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Large dugong (*Dugong dugon*) aggregations persist in coastal Qatar

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Dugongs (*Dugong dugon*) are large herbivorous marine mammals of the order Sirenia commonly referred to as sea cows. Due to their herbivorous diet, feeding and foraging dominate their natural history. Dugongs have evolved a specialized feeding apparatus for efficient grazing and processing of sea grass, which can occur by cropping blades or the excavation of roots and rhizomes (Marsh *et al.* 1999; Marshall *et al.* 2003; Lanyon and Sanson 2006*a, b*). The excavation of seagrasses results in signature benthic feeding trails in which 60%–90% of the vegetation may be removed (Heinsohn *et al.* 1977; Preen 1992, 1995; Marsh *et al.* 2011). Sediment plumes from dugong foraging are easily observed during aerial surveys. Due to their low reproductive output, dugongs are vulnerable to perturbations in their environment, such as habitat degradation, fisheries bycatch and contaminants (Baldwin and Cockcroft 1997, Marsh *et al.* 2011, Reynolds and Marshall 2012) from which populations may be slow to recover.

Dugongs of the Arabian Gulf are consistently referred to as the largest population outside Australia, and the Gulf has been cited as the most important region for dugongs in the western portion of their range (Marsh *et al.* 2002, 2011). These statements are based on extensive surveys conducted 30 yr ago in which the entire Arabian Gulf population was estimated at approximately 6,000 dugongs (Preen 1989, 2004; Preen *et al.* 2012). However, relatively little is known regarding dugong distribution, population biology, and their natural history in this region of the world (Al-Abdulrazzak and Pauly 2017). The population status and natural history of dugongs in the Arabian Gulf are of interest because the region is

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experiencing rapid and extensive coastal development, oil and natural gas activities, and increased dredging and sedimentation. Despite being protected nationally (Qatar Ministry of Municipality and Environment) and internationally (International Union for Conservation of Nature; Marsh and Sobtzick 2015), localized fishing activity appears to be resulting in substantial incidental bycatch in the region (personal observation). Furthermore, the Arabian Gulf is an extreme environment with high ambient temperatures (Pal and Eltahir 2016), limited freshwater input, and evaporation rates in excess of 2 m/yr, resulting in hypersaline marine habitats (Meshal and Hassan 1986). The hypersaline conditions constrain seagrass biodiversity; only three species (*Halophila stipulacea*, *H. ovalis*, and *Halodule uninervis*) are found in the Arabian Gulf (Phillips 2003, Erfteimeijer and Shuail 2012). Minimal winter water temperatures that range between 12°C and 16°C from southern Saudi Arabia to Abu Dhabi in the United Arab Emirates (UAE; Kinsman 1964, Coles and Fadlallah 1991) indicate that this region is at the northern limit of the dugong's population range in the Arabian Gulf. In Australia, dugongs make seasonal movements in response to lower water temperatures of <17°C–18°C (Sheppard *et al.* 2006), but in general appear to be restricted to water temperatures that range from 15°C to 19°C (Anderson 1986, Hodgson 2004). Preen (1989) also reported a seasonal change in dugong distribution in the Arabian Gulf that he assumed was related to water temperature.

The State of Qatar is important to the population health of dugongs in the Arabian Gulf. Although the majority of dugongs in the region have been found in the UAE (Preen 1989, 2004; al-Ghais and Das 2001), Qatar shares two of the three most important regions for dugongs in the Gulf. These important regions are: (1) the coastal area in the UAE near Murawah Island, (2) the northwest coast of Qatar from the Zekreet peninsula and the Hawar Islands to Ras Ushayriq and offshore to Fasht Adhm, Bahrain, and (3) the coastal region of Saudi Arabia between the UAE and Qatar (Fig. 1; Preen 1989, 2004; Marsh *et al.* 2002). In 1986, the number of dugongs reported within Qatar's coastal waters was approximately one-third of the Arabian Gulf population (2,164 individuals; Preen 1989, 2004). In fact, the largest single dugong group ever observed was located between Qatar and Bahrain during Preen's winter survey (5–6 March 1986; Preen 1989, 2004; Marsh *et al.* 2002). Two large groups, numbering 577 and 97 dugongs, respectively, were sighted within 1 km² of each other (674 individuals total; Preen 1989). Although Bahrain and the UAE (Environmental Division, Abu Dhabi [EAD]) have pursued dugong conservation programs (*e.g.*, al-Ghais and Das 2001; EAD 2005, 2015, 2016; Preen *et al.* 2012), little additional research has been conducted in Qatar to further characterize dugong population abundance and distribution. Available evidence points to the northwest region as particularly important for Qatari dugongs and perhaps the entire Gulf. Therefore, we initiated several exploratory *ad hoc* boat and helicopter surveys of the region where Preen reported his large dugong group. The objectives of these surveys were to determine whether dugongs are still in the region, document their presence, document the timing of their arrival to, and departure from, the area, and plan for future systematic effort-based surveys. Many Qatari biologists have been skeptical that dugongs still exist in Qatari coastal waters, and documenting their presence is integral to gaining government support for continued dugong conservation efforts. Investigations regarding the distribution, abundance, and natural history (*e.g.*, foraging ecology and reproductive biology) throughout the Arabian Gulf are necessary to provide information to wildlife managers that seek to conserve dugongs in their country and the region.

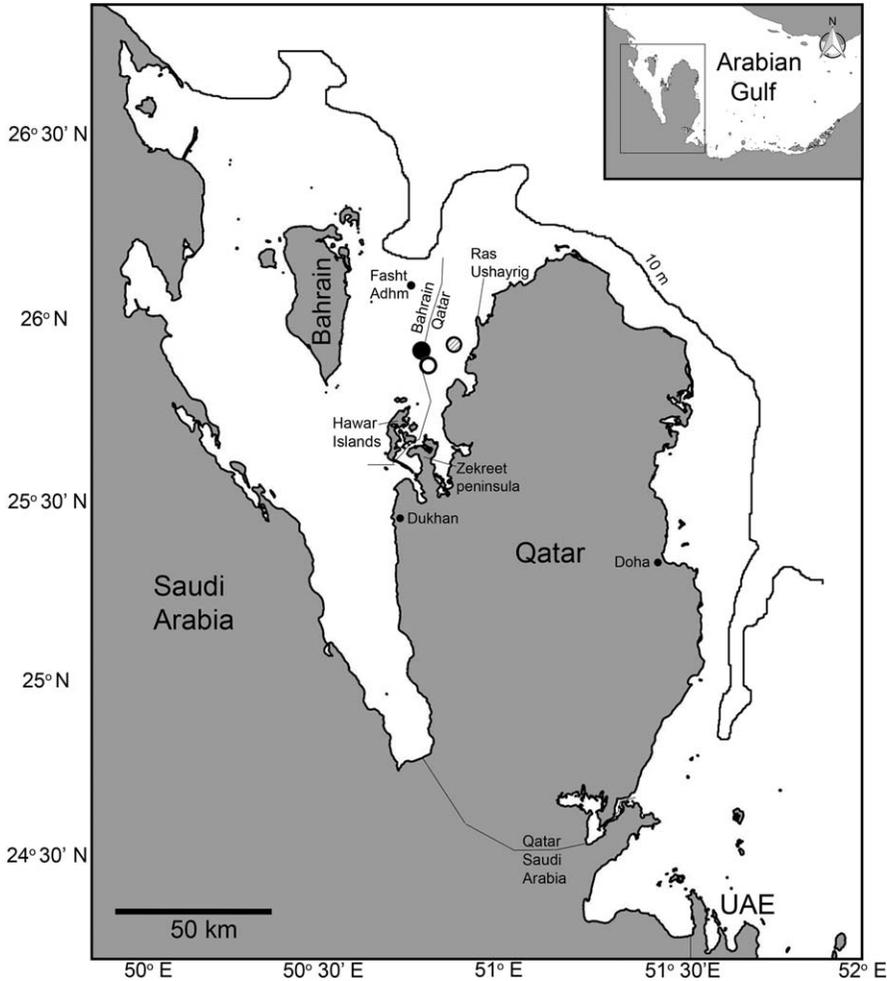


Figure 1. Location of dugong herds in northwest Qatar. Black lines demarcate 10 m bathymetric line (after Preen 2004). Thin black lines indicate Qatar-Bahrain border. White circle indicates the location of a dugong herd in excess of 500 individuals reported in this study. Black circle indicates location of a large dugong herd reported by Preen (1989, 2004). Hashed circle indicates location of herds during the 2015 helicopter survey.

Four boat-based surveys were conducted to locate dugongs: on 2 January, 8 February, and 9 and 17 March 2015. In addition, we conducted two helicopter surveys on 2 and 3 December 2015. Our efforts focused on the northwest coastline region. We did not conduct transect-based boat-surveys since a local member of our Qatari team was familiar with the area and knew where dugongs had been found. Our February 2015 boat-based surveys incorporated an unmanned aerial vehicle (UAV; DJI Phantom Quadcopter drone) outfitted with a GoPro Hero 4 camera. The UAV was flown approximately 75 m over the herd for 15 min and was always

in sight by the operator (Abdulla Al-Naem, Qatari Private Engineering Office) on the vessel. There was no observed effect on dugong individuals by the overflight of the UAV. Still images from the UAV video footage were used to quantify dugong group size. Two readers, blind to each other's counts, conducted six independent counts of individuals and the number of cow-calf pairs. We defined cow-calf pairs as (1) two animals <0.5 body length apart, (2) traveling in the same direction, and (3) one dugong (calf) smaller than the other (cow). In addition, during the February 2015 survey, we conducted two short, *ad hoc* snorkeling surveys (45 min each) adjacent to where dugongs were located to determine benthic composition, water depth, and to document dugong behaviors underwater. The helicopter in December was used to explore the greater northwest region where dugongs were found by boat-surveys (Fig. 1), as well as to determine whether dugong aggregations were in the area earlier in the winter season. Helicopter surveys departed from Doha and flew directly to Dukhan on the west coast. Since the Bahraini border is very close to Qatar near Dukhan, the helicopter flew along the coast to the tip of the Zekreet peninsula and commenced transects at 1,000 m. Transects were conducted from Zekreet to Ras Ushayriq, perpendicular to the coast, out to the Bahraini border and were spaced at 0.8 km intervals. Transects were conducted only to completely explore the region. Observations were made on the right side of the helicopter only, with the door open. Still images were taken with a Nikon D810 DSLR camera and a 400 mm lens. Video was taken with a Sony HD Handycam attached to a neck harness for stability to document dugongs and to conduct estimates of the number of individuals and cow-calf pairs. As before, two readers, in the blind, conducted six independent counts of individuals and the number of cow-calf pairs from DSLR images. To investigate the correlation of sea surface temperature (SST) with dugong aggregations, we chose a location in the middle of the three observations (Fig. 1; 50.80032°E, 25.90339°N) and extracted monthly-averaged sea surface temperature (°C) from the MODIS Terra (Moderate Resolution Imaging Spectroradiometer) satellite system at a 4 km resolution (<http://podaac.jpl.nasa.gov>). SST data extraction was performed using the "raster" package (Hijmans *et al.* 2016) in the R statistical software version 3.3.3 (R Core Team 2017).

During each of the first three boat surveys we consistently, and repeatedly, located a single large group of dugongs between Qatar and Bahrain (Fig. 2) that was comprised of several hundred individuals. Only 2–3 individuals were observed outside this large group during any of these surveys. Using the UAV images from February 2015, the group size was estimated to be 508 individuals within an area <1 km². Cow-calf pairs comprised 9.9% of the group (51 pairs; Fig. 2). Although the entire water column could be visualized, we were not able to count all individuals in the image due to glare. Therefore, our observed group size is an underestimate. Underwater observations of this large group in February *via* mask and snorkel adjacent to this large group verified the presence of numerous cow-calf pairs and that dugongs were foraging upon a mixed stand of *Halodule univernis* and *Halophila ovalis* in clear, shallow water (<6 m). Samples of both species of seagrass were collected and positively identified; the mixed seagrass habitat was likely greater than 10 km² but we were not able to measure the area. Foraging behavior was evident from sediment plumes, signature dugong benthic feeding trails through seagrass, and direct observation of dugongs feeding. Large aggregations of dugongs were not found in March and had apparently dispersed. Only two small groups of dugongs (2–3 individuals) were observed in a much wider region, instead of a single large group, during this survey. However, it is possible that a large herd was missed due



Figure 2. Large, single herd of dugongs estimated at 508 individuals located near the Qatar Bahrain border, 8 February 2015. *indicates the presence of representative cow-calf pairs. Location is indicated by solid white circle in Figure 1.

to the lack of effort-based transect surveys. As in other studies, the use of UAVs will be a valuable tool in this region (Hodgson *et al.* 2013, 2016). During the helicopter-based survey in December we observed two large herds comprised of 226 and 166 dugongs, respectively (Fig. 3). Both groups were foraging (based on plumes of sediment and individuals diving repeatedly to the bottom), and were observed within a few kilometers of each other during a single survey. The entire water column was visible and dugongs could be observed foraging on the seafloor. Cow-calf pairs comprised 5.8% and 5.4% of each group, respectively (13 pairs and 9 pairs, respectively; Fig. 3). Mean monthly SST for 2015 demonstrate that temperatures ranged from 18.03°C to 34.44°C. SST increased in March and fell again in November/December in the northwest region of Qatar where dugongs were observed (Table 1). SST was lowest December–March (Table 1 in bold). This pattern of SST is representative of prior and subsequent years for this location.

Our observations of wild dugongs in northwest Qatari coastal waters are consistent with Preen's (1989) winter observations of dugongs in this same region and with Hodgson's (2009) observations of a large herd (50 individuals) in nearby Bahrain. We consistently located a single large herd of several hundred animals over the course of three of the four boat-based surveys between January and March 2015 in northwest Qatari coastal waters, as well as located two separate herds, comprised of several hundred animals, by helicopter in December 2015. The locations of herds that our group observed were relatively consistent (locations in January, February, and March were within 5 km of each other) and were in the same approximate area reported by Preen (1989). However, we were not able to ascertain if these were the same group or individuals in any of our surveys. The largest single herd that we were able to count was comprised of 508 dugongs, but this is certainly an underestimate. Based on the large area on photographs obscured by glare, the size of this herd could easily have been 600 individuals. Preen (1989) observed two adjacent large groups, 577 and 97 individual dugongs (total = 647), respectively, during his



Figure 3. Two dugong herds observed from helicopter survey. A. large herd estimated at 226 individuals. B. large herd estimated at 166 individuals, 3 December 2015. *indicates the presence of representative cow-calf pairs. Location is indicated by hashed circle in Figure 1. Dark regions on the seafloor indicate seagrass habitat bounded by sand habitat.

1986 winter survey at nearly the same location between Qatar and Bahrain (Block 8). His two large groups were observed in an area $<1 \text{ km}^2$, similar to our observations in December 2015. Our estimate of 9.9% cow-calf pairs in February 2015 is similar to Preen's (1989) range of 7%–12.9% at this location from this particularly

Table 1. Mean monthly SST 2015. Months and SST values in bold indicate the presumed timing of large dugong aggregations present at the study location.

Month	SST
January	18.03
February	19.69
March	21.03
April	24.04
May	29.56
June	31.15
July	33.33
August	34.44
September	33.05
October	30.81
November	26.16
December	20.66

large herd. Dugong group size was smaller in December 2015, which supports our hypothesis (and anecdotal information from local fishermen) that dugongs begin arriving in this region in late November or near the beginning of December. Cow-calf percentage at this time was also lower than that reported for the previous February. Overall, Preen (1989) estimated that calves comprised 14.5%–15.3% of the Arabian Gulf population. Our values are comparable to data from other locations such as Palau (13%–24%; Brownell *et al.* 1981) Shark Bay, Australia 11%–12% (Anderson 1982), northeast Queensland, Australia 7.7%–16.3%; (in Preen 1989), and Moreton Bay, Australia 1.31%–7.04% (Lanyon 2003). However, the proportion of calves can be widely variable; for example, calf proportion in Hervey Bay, Australia ranged from 2.2% to 22% and was susceptible to environmental conditions (Fuentes *et al.* 2016).

Our observations of calf location relative to their mother's agree with Preen's (1989) and Anderson's (1982) observations in that calves could be found immediately beside their mothers, on top but also below (based on our underwater observations) and therefore our cow-calf pair estimates are also likely an underestimate. Since our boat surveys were opportunistic and qualitative, it is possible that other large aggregations were also present in the area, despite our efforts to search 5 km north and south of the large herd's location and toward the coastline. Our search was constrained by the international border with Bahrain. A more thorough and systematic search of the region in December 2015 by helicopter survey suggests that dugongs begin to aggregate in the region during that time, but additional systematic surveys need to be conducted to verify the timing. Our local Qatari team members, as well as fishermen in this part of Qatar, report that dugong groups of several hundred individuals can be found in this specific area every winter, and that the animals disperse when water temperatures increase in March. Such information regarding yearly and consistent winter aggregations of dugongs in this location, followed by dispersion in March is consistent with Bahraini fishermen interviews and water temperature values reported by Preen (1989) and this study. Preen (1989) suggested that warm water springs in the area may explain why dugongs aggregate in this region. Unfortunately, water temperature was not directly recorded during this

study. Freshwater springs do occur in this area but are anecdotally reported to be fewer in number and less forceful than in the past due to extensive drilling of water wells, and subsequent lowering of the water table, on both the Bahraini and Qatar side of the border. The reason for, and timing, of this aggregation(s), remains unclear but is likely tied to behavioral thermoregulation.

Preen (1989) reported that the substrate in this region of Qatar was not visible from the air, but that Bahraini satellite-based maps indicated a wide coverage of dense seagrass (Vine 1986) in approximately five meters of depth. Our direct observation of the substrate confirms a mixed, dense area of *Halodule univernis* and *Halophila ovalis* in 6 m of water, but water depth in the entire area was variable (approximately 1–8 m) based on our vessel's navigational equipment. Our helicopter surveys suggest vast areas of seagrass habitat in the region (Fig. 3), but systematic ground-truthing needs to be conducted to corroborate this observation. The main dugong activity observed during all our surveys was foraging. Dugongs continuously dived and foraged on vast, substantial and apparently healthy seagrass habitat in this particular region.

There is a general consensus among local Qatari fishermen and local biologists that dugong populations in Qatar are in decline. In our experience, insofar as this is true, it is likely due to negative impacts from coastal development, habitat degradation, and the high number of fisheries bycatch despite the fact that dugongs are protected. Due to the expansive seagrass habitat, the high number and density of dugongs recorded in both Qatari and Bahraini coastal waters during the winter (Preen 1989, 2004; Hodgson 2009; this report), this region is likely of particular importance to the population of dugongs in the Arabian Gulf and their management. Since these aggregations comprise a significant proportion of the Arabian Gulf dugong population, it is important to the management of the species that conservation and research efforts in Qatar be focused in this northwest region, the habitat, the collection of environmental parameters and the purpose for these aggregations during this time of the year. Currently the region has experienced relatively minimal coastal development. To date, most coastal development in Qatar has occurred on its east coast, but this will change in the near future. This study demonstrates that large groups of dugongs still frequent coastal waters of northwest Qatar and provides a solid justification and foundation to expand conservation and research efforts to include effort-based systematic boat surveys in this region, and throughout Qatar. This study also provides valuable information for planning country-wide aerial surveys to further characterize dugong distribution and abundance in Qatar and throughout the Arabian Gulf. International efforts are needed to fully characterize and protect dugongs in this region. Results of this study have been provided to local wildlife biologists that make management recommendations within the Qatar Ministry of Municipality and Environment regarding dugong conservation, and we have advocated that a marine protected area be established in this region. At the time of this publication, the efforts of our research team continue and the Qatar Ministry of Municipality and Environment is an active partner in these activities.

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