Scars of hope and forewarn of a bleak future: post-mortem findings of dugongs (*Dugong dugon*) belonging to a relict population in the Gulf of Kachchh, India

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A relict dugong population resides in the Gulf of Kachchh (GoK), Gujarat, India. Very little is known about this population stemming from a lack of focused studies and inadequate examination of previous strandings. The present study gathers crucial ecological information through a systematic post-mortem examination of stranded dugongs in GoK. As indicated through dorsal tusk-rake scars on two carcasses, this study presents records of derivative physical evidence. Progressive healing and differences in the width of the scars indicated more than two individuals had participated in a sexual agnostic or courtship event. Conversely, our findings report that both animals suffered relative effects of asphyxiation after fishing net entanglement. The implication of a prior pathological condition(s) in the form of dermal cysts, swollen mesenteric lymph nodes and endoparasites is also reported. Stomach content was examined for a qualitative dietary characterization. *Halophila beccari*, *Halophila ovalis* and *Halodule uninervis* were found in the stomach content. Other potential threats as well as fishing net microfilaments found in the stomach contents of both dugongs are discussed.

Keywords: Dugongs, necropsy, relict population, stomach content analysis, Tusk-rake scars.

INDIAN dugong populations are considered 'Regionally Endangered' compared to the global IUCN Red List status of the species as 'Vulnerable'[1], making them the most threatened marine mammal species along the Indian coastline. Their foraging range along the shallow near-shore areas brings them in direct conflict for using space with artisanal fisheries and other coastal activities such as tourism, port activities[2], etc. The current range of dugongs in the country is restricted to parts of the Gulf of Kachchh (GoK), Gujarat; Palk Bay and Gulf of Mannar (Tamil Nadu) and Andaman & Nicobar Islands (except in Great Nicobar)[1]. Although ecological information (such as foraging behaviour[3] and abundance[4,5]) about dugong populations in Tamil Nadu and Andaman and Nicobar Islands is available, there is a dearth of knowledge regarding the GoK population.

To date, no extant dugong population has been confirmed from the west coast of India, except for the small population in GoK, estimated to be around 15 animals[6], making it an important dugong habitat in the region. This population is known to be restricted to the islands and reefs of the southern coast of GoK[7]. Naturally low fecundity and slow growth rate make dugong populations around the world extremely sensitive to adult mortalities[8]. Further, the low population size and the elusive nature of dugongs make it difficult to study them in the wild. For a small marine mammal population, studying the type and consequences of anthropogenic pressure becomes a difficult task in the wild. Given the lack of long-term datasets on this geographically isolated population, stranding events provide a rare window to collect essential data about health, feeding ecology, reproductive status, etc., which otherwise ecological data is hard to get for behaviourally cryptic animals. Here, we present a brief discussion on salvaged information deduced from two dugong carcasses of stage I and stage IV decomposition states. This study provides crucial insights into a relict dugong population on the verge of extinction.

Methods

We obtained dugong stranding information through a volunteer network developed in the fisher community of Beyt Dwarka and Arambada village in GoK. This network comprised of fisherfolk who were sensitized through a series of community interaction programmes ($n = 3$) conducted at Okha and Beyt Dwarka fisher villages, viz. Balapur, Arambada, and Rupen. Two dugong strandings were reported in February and May 2018 respectively. The initial photograph of the Ajad Island dugong was taken when the carcass was

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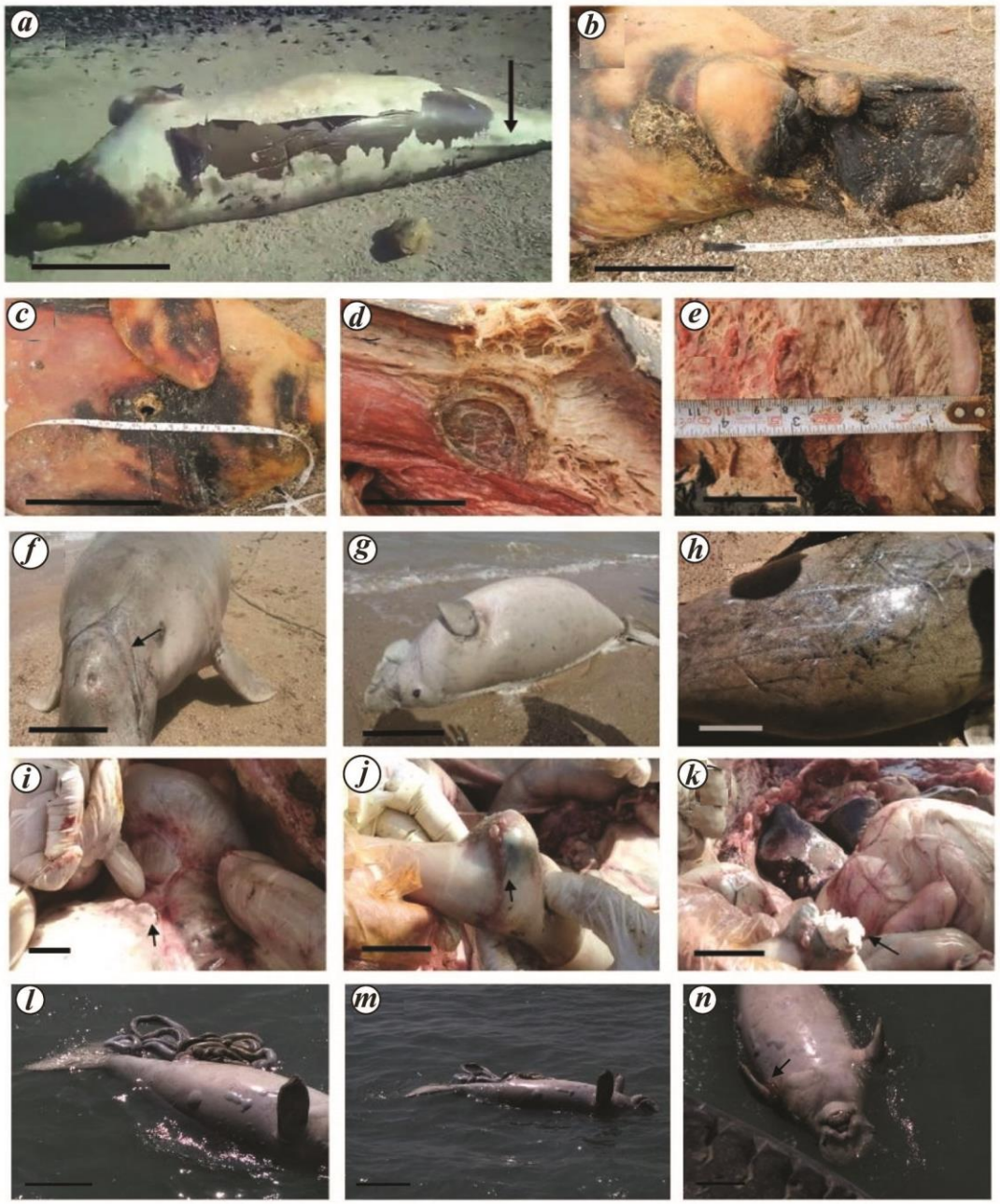

Figure 1. ***a*–*e***, Ajad Island dugong carcass in the Gulf of Kachchh (GoK), Gujarat, India: ***a***, Decomposed carcass of a mature female dugong (scale – 30 cm); ***b***, Rope burn marks around the neck (scale – 18 cm); ***c***, Thorax with cavity caused by parasitic infestation (scale – 15 cm); ***d***, Cross-section through the cavity showing cyst of an unidentified parasite (scale – 3.2 cm); ***e***, Cross-section across the mid-ventral tissue layer (scale – 4 cm). ***f*–*k***, Positra dugong carcass (scale – 40 cm, GoK): ***f***, Rope burn marks (black arrow) are visible around the snout (scale – 16 cm); ***h***, Numerous healed wounds on the back (scale – 15 cm); ***i***, Swollen mesenteric lymph nodes (scale – 2.5 cm); ***j***, ***k***, Purulent tumour in the small intestine (scale – 4.5 cm); ***l***, ***m***, Drifting bloated carcass exhibiting evisceration (scale – 20 cm); ***n***, Ante-mortem wound under flipper (scale – 30 cm).

relatively fresh (Figure 1 *a*). The carcass was reported and was necropsied two weeks after the stranding event.

Carcass photo-documentation and necropsy were performed using standard salvage and necropsy procedures[9]. Each animal was examined for external marks, lesions, bruises and other injuries prior to internal examination. Morphometric data (Supplementary Table 1) was also noted. Since decomposition is relatively faster in the intestines, visceral organs after the stomach of the Ajad Island dugongs were rendered unexaminable.

Stomach content analysis was performed on samples (300 g) collected from the cardiac end. The stomach content was preserved using 10% neutral-buffer formalin within 9 h of necropsy. Qualitative analysis of the gut contents

was done after diluting 5 g of the sample ($n = 2$) with 50 ml of distilled water. To avoid crowding of seagrass segments, a volume of 5 ml was used from the diluted subsample (50 ml) for observations on a 2 × 2 cm^2 graded Petri plate.

Results

Ajad island stranding

A stage IV, badly decomposed carcass was necropsied[9] in the northeastern part of Ajad Island (centrepoint – 22°23′N, 69°19′E), where it was stranded. The animal was a 2.6 m (straight body length) adult female. The skin had been sloughed-off completely, but the remaining attached skin on the mid-dorsal side retained a hyperpigmented rake mark (Figure 1 *a*), indicating that it had interacted with an adult male dugong. The head showed clear signs of severe intramuscular haemorrhage with a cutaneous abscess on and around the nostrils (Figure 1 *a*). This haemorrhage could result from blunt force trauma to the head after a collision with a boat. On the dorsal side of the animal, the caudal vertebral processes were markedly visible (black arrow, Figure 1 *a*) indicating emaciation, but other signs of starvation such as caved-in body mass around the peduncle could not be verified due to the advanced stage of decomposition. Starvation was further ruled out as the stomach was full of seagrass and the blubber layer was intact in both consistency and thickness (Figure 1 *e*). A cross-sectional examination through the cavity of the dermal wall of the thorax (Figure 1 *c*) revealed the presence of a single, oval and well-demarcated parasitic cyst of dimensions 32.11 × 40.40 mm (Figure 1 *d*). Nematode *Paradujardinia halicoris*, a common endoparasite in dugongs[10,11] and manatees[12], was found in the animal's stomach.

Positra island stranding

A sub-adult male dugong with the straight-body length of 2 m was reported by fishers of Positra near Man-marudi Island (centrepoint – 22°25′59.56″N, 69°13′23.86″E) in GoK. There were no signs of decomposition (bloating, discolouration, etc.). Since the flippers had mobility when the carcass was found, rigor mortis had not set in, conclusively indicating mortality in the past few hours. Fishers confirmed mortality due to suffocation after net-entanglement, which was factualized by rope-burn marks around the head and neck (black arrow, Figure 1 *f*). The skin was in good condition and showed no signs of sloughing (Figure 1 *g*). The intact skin revealed various important clues to the type of interaction the dugong had undergone before its death. Small scars of several healed wounds were found extending from the lower neck to the peduncle of the animal's dorsum (Figure 1 *h*), the significance of which will be discussed later in that text. Since the visceral organs were intact, a thorough examination of the gastrointestinal tract could be conducted. A localized, single tumour of radius 5 cm was found on the duodenum (Figure 1 *j*). The purulence of the outgrowth had a hard, greasy consistency (Figure 1 *k*). Moreover, the mesenteric lymph nodes appeared swollen (Figure 1 *i*).

Tusk-rake scars

Several healed indentations and wounds were found on the dorsum of the animal from various interactions (Figure 2). The source of these wounds can be either biological through intraspecific interactions or non-biological due to the scratching behaviour of dugongs over sandy sediments[13]. Except for a few deep indentations, most of these marks were shallow. More important were the parallel marks on the back, which were made due to the grazing action of a pair of tusks. We discovered several counts of such tusk-rake scars (TRS) on the back of this dugong individual. Scars of different widths indicated that sexually mature conspecifics of different age groups had interacted with this male dugong (Figure 2). Based on width, five distinctly different scars were identified. These were then broadly categorized into two stages depending on the progressiveness of healing (Table 1). A new scar indicates a 'recent' (stage I) agnostic interaction, whereas completely healed marks appearing shallow and discoloured are evidence of 'older' (stage II) instances[14]. Only one of the five scars that appeared was recent (stage I), as it had not completely healed (scar 1, Figure 2). The remaining four scars (scars 2–5, Figure 2) were older (stage II) and probably inflicted during a single event. Hence, at least two separate events of ritualistic sexual conflicts were experienced by the Positra dugong. Moreover, a scar inflicted by a relatively younger dugong (mark 4, width – 5.3 cm) was also observed.

Stomach content analysis

Leaf tip characteristics, leaf venation patterns and numbers and leaf scars on rhizomes are the most prominent and important morphological features examined to identify seagrass species[15] (Figure 3); *Halophila beccarii* (oblong leaf, parallel venation, smooth; trichome-less lamina), *Halophila ovalis* (oval leaf, cross venations, smooth; trichome-less lamina) and *Halodule uninervis* (trident apex, strap-shaped leaf) were found in the stomach contents of both the stranded individuals. The dugongs also had ingested fragments of nylon fishing net microfilaments of length ranging from 0.23 to 30 mm.

Discussion and conclusion

There is little information regarding the social and reproductive behaviour of dugongs in India. As concluded from

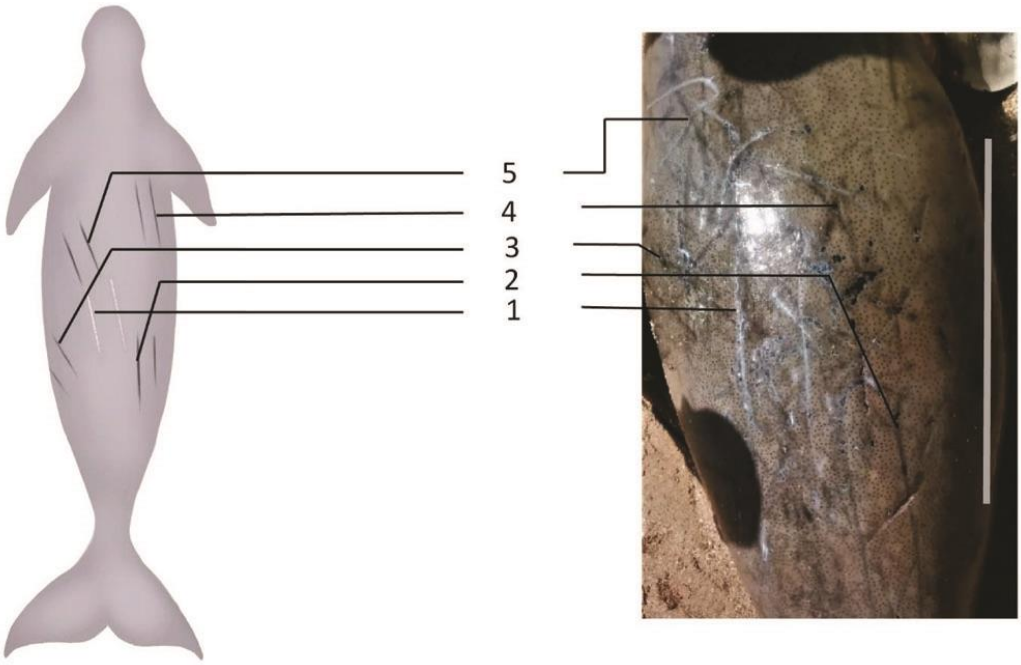

Figure 2. Illustration of tusk-rake scars as seen on the dorsum of the Positra dugong (scale – 60 cm).

Table 1. Measurements and healing stages of six different tusk-rake marks observed on dugongs stranded in the Gulf of Kachchh, Gujarat, India. The healing stage of TR56, i.e. recent or a healed scar was not clear from the photographic evidences

Tusk-rake scar (TRS)	Dugong case	Length (cm)	Width (cm)	Healing stage
TRS1	Beyt Dwarka	33.3	11.3	Stage 1
TRS2	Beyt Dwarka	26.5	8.7	Stage 2
TRS3	Beyt Dwarka	22	6.5	Stage 2
TRS4	Beyt Dwarka	18	5.3	Stage 2
TRS5	Beyt Dwarka	21.4	10	Stage 2
TRS6	Ajad	32	10.8	NA

NA, Healing stage could not be inferred on-field due to advanced decomposition.

the presence of tusk-rake scars, both dugongs were involved in inter- and intra-sexually aggressive conflicts which reflect positively on the social behaviour of this small population in GoK. Similar teeth-rake marks in bottlenose dolphins are reported to be a reliable indicator of conflicts over resources and mates[16]. Paired parallel tusk rake marks in dugongs also provide insights into the diversity in age – a class of the dugongs under study in GoK.

Dugong cows less than 2 m long have almost certainly not been born a calf (non-parous), whereas those larger than 2.50 m are likely to have given birth (parous)[17,18]. Hence, conclusively, the Ajad Island dugong was a sexually mature female, although due to liquefaction of the ovaries, it could not be confirmed whether the cow had birthed a calf during her lifetime or not. Marine traffic exerts a growing pressure on marine megafauna[19]. This contributes to net entanglement as one of the leading causes of death for dugongs[20,21]. Although range-resident, the dugong population in GoK is highly mobile within this range. Their movement response is adapted to a dynamic tidal regime and local knowledge of the widely distributed seagrass habitats in GoK. This makes them mildly susceptible to threats due to fishing activities in their foraging habitats.

Dugongs, like other marine mammals, are susceptible to a wide range of diseases, infectious, non-infectious and idiopathic[9]. Both stranded animals, collectively, suffered from underlying conditions like visceral tumours, inflamed mesenteric lymph nodes and parasitic cysts. This might indicate the immunoreactive state of the body before its ultimate death. We infer that the Ajad Island dugong might have suffered from head trauma due to a boat collision and underlying parasitic infection. This can further be consolidated as the animal showed distinct signs of emaciation and had a relatively full stomach. A fishing net entanglement is evident from the rope impressions around the neck and is suspected to be the ultimate cause of its death. The same can be concluded for the Positra dugong.

Seagrass meadows are known to reduce the velocity of tidal currents[22], thereby causing sedimentation of fine particles[23] and coincidentally of fishing net microfilaments. This naturally makes seagrass meadows extremely prone to microplastic pollution, herbivory becoming a medium for plastic/nylon microfilaments to enter into diverse food chains. Anthropogenic marine debris has also been documented in subtidal seagrass meadows of the Philippines[24]. However, the impact of microplastic sedimentation in dugong foraging habitats depends upon their bioavailability and

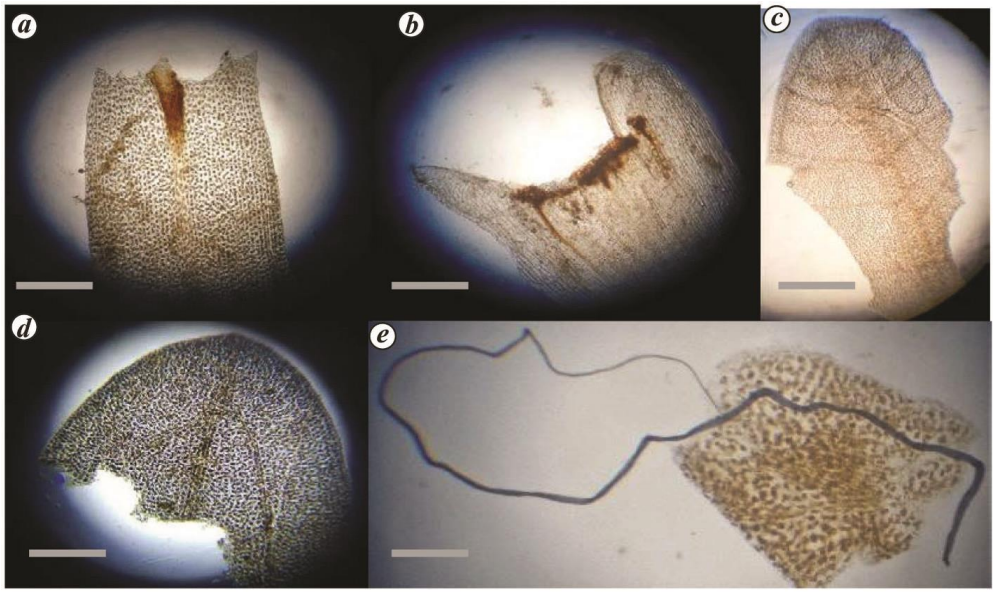

Figure 3. Photomicrographs of seagrass and plastic micro-filaments from the stomach content (scale – 2 mm). ***a***, *Halodule uninervis* leaf apex. ***b***, *H. uninervis* leaf sheath. ***c***, *Halophila beccarii.* ***d***, *Halophila ovalis.* ***e***, Nylon micro-filament from fishing nets.

post-consumption consequences in these animals, which remain obscure. Although the clinical significance of ingestion of plastic micro-filaments is unknown in dugongs, it can have potentially lethal effects on sediment biota of seagrasses.

Photo-documentation and necropsy techniques serve as key conservation tools to understand the underlying stressors of the cryptic dugong population. However, even with limited logistics to access the carcasses, unavailability of laboratory facilities locally and a lack of trained workforce to conduct marine mammal necropsies, the data presented here are critical for the study of dugong species in GoK. Studying the foraging behaviour and the reproductive status of dugongs in the wild is considered difficult owing to their rarity and cryptic behaviour. This is more so for a small population wherein the chances of detecting, observing and following a live animal are further reduced by the turbid waters of GoK (<0.5–2 m visibility). Hence salvaging information from carcasses proves to be a boon to understand their biology, reproductive and health status, and natural and anthropogenic stressors.

The initiation of our study regarding dugong foraging ecology across GoK was an extension of conclusions drawn from necropsy examinations[25]. GoK is home to various ecologically significant species and shares the same habitat as dugongs. With dugongs being an umbrella species, their conservation may also indirectly protect these ecological communities.

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