

Keywords: Dugong; historical ecology; Persian Gulf; Arabian Gulf

Introduction

Historical data are necessary to help clarify the underlying causes and rates of ecological change and to set appropriate management targets for the restoration and management of coastal ecosystems (Jackson et al., 2001). Retrospective estimates of historic abundances and distributions of marine organisms are crucial to understanding the profound and long-lasting effects of human activity to the structure of coastal ecosystems (Baum et al. 2003; Myers & Worm, 2003; Pandolfi et al., 2003; Lotze & Milewski, 2004; Jackson, 2008; McClenachan & Cooper, 2008). This is especially important for vulnerable species, such as the Dugong (*Dugong dugon*).

The dugong is one of the four living species in the order Sirenia and the only surviving member of the once diverse Dugongidae family. Dugongs are found in the coastal waters of at least 48 countries (Marsh, Penrose, Eros, & Hugues, 2002) and are almost entirely dependent on seagrass for food (Marsh & Saalfeld, 1986; Preen, 1989; Ponnampalam, Fairul Izmal, Adulyanukosol, Ooi, & Reynolds, 2015). Dugongs are classified as vulnerable to extinction by the International Union for the Conservation of Nature (IUCN) and are thought to be declining or extinct in at least a third of its range and of unknown status in about half its range (Marsh & Soltzick, 2015). According to the IUCN, global Dugong populations have declined by 30% in the last six decades (Marsh & Soltzick, 2015).

The Persian/Arabian Gulf, herein referred to as The Gulf, is home to about 7,300 dugongs, the second largest population in the world after Australia, and the most im-

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portant dugong habitat in the western half of the dugong's range ; Preen 2004). Numerous studies have described the abundance, distribution, and ecological role of Dugongs in Australia (Anderson & Birtles, 1978; Marsh, Channells, Heinsohn, & Morrissey, 1982; Marsh, De'Ath, Gribble, & Lane, 2005), far less is known about the Dugong population trajectories in The Gulf (Preen, 2004), where they face a number of anthropogenic threats.

Dugongs are known by several local names including *baqarah al bahr* (Arabic: cow of the sea), *arus al bahr* (Arabic: bride of the sea) and *cow diryali* (Farsi: marine cow). The earliest evidence for their exploitation in The Gulf has been found in middens dating back to 3500–3200 BC (Beech, 2010; Mery et al. 2009). Archaeological excavations have revealed carefully selected dugong remains arranged in ritualistic displays, suggesting the long-term presence and cultural importance of the species to the region (Mery et al., 2009; Beech, 2010). Interestingly, analogs to the ritualistic mounds have been found in other places in the world (albeit at much later date) such as on the coasts of the Torres Strait in Australia (Mery et al., 2009)

Prior to the discovery of oil in the Gulf in the 1930s, tribes of traditional dugong hunters in Bahrain may have killed up to hundreds of dugongs each year (Marsh et al. 2002). Dugongs provided a rich source of meat, oil, fat and hide to the prehistoric and historic coastal communities of the Gulf (Beech 2010). A single individual weighed between 200 and 300 kg and provided 24–56 litres of oil, which would have been used for cooking, fuel for lamps, medicine, and as a sealant for wooden boats (Agius, 2009; Beech, 2010). Dugong meat was used for personal consumption, or dried into strips and traded with neighbouring villages. The bone marrow was also consumed, but the tailstock was the preferred section. The hide was used to make sandals and the tusks were used in the sword handles of Emirs and Sheikhs (Beech, 2010). Traditionally, Dugongs were hunted by herding individuals into shallow water and clubbing them to death (Preen, 1989).

While the significance of Dugongs to local culture and diet has lessened in recent decades, they are still occasionally captured intentionally or as bycatch. Interviews conducted by the Emirates Natural History Group in 1976 estimated that between 50 to 70 Dugongs were sold every year. By the mid-1980s between 70 to 100 dugongs were captured every year and sold at the Abu Dhabi Fish market (Preen, 1989).

At present, Dugongs in the Gulf are only offered protection in the waters of the United Arab Emirates (Federal Law No. 23 and Article 28/2000 Amiri Decree). It is worth noting that Dugongs are considered *halal* or permissible to eat by Islamic law. In contrast, the meat of terrestrial animals cannot be eaten unless they have been killed in according to *halal* requirements.

Despite their cultural significance to the region, very little is known about dugongs' true status in the Gulf. Only a handful of scientific articles describing dugongs in the Gulf exist (Preen, 1989; Baldwin & Cockcroft, 1997; EAD 2005, 2015, 2016; ERDWA, 2007) and the most recent peer-reviewed ecological study was published more than a decade ago (Preen, 2004). Results of these studies describe Dugongs to be limited to the southwest and southern Gulf between Ras Tanura on the Saudi coast and Abu Dhabi in the UAE, with no evidence of Dugongs in Iran, Iraq, or Kuwait (Preen, 2004).

Population estimates for the Gulf range from 5800 to 7300 individuals (Preen, 1989; Baldwin & Cockcroft 1997; EAD 2005, 2015, 2016; ERDWA, 2007). Here, we estimate past distribution and relative perceived abundance, as well as examine global Dugong densities in order to provide context to the conservation targets and management plans for the region.



Figure 1. Dugong records in The Gulf. Grey triangles represent records prior to 1950, black circles records after 1950. Green areas represent seagrass areas according to UNEP-WCMC & Short (2005), limited by <30 m depth and winter water temperatures of >18 C.

Methods

Historical and present-day (up to 2014) records of Dugongs in The Gulf were compiled from published and written sources including the British National Archives in London, New York Public Library, Simon Fraser University, The Environment Agency Abu Dhabi, and the University of British Columbia. The majority of archival records on The Gulf are held outside the region (much of it in London) due to historic circumstances, and also for preservation purposes. Accounts in Arabic, Farsi and English were compiled.

In total, 155 records were found and categorized according to usefulness and type. The records were then ranked against a species abundance classification scheme based on previously established methods (Pandolfi et al., 2003; Palomares, Mohammed, & Pauly 2006; Al-Abdulrazzak, Naidoo, Lourdes, Palomares, & Pauly, 2012) to infer perceived long-term changes in relative species abundance. Here, we use the ranking system established by Al-Abdulrazzak et al. (2012) based on five categories (1 = absent, 2 = rare, 3 = present, 4 = common, 5 = abundant) and graph the average rank for each decade.

Of these 155 records, 80 were location-specific and were mapped in a geographic information system database using ArcGIS in two categories, records dated before 1950 and records after 1950, to examine changes in species range and distribution. We chose 1950 as the boundary year as it corresponds to the start of industrial fishing in the Gulf. To determine the total suitable habitat for dugong in the Gulf, we mapped the seagrass area (9,930 km²; UNEP-WCMC & Short, 2016) limited by <30 m depth and winter water temperatures of >18 C. To measure changes in range, half-degree grid cells were overlaid along the coast of the Gulf (with the exception of the Iraqi coast which, because of the Shatt Al Arab, has a low salinity and no seagrass) and for each cell with a dugong record, the total suitable dugong habitat was calculated (Al-Abdulrazzak, 2015).

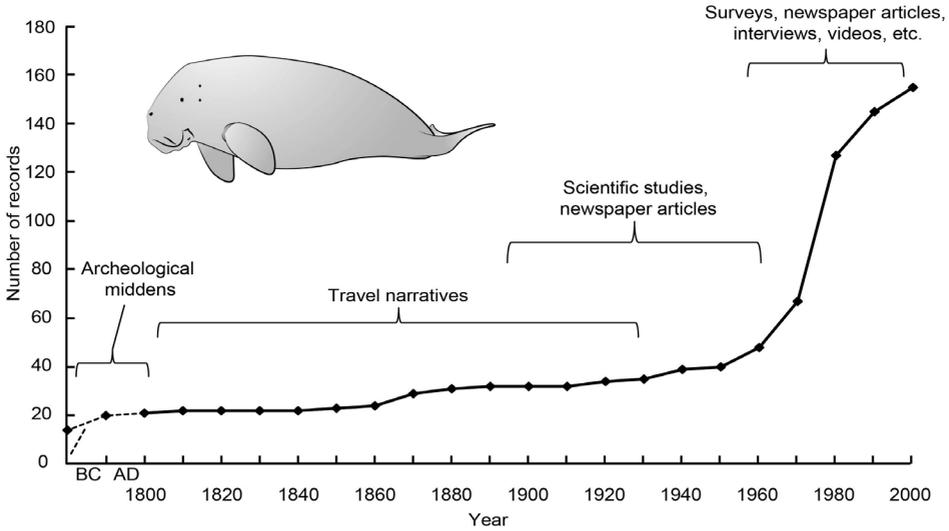


Figure 2. Dugong discovery curve for The Gulf. Interest in Dugongs peaked in the 1980s due to the Nowruz oil spill in Iran, which was thought to have eradicated the local population.

Data compiled from historical records represent a small fraction of the total number of actual dugong encounters in the Gulf. Relying solely on the historical evidence would likely result in an underestimation of the past distribution and abundance of dugongs. Therefore, we compare dugong densities in the Gulf with densities found in other parts of their range as a proxy for overall population viability in the region. Thirty-six estimates of dugong densities on seagrass beds within their entire range were compiled from peer-reviewed literature (Al-Abdulrazzak, 2015), and the mean ratio (0.878 individuals \cdot km⁻²) was applied to the total suitable habitat in the Gulf.

Results

Historical accounts of Dugongs were found in all countries in The Gulf except for Iraq and Oman (which have limited coastline in the Gulf; Figure 1). The majority of records were found in the UAE (30%) and Bahrain (27%), followed by Saudi Arabia (11%), Iran (5%), Qatar (4%) and Kuwait (2%). Comparing pre- and post-1950 records indicates that the population may have experienced a range contraction of up to 26%, from 41,236 km² prior to 1950, to 30,606 km² after 1950. This is mainly due to records being found in Kuwait and Iran, which were previously thought not to have Dugongs (Figure 1).

A cumulative curve of Dugong records indicates a sharp increase in records in the 1980s, coinciding with interest from the 1983 Nowruz oil spill (Figure 2). The types of records containing information on dugongs changed over time; travel narratives dominated from 1800–1930s, while scientific studies began in the early 1900s. Interest from news media began in the mid-1900s, long after the start of dugong exploitation. Perceived abundance of Dugongs has generally declined in the Gulf from ‘abundant’ and ‘common’ through the 1850s, to ‘rare’ starting about 1950 (Figure 3). Our Dugong density calculations yield an estimated 8,738 \pm 2,953 individuals for the region (See Al-Abdulrazzak 2015 for detailed calculations).

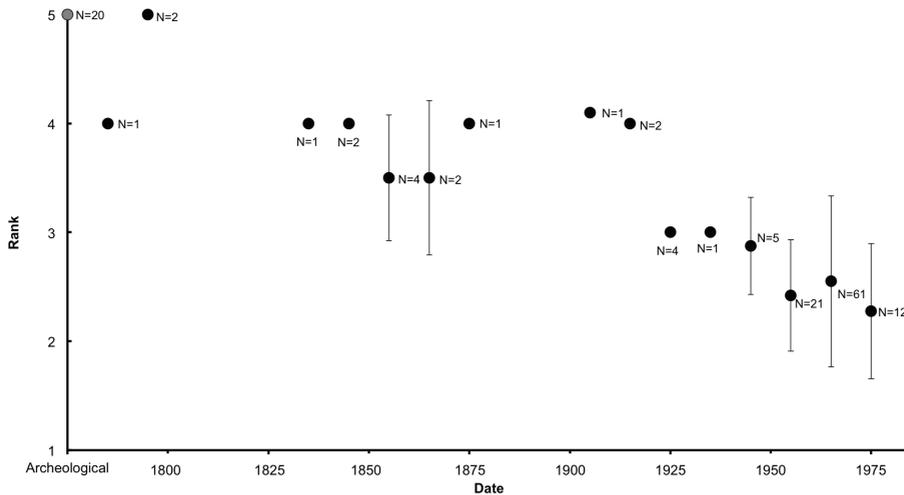


Figure 3. Changes in the perceived abundance of Dugongs in The Gulf through time (1 = absent, 2 = rare, 3 = present, 4 = common, 5 = abundant).

Discussion

The first field survey for dugongs in the Gulf was conducted in 1986, long after populations were exploited. Aerial surveys conducted by Preen (1989) indicated that they were restricted to the southern and southwestern coastline between Ras Tannurah in Saudi Arabia and Abu Dhabi in the United Arab Emirates (Figure 1). Within this area the population was estimated to be $7,307 \pm 1,302$ individuals. Our methods for the entire Gulf yield estimates of $8,738 \pm 2,953$ individuals, suggesting that despite the population being the second largest in the world, their average density is much lower than at other sites in the Indo-Pacific such as the Andaman coast in Thailand (1.2 individuals \cdot km $^{-2}$; Hines, Adulyanukosol, & Duffus, 2005). This may indicate that their populations in the Gulf are more impacted than previously considered and may explain people's perception of declining Dugong abundance (Figure 3).

Contrary to previous studies (Preen, 1989; Preen, 2004), historical records (as well as modern sightings in the case of Iran: Keijl & van der Have 2002; Braulik et al., 2010) suggest that Dugongs had a larger range than previously thought. Their present range may be about 74% of the historical range. Thus, setting conservation targets on partial information may result in lowered expectations for the ecological role of Dugongs. For example, although the IUCN lists populations in Iran to be 'vagrant', the findings from this study suggest a past resident population, which has management implications that were previously not considered. In addition, based on the 1986 survey (Preen, 1989), the sustainable annual take is 60–120 dugongs (2–4%). However, this estimate is based on a population that is thought to be relatively stable, without consideration of its historic 'pristine' population, and therefore, the take limits may be set too high.

Dugongs face a number of threats in the Gulf due to rapid coastal development including dredging, trawling, and land reclamation, all of which damage their crucial seagrass habitats. Several large dredging and reclamation sites occur within critical dugong habitats in the Gulf, such as the seagrass beds of the Gulf of Salwa, between

Saudi Arabia and Qatar (Sheppard et al. 2010; Sale et al., 2011). Dredging may increase salinity by impeding water flow (Marsh et al., 2002), and thus further threatening seagrass beds. Future Dugong management plans should take into consideration the impacts of dredging from local coastal developments on Dugong habitats, especially in light of this study's findings that Dugong's range may be larger than previously thought.

Dugongs are also captured as incidental bycatch in gillnet and driftnet fisheries. Interviews with fishers in the UAE suggest that dugongs are most often caught in 14–18 cm gillnets targeting kingfish (*Scomberomorus* spp.) and sharks (Baldwin & Cockcroft, 1997). An average of 15 new Dugong carcasses are seen along the coastline of the UAE every year and are thought to be discarded bycatch (EAD 2016). In some cases some Dugong meat is missing from the carcasses, indicating that some fishers will take a portion of meat for their own consumption. Currently, no bycatch mitigation efforts are enforced. Left unchecked, this may lead to further declines in the local dugong population (Figure 3).

Oil spills are common in the Gulf and two of the largest spills ever recorded occurred during the Iran-Iraq War in 1983 and the Gulf war in 1991, and resulted in large Dugong mortalities. The Strait of Hormuz is considered the world's most important 'oil chokepoint' with an oil flow of 17 million barrels per day in 2013, about 30% of all seaborne-traded oil (EIA, 2014). The present-day distribution of dugongs in the Gulf corresponds with habitats most at risk from oil pollution, due to the location of oil loading terminals in the immediate vicinity (Marsh et al., 2002). Moreover, it is thought that the counter-clockwise current in the Gulf will force oil-polluted water from the north-western Gulf, where the majority of oil extraction occurs, to the centre of dugong habitats in the southwest (Marsh et al., 2002). Therefore, management plans for the Gulf should be considered 'holistically' as impacts from oil extraction in the north can still affect dugongs within their current range in the southwest.

Historical accounts such as those by naturalists or archaeological records hold clues to the past population abundance and distribution of marine mammals. As we gain a better understanding of the historical trajectories for Dugongs in the Gulf, the need for improved management becomes clearer, which will hopefully garner public support for greater conservation initiatives in the region. A tri-party agreement signed in 2014 between ExxonMobil Research Qatar, Qatar University, and Texas A&M University may be a good first step into setting appropriate management targets in place. However, countries must work in coordination despite the difficult political climate to protect transboundary species such as the dugong.

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Disclosure Statement

No potential conflict of interest was reported by the authors.

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