ARTICLE IN PRESS

Egyptian Journal of Aquatic Research xxx (xxxx) xxx

HOSTED BY

ELSEVIER

Contents lists available at ScienceDirect

Egyptian Journal of Aquatic Research

journal homepage: www.sciencedirect.com/locate/ejar

Evidence of the occurrence of a large dugong in the Red Sea, Egypt

Ahmed M. Shawky

Technical Office of the Minister of Environment, Egypt

ARTICLE INFO

Article history:
Received 7 March 2019
Revised 14 July 2019
Accepted 2 August 2019
Available online xxxx

Keywords:
Dugong dugon
Feeding trails
Seagrass
Marsa Alam

ABSTRACT

Three feeding trails of a large dugong with a width of 30 cm were recorded at 11 m depth at Marsa Hermez off the Egyptian Red Sea coast (25.321° N and 34.744° E) on the 23rd January 2019. Additionally, four other feeding trails (with widths of 6 cm, 15 cm, 20 cm and 25 cm) were also noted within the seagrass patches. The small size of a trail beside a larger one suggests the presence of calf with mother. Thus, the present results demonstrate indirect evidence for the existence of a large female dugong in the Red Sea. The present study documents the presence of female dugongs with calves in a key habitat, which is important for dugong conservation in Egypt.

Introduction

Dugongs (*Dugong dugon* Müller, 1776) are herbivorous marine mammals. They are represented by only one surviving species in the order Sirenia, family Dugongidae (Marsh et al., 2011). They are listed as vulnerable on the IUCN Red List of Threatened Species. Moreover, dugongs are found in the tropical and subtropical borders of the Indo-Pacific region from the east coast of Africa to the Red Sea and Arabian Gulf, as well, through the Indian Ocean to the east coast of Australia and beyond that into shallow areas of Melanesia and parts of Micronesia in the Pacific Ocean (D' souza and Patankar, 2013; Marsh, 2002; Nishiwaki and Marsh, 1985; Pilcher et al., 2017). Dugongs feed on shallow coastal seagrass, and during their feeding, they excavate long winding feeding tracks in seagrass beds that are termed as feeding trails (Anand, 2012; Mizuno et al., 2017; Preen, 1992).

The width of the feeding trails normally ranges from 10 to 25 cm (approximately the width of a dugong's facial disk) and the length ranges from 30 cm to several metres (Anderson and Birtles, 1978; Aragones, 1994; Preen, 1992). In the Egyptian Red Sea, the average widths of feeding trails are 17.2 ± 4 cm and 17.6 ± 1.3 cm in Marsa Alam and Wadi El-Gemal National Park, respectively (Shawky, 2018). In the Red Sea, data on dugongs are limited; therefore, further studies are needed to confirm the status of this species (Nasr et al., 2019).

Evidence of dugongs using a locality can be obtained from their feeding trails. The challenge of using feeding trails is the difficulty to determine the number of animals creating them. This technique enables to distinguish the feeding trails of dependent young (and therefore their mothers who feed close to them). D'Souza et al., (2015) studied the way by which dugongs use their habitat and move between foraging grounds; they showed that this understanding has significant consequences for the management of these mega-grazers populations in Andaman Island and Nicobar Archipelago, India. Those authors were able to determine the characteristics of seagrass meadows that dugongs use continuously and they tracked the persistence of use (presence of feeding trails) of these meadows over several years. Further studies regarding the relationship between the total length and muzzle width as well as between the muzzle width and the feeding trail width are needed to be investigated.

Shawky et al. (2017, 2019) documented 30 identified dugongs within 22 sites in the Egyptian Red Sea using photo identification technique, much more information about the number of dugongs using a site (and therefore the relative importance of the site) is essential to be recorded. In this study, we provide a record for the biggest feeding trail width ever recorded in the Red Sea, Egypt.

Materials and methods

The current study was performed at different sites in the Egyptian Red Sea, as a part of a dugong project funded by Rufford Foundation (26053-B) and entitled "Analysis of Feeding Trails Provides Evidence of the Number of Dugongs Excavating Seagrass at Key Habitats Seasonally in the Egyptian Red Sea". Marsa Hermez

Peer review under responsibility of National Institute of Oceanography and Fisheries.

E-mail address: ahmedshawky_7@hotmail.com

https://doi.org/10.1016/j.ejar.2019.08.001
1687-4285/

Please cite this article as: A. M. Shawky, Evidence of the occurrence of a large dugong in the Red Sea, Egypt, Egyptian Journal of Aquatic Research, https://doi.org/10.1016/j.ejar.2019.08.001

(25.320° N, 34.747° E) lies 30 km north of Marsa Alam city (Fig. 1) and it was one of the main sites studied. It has a sandy bottom facing the outlet of Abou Dabbab valley that was flooded during the winter months. The data were collected by SCUBA diving and digital photos for the seagrass and feeding trails were recorded using HD digital camera (GoPro Hero 4 Silver Edition with a red filter and set in 4 K mode). Water depth and sea temperature were recorded using the diving computer. During the project, the width of the dugong's muzzle and its body length were measured underwater using a laser photogrammetry technique (Rohner et al., 2015).

A laser photogrammetry system with two beams of green laser light (Moray Inc.; < 5 mW power) with calibrated 20 cm distance was mounted on a housed GoPro camera and the lens is set in wide view. To calculate the correction factor, a grid of 10 × 10 squares (5 cm each) was photographed and the pixels across the diagonal of the middle square was measured then multiplied by 2, 3, 4, 5, 6, 7, 8, 9 and 10 respectively. The observed vs. expected values were plotted in Microsoft Excel program and a linear regression was fitted to calculate any changes with lens curvature and the setting of the camera. Photos from two meters away were taken perpendicular to measure the total body length and muzzle width of the dugong body after Heinsohn (1981). All photos were analyzed to measure the distance using Image J Software. Using this technique, a relationship between the dugong total body length, muzzle width and feeding trail width will be calculated, then the estimation of the population size could be determined from the presence of feeding trails on the seagrass bed.

Feeding ecology data were collected according to Preen (1992). Feeding trail dimensions (width "cm"; length "m") were measured by means of a plastic tape measure. Two 20-meter line transects were constructed in the seagrass area. Seagrass abundance was assessed using 10 randomly located quadrats (0.25 m^2) at 2-meter intervals along each transect (20 quadrats/site). The relative abundance of seagrass in each quadrat was estimated by counting the shoots of each species. The percentage of dugong grazing was measured using 0.1 m^2 quadrat (10 cm × 10 cm) by comparing the abundance of seagrass inside and outside the feeding trails. This was carried out by haphazardly locating the quadrats along several feeding trails and another equivalent number of matched quadrats were positioned immediately adjacent to them (2–5 cm away). The amount of seagrass removed from the feeding trails was calculated by deducting the mean abundance of seagrass inside and outside to the feeding trails. Statistical analysis using one-way ANOVA by excel program will be conducted to calculate the significant difference of grazing.

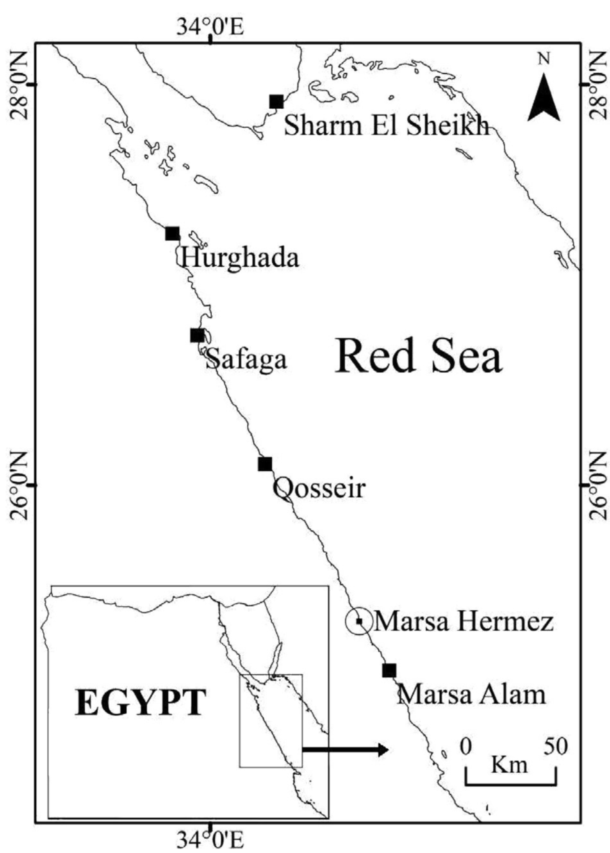

Fig. 1. Map of the Egyptian Red Sea shows the location of Marsa Hermez.

Results

On the 23rd of January 2019, three dugong feeding trails with a width of 30 cm were observed at 11 m depth and 250 m offshore at Marsa Hermez (25.321° N and 34.744° E), Fig. 2. The mean density of the seagrass per 1 m^2 is 1225 ± 133 (Mean shoot count ± SE), which was established for *Halophila stipulacea.* The feeding ecology data for the feeding trails are presented in Table 1. The results confirmed the presence of a large dugong that consumed 1.55 m^2 of seagrass. The mean percentage of grazing was 97% along the three feeding trails. A highly significant difference was found between the feeding trail lengths and the amount of seagrass removed by manipulation of dugong grazing (one-way ANOVA: P = < 0.05). The water temperature was 23 °C. In addition to the current findings, four other feeding trails with different widths of 6 cm, 15 cm, 20 cm and 25 cm were also observed within the same seagrass bed, Fig. 3. The results of laser photogrammetry are not included in the current research and it will be published in the further study.

Discussion

The presence of feeding trails with a width of 30 cm is considered as indirect evidence for the existence of a large dugong. Maximum width of the dugong's feeding trails was reported by several authors, it was recorded as 23.3 cm by Anderson and Birtles (1978); 28 cm (Apte et al., 2019), 22.7 cm (Preen, 1992); 26 cm (Shawky, 2018) and 25 cm (Thayer et al., 1984). Therefore, the present width of 30 cm is greater than the previous records.

The maximum length of dugongs that has been consistently measured is 3.31 m (Nishiwaki and Marsh, 1985), whereas females are slightly greater in length than males (Marsh, 1980). Further, dugongs weigh greater than 420 kg (Spain and Heinsohn, 1975). On the 30th of July 1959, the biggest dugong with a body length of 4.06 m and around 1000 kg weight was stranded at Bedi Bunder, Gulf of Kutch, India (Mani, 1960). On the other hand, in the Egyptian Red Sea, 16 dugongs were recorded around Hurghada, and the biggest dugong recorded was a female with a body length of 288 cm and a muzzle width of 27 cm (Gohar, 1957). In the current study, the dugong with a feeding trail of 30 cm width is a result of a large female that may be close to 4 m in total length. If the further results by the laser photogrammetry regarding the relationship between the muzzle width and the body length are confirmed, then this finding will be considered the evidence for the existence of the largest dugong in the Red Sea to date.

In the present study, five different sizes of feeding trails were recorded (i.e. with a width of 6 cm, 15 cm, 20 cm, 25 cm and 30 cm). In Marsa Hermez, Shawky et al. (2017; 2019) reported five different dugongs (i.e., three males, one female and one calf) using a photo identification technique. In addition, a feeding trail of a 7 cm width was recorded in Wadi El-Gemal National Park, located

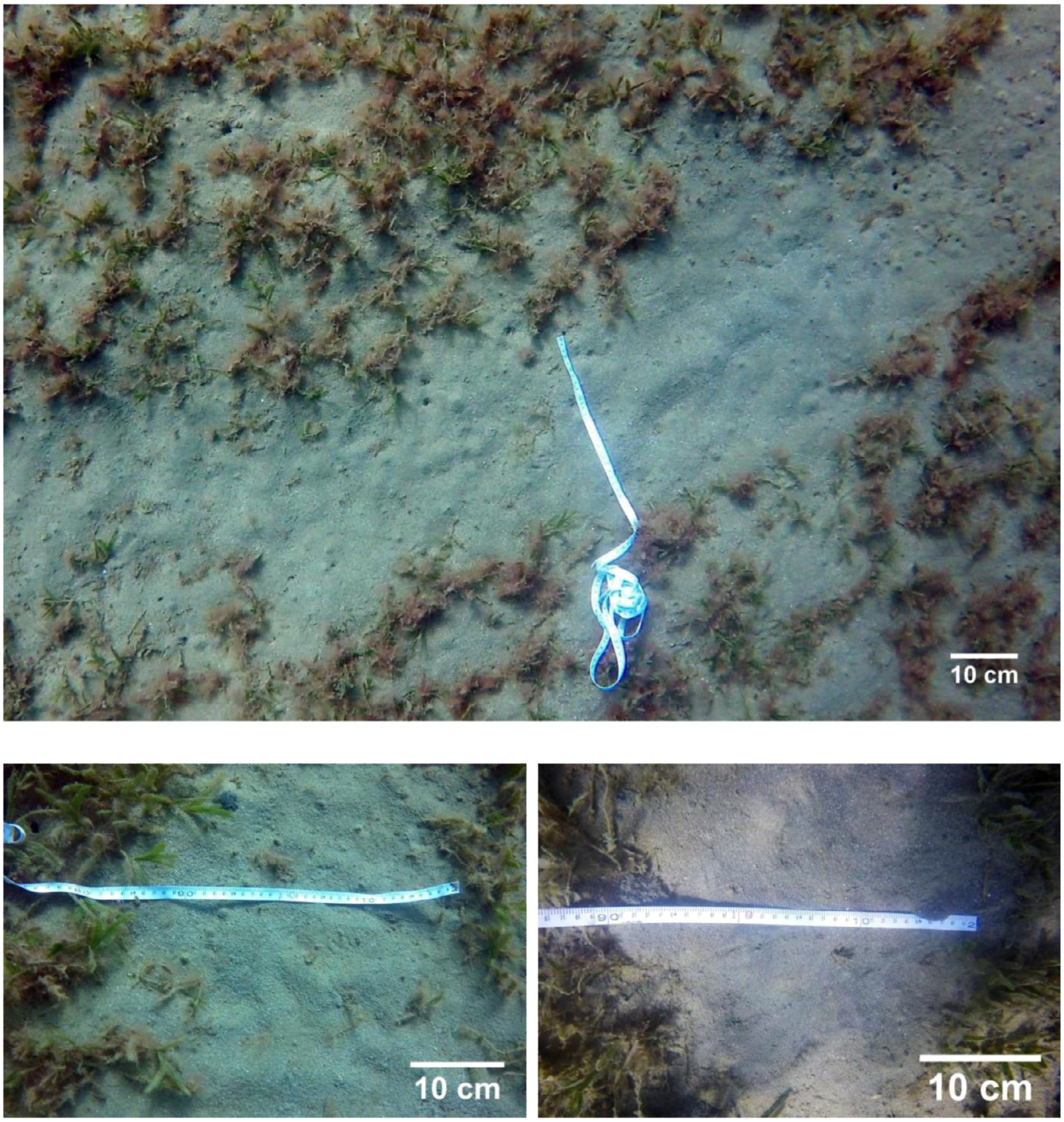

Fig. 2. Dugong feeding trails with a width of 30 cm at Marsa Hermez.

Table 1
Summary of the seagrass abundance for the three feeding trails (30 cm width).

Trail No.	Trail Length (m)	Seagrass abundance (Shoot density/m^2)			Seagrass Reduction (% grazing)
		Outside the feeding trail	Inside the feeding trail	n	
1	0.9	2529	57	7	98
2	1.95	1330	40	10	97
3	2.3	830	30	20	96

50 km south of Marsa Alam (Shawky et al., 2016). Therefore, our results confirm the presence of at least one large female dugong with her calf. In a previous study, 30 dugongs were reported with a male–female ratio of 7:1 at the Marsa Alam region (Shawky et al., 2017, 2019). Otherwise, the females tend to visit the feeding areas in undisturbed periods of the day (i.e. late night or early morning) to avoid human disruptions. In this study, the consumption of 1.5 m^2 of seagrass during foraging is requiring energy and this suggests seasonal movements. This behaviour was recorded for the dugongs during their temporal migration and seasonal movements (Cleguer, 2015; Sheppard, 2008). The same behaviour is reported for Florida manatees as they migrate in the winter season to warmer water in the south (Deutsch et al., 2003).

Our conclusion may omit the fact that females of dugongs are not as common as males (Shawky et al. 2017; Shawky et al. 2019), by indirect evidence recorded through measuring the large widths of the feeding trails instead of direct encounters. Also, laser photogrammetry is an accurate and valuable tool for dugong measurements that can be used for estimating the body length from measuring the trail width. Using this technique will detect the spatial and temporal variation of dugongs with different size, mainly the mother with calf that range by measuring growth rates over decades. Thus, it is considered a challenge to successfully re-sighting the migratory dugongs over years and such finding will be pertinent to the understanding of their life-history to improve management and conservation for this threatened species worldwide.

Please cite this article as: A. M. Shawky, Evidence of the occurrence of a large dugong in the Red Sea, Egypt, Egyptian Journal of Aquatic Research, https://doi.org/10.1016/j.ejar.2019.08.001

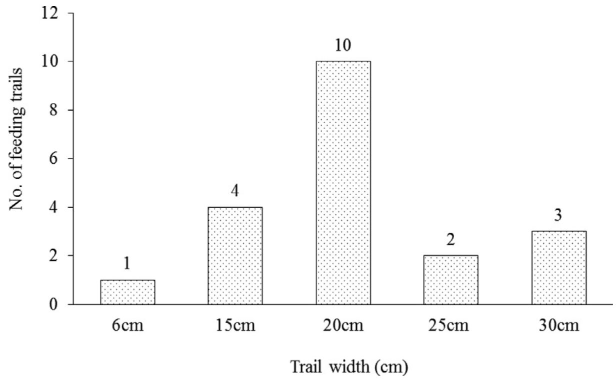

Fig. 3. Widths and numbers of the feeding trails in the study site.

The predicted habitat using Maxent (Phillips et al., 2006) will be used as an input to a simulated annealing algorithm (MARXAN) (Ball et al., 2009). This will be helpful to optimize the area selected for the conservation of the species with the specified targets and along with other factors including cost and other conservation features. The data are used to produce layers of predicted suitable habitat, suitable calving habitat and a predicted density surface of the species over the study region in the Egyptian coast of the Red Sea. The product of the prioritization is assessed against the current marine protected areas (MPAs) system as for the completion of conservation objectives and improved score. Finally, conservation recommendations are formulated for species management. These results will be useful for dugong conservation in the Egyptian Red Sea by identifying key habitats of the female and calf with the goal of declaring them as a dugong protected areas (DPAs) (Marsh, 2002).

Acknowledgement

This study was supported by the financial assistance of the Rufford Foundation (26053-B), which is thankfully acknowledged. I'm delighted to introduce my grateful thanks to Prof. Helene Marsh for her advice and help. I'm pleased to express my sincere thanks to Dr. Mikki McComb- Kobza who kindly edited the English text of the manuscript.

References

Anand, Y., 2012. First record of feeding trails of dugong in Gulf of Kachchh (GoK), Gujarat. Indian For. 138, 968–969.

Anderson, P.K., Birtles, A., 1978. Behaviour and ecology of the Dugong, *Dugong dugon* (Sirenia): observations in Shoalwater and Cleveland Bays, Queensland. Wildl. Res. 5, 1–23.

Apte, D., Parasharya, D., Patel, B., 2019. Feeding trails of Dugong *Dugong dugon* (Müller, 1776) (Mammalia: Sirenia: Dugongidae) in the Gulf of Kachchh, western coast of India. J. Threat. Taxa 11, 13151–13154 https://doi.org/10.11609/jott.4315.11.1.13151-13154.

Ball, I.R., Possingham, H.P., Watts, M., 2009. Marxan and relatives: software for spatial conservation prioritisation. Spatial conservation prioritisation. Quant. Meth. Comput. Tools, 185–195.

Cleguer, C., 2015. Informing dugong conservation at several spatial and temporal scales in New Caledonia (Doctoral dissertation, Université Pierre et Marie Curie, Paris (France); James Cook University. Townsville (Australie), 60–96.

D'souza, E., Patankar, V., 2013. First underwater sighting and preliminary behavioural observations of Dugongs (*Dugong dugon*) in the wild from Indian waters, Andaman Islands. J. Threat. Taxa 1, 49–53 https://doi.org/10.11609/jott.o2002.49-53.

D'Souza, E., Patankar, V., Arthur, R., Marbà, N., Alcoverro, T., 2015. Seagrass herbivory levels sustain site-fidelity in a remnant dugong population. PLoS One 10, (10) e0141224.

Deutsch, C.J., Reid, J.P., Bonde, R.K., Easton, D.E., Kochman, H.I., O'Shea, T.J., 2003. Seasonal movements, migratory behavior, and site fidelity of West Indian manatees along the Atlantic coast of the United States. Wildl. Monogr., 1–77

Gohar, H.A.F., 1957. The Red Sea dugong. Publ. Mar. Biol. Stn Ghardaqa 9, 3–49.

Heinsohn, G.E., 1981. 'Methods of taking measurements, other data and specimen material from dugong carcasses. In: The Dugong: Proceedings of a seminar/workshop held at James Cook University 8-13 May 1979. Marsh, H., (Ed.) James Cook University, Townsville, Queensland, Australia. pp. 228–238.

Mani, 1960. Occurrence of the sea cow, *Halicore dugong* (Erxl.) off the Saurashtra coast. J. Bombay Nat. Hist. Soc. 57, 216–217.

Marsh, H., 1980. Age determination of the dugong (*Dugong dugon* (Miiller)) in Northern Australia and its biological implications. Rep. Int. Whal. Commn., 181–201

Marsh, H., 2002. Dugong: Status report and action plans for countries and territories. UNEDP/DEWA/RS.02/1, Early warning and report series. UNEP. 129–132.

Marsh, H., O'Shea, T.J., Reynolds III, J.E., 2011. Ecology and Conservation of the Sirenia: Dugongs and Manatees. Cambridge University Press, pp. 23–24.

Mizuno, K., Asada, A., Matsumoto, Y., Sugimoto, K., Fujii, T., Yamamuro, M., Fortes, M.D., Sarceda, M., Jimenez, L.A., 2017. A simple and efficient method for making a high-resolution seagrass map and quantification of dugong feeding trail distribution: a field test at Mayo Bay, Philippines. Ecol. Inform. 38, 89–94.

Nasr, D., Shawky, A.M., Vine, P., 2019. In: Status of Red Sea Dugongs BT - Oceanographic and Biological Aspects of the Red Sea. Springer International Publishing, Cham, pp. 327–354. https://doi.org/10.1007/978-3-319-99417-8_18.

Nishiwaki, M., Marsh, H., 1985. Dugong Dugong dugon (Miiller, 1776). In: Ridgeway, S.H., Harrison, R.J. (Eds.), Handbook of Marine Mammals. Academic Press, London, pp. 1–31.

Phillips, S.J., Anderson, R.P., Schapire, R.E., 2006. Maximum entropy modeling of species geographic distributions. Ecol. Model. 190, 231–259. https://doi.org/10.1016/j.ecolmodel.2005.03.026.

Pilcher, N.J., Adulyanukosol, K., Das, H., Davis, P., Hines, E., Kwan, D., Marsh, H., Ponnampalam, L., Reynolds, J., 2017. A low-cost solution for documenting distribution and abundance of endangered marine fauna and impacts from fisheries. PLoS One 12, 1–15. https://doi.org/10.1371/journal.pone.0190021.

Preen, A.R., 1992. Interactions Between Dugongs and Seagrasses in a Subtropical Environment PhD Thesis. James Cook University, QueenIsland, Townsville, Australia.

Rohner, C.A., Richardson, A.J., Prebble, C.E., Marshall, A.D., Bennett, M.B., Weeks, S.J., Cliff, G., Wintner, S.P., Pierce, S.J., 2015. Laser photogrammetry improves size and demographic estimates for whale sharks. Peer J. 3, e886.

Shawky, A.M., 2018. Ecological and Behavioural Studies on the Dugong (Dugong dugon) Inhabiting Marsa Alam Egyptian Red Sea PhD Thesis. Suez Canal University, Ismailia, Egypt.

Shawky, A.M., Sallam, W.S., Alwany, M.A., Mohammad, D.A., Mohamed, S.Z., 2016. Stranding of a neonatal dugong calf in Wadi El Gemal National Park: implications for dugong conservation in Egypt. Al Azhar Bull. Sci. 27, 1–11.

Shawky, A.M., Sallam, W.S., Alwany, M.A., Mohammad, D.A., Mohamed, S.Z., 2017. Photo Identification of Dugongs in Marsa Alam and Wadi El Gemal National Park, Egyptian Coast of the Red Sea. Al Azhar Bull. Sci. 28, 1–10.

Shawky, A.M., Sallam, W.S., Alwany, M.A., Mohammad, D.A., Mohamed, S.Z., 2019. Photo identification of Dugongs in Marsa Alam and Wadi El Gemal National Park. Ind. J. Geo Mar. Sci. (In press)

Sheppard, J.K., 2008. The Spatial Ecology of Dugongs : Applications to Conservation Management, pp. 245.

Spain, A.V., Heinsohn, G.E., 1975. Size and weight allometry in a North Queensland population of dugong dugon (Miiller) (Mammalia: Sirenia). Aust. J. Zool. 23, 151–157. https://doi.org/10.1071/ZO9750159.

Thayer, G.W., Bjorndal, K.A., Ogden, J.C., Williams, S.L., Zieman, J.C., 1984. Role of large herbivores in seagrass communities. Estuaries 7 (4A), 351–376. 5 Tables.