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Reasons for seagrass optimism: Local ecological knowledge confirms presence of dugongs

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ABSTRACT

Dugongs (*Dugong dugon*) depend on seagrass meadows for food. As such seagrass and dugong conservation should go hand in hand. Assessing dugong populations is notoriously challenging. In the most resource dependent communities Local Ecological Knowledge (LEK) is generally high and can provide an alternative to the use of expensive ecological surveys to understand dugong populations and support associated resource management decisions. Residents of the Wakatobi National Park (WNP), SE Sulawesi, Indonesia are highly dependent on marine resources for livelihoods and correspondingly LEK is high. Here LEK documents the presence of *D. dugon* in the WNP and infers changes in population size. Interviews with local residents in 2012–2013 revealed 99 sightings of dugongs since 1942, 48 of which occurred between 2002 and 2012, with 79.82% of respondents having seen a dugong. Declines in the frequency of sightings within the lifetime of several respondents were reported, respondents speculating that populations are reduced. This information can guide further cooperative research and conservation efforts for the protection of a vulnerable species and the seagrass habitat on which it depends.

1. Introduction

Seagrass meadows support high biodiversity which includes charismatic megafauna such as the dugong (*Dugong dugon*). The dugong is a large herbivorous, exclusively marine mammal of the order Sirenia (Marsh et al., 2002). Dugongs feed almost exclusively on shallow seagrass beds, as such the global trend of seagrass decline (around 7% annually (Waycott et al., 2009)) represents a worrying scenario for this vulnerable species. *D. dugon* appears on the IUCN endangered species list as 'vulnerable to extinction' across its range (Marsh and Sobtzick, 2015). Dugongs are found in the coastal waters of more than 40 countries from East Africa to Vanuatu (UNEP/CMS, 2017a), yet much of our current range and population estimates are based on limited observational and anecdotal evidence (Marsh et al., 2002; Marsh and Sobtzick, 2015). With the exception of their primary population in Australia, dugongs are thought only to exist in small fragmented populations (Hines et al., 2012; Marsh et al., 2005, 2002).

Minimal information is available regarding the population and distribution of dugongs in Indonesia (De Iongh et al., 2007). Populations have been reported from West Papua, multiple small bays around Sulawesi and Sumatra, northwest and southeast Java, Timor, Togian Island, the Berau delta and Balikpapan Bay (deIongh et al., 1997; Hendrokusumo et al., 1979; Marsh et al., 2002; Salm and Clark, 1984). Seagrass habitat that can support dugong populations are believed to occur from Arakan Wawontulap to the Lembeh Strait off North Sulawesi, the east coast of Biak Island, in Cendrawasih Bay Marine National Park (Papua Barat), around the Lease and Aru Islands (Maluku), around the Flores-Lembata Islands (East Nusa Tenggara), in Ujung Kulon National Park, Sunda Strait, Banten Bay, Bangka Belitung and Trikora Beach (Bintan) (De Iongh et al., 2009).

Scientific monitoring of dugong populations has traditionally been conducted via aerial survey (Findlay et al., 2011; Holley et al., 2006; Hughes and Oxley-Oxland, 1971; Marsh et al., 2004) and more recently using unmanned aerial vehicles (UAV) (Hodgson et al., 2013). But aerial survey techniques come with high costs (Hodgson et al., 2013) and can be affected by availability bias in unfavourable environmental conditions such as turbidity and glare (Hagihara et al., 2014). Additionally, these methods generally provide only a narrow snapshot of

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what might be occurring in any particular area within a narrow timeframe. They also deny a good opportunity for constructive engagement and multilateral knowledge transfer between local knowledge holders, scientists and resource managers. Local ecological knowledge (LEK) is increasingly recognised as a valuable asset in environmental management and conservation biology (Beaudreau and Levin, 2014; Drew, 2005; Drew and Henne, 2006; Frans and Augé, 2016; Johannes et al., 2000; Moller et al., 2004). While science, in most cases, provides precise and quantitative information on a short term basis, LEK more frequently incorporates observations over long time periods, includes large sample sizes and is more likely to pick up rare or extreme events (Moller et al., 2004). LEK has also been shown to accurately reflect local species abundances and population trends specifically where densities are low (Anadon et al., 2009). In this way LEK can make a significant contribution to understanding complex systems and historical change (Frans and Augé, 2016). Reliance on marine resources has been linked to individuals with higher levels of accumulated LEK (Pilgrim et al., 2007a, b). The use of LEK in designing marine protected areas continues to gain traction both as a tool to support science based approaches and as a proxy for scientific approaches (Ban et al., 2009). The engagement of fishers in particular (Hashim et al., 2017) can be useful, drawing on their regular access to the marine environment and resultant evolving knowledge base, and provides a platform for the integration of local and scientific knowledge, recognising the value of LEK and supporting constructive engagement.

In Indonesia dugongs are largely dependent upon intertidal seagrass meadows for their survival (De Iongh et al., 1995). However, there is growing evidence of the rapid decline and increasing threats to Indonesian seagrass meadows (Cullen-Unsworth and Unsworth, 2013a). Dugong populations are facing increasing anthropogenic pressure, particularly habitat degradation with a major threat being coastal development (Hines et al., 2012). Other threats to Indonesian dugong populations specifically include degradation of seagrass meadows caused by coastal development, boat traffic, agricultural and domestic run-off, oil spills, destructive fishing, accidental catch in a variety of fishing gears, Indigenous hunting and direct impact with boats (De Iongh et al., 2007, 2009; deIongh et al., 1997; Marsh et al., 2002). Thus, there is an urgent need to document the presence of and monitor dugong populations. As *D. dugon* is nutritionally reliant on seagrass, it is also essential to monitor and protect the seagrass they depend on (Unsworth and Cullen, 2010). Indonesian dugongs are protected under the Conservation of Flora and Fauna Act No.7 (1999) and under the Indonesian Government's commitment to the Convention on Biological Diversity (CBD) with key focal species listed under the Convention on Migratory Species Appendix II (dugong). Indonesia is signatory to the Memorandum of Understanding on the Conservation and Management of Dugongs (Dugong MoU) and their Habitats throughout their Range and party to the Dugong and Seagrass Conservation Project (UNEP/CMS, 2017b) but there is limited accessible information regarding population numbers or their geographical range (De Iongh et al., 2007).

Dugong and seagrass conservation go hand in hand (Tol et al., 2016), recognition of the importance, perilous state and threats to both is well acknowledged (Al-Abdulrazzak and Pauly, 2017; Maxwell et al., 2017) but data deficiency remains a problem (D'Souza et al., 2013; Jones et al., in press). Better information on the distribution and status of seagrass and the population distribution of dugongs is required to support the development of appropriately targeted management strategies. Here we preliminarily investigate the availability of quantifiable evidence from stakeholders, in particular fishermen, who have the closest links to the marine environment and the best opportunity to monitor dugong populations. This work therefore sets out to confirm the presence of a vulnerable species, drawing attention to the need for seagrass conservation action to support the maintenance of previously unrecorded dugong populations. Our study site is a biosphere reserve striving to become a learning laboratory and this work demonstrates just one small contribution from the potential of LEK in this capacity.

2. Methods

2.1. Study site

The Wakatobi National Park (WNP) off SE Sulawesi in Indonesia (− 5.5013427 123.78656), incorporates the waters surrounding four major islands, Kaledupa, Binongko, Tomia and Wangi-Wangi, and supports a population of around 100,000 people. The Wakatobi obtained national park status in 1996 (Clifton, 2003) with a revised 25 year management plan released in 2008 that envisaged the park as a sustainable environment benefiting local people and supporting regional development. The plan identifies key habitats as priorities for management, including (for example) coral reef, seagrass meadows, mangroves and important bird and turtle nesting sites, but does not define targets for management other than to maintain hard coral cover (Clifton, 2013). In 2012 the Wakatobi was declared a Biosphere Reserve with the Wakatobi National Park Authority taking on additional administrative authority for the reserve (UNESCO, 2012). The reserve was designated in recognition of the high biodiversity contained within WNP, the presence of rare and endangered species, including the dugong, and as a *learning laboratory for researchers, students, local government, NGOs, the public and private sectors, and other stakeholders* as well as the ethnically diverse local population (UNESCO, 2012).

The population of the WNP is essentially divided into two distinct cultures, islanders known locally as 'Pulo' and traditional sea nomads, who now live in permanent stilted houses on the intertidal sand flat and seagrass areas, known locally as 'Bajo' (Clifton et al., 2010; Cullen-Unsworth et al., 2011). Bajo people are regarded to be the most heavily dependent on marine natural resources; however both Bajo and Pulo communities are reliant on marine resources for food, raw materials and income, with 100% of households in the Kaledupa sub-district of the WNP dependent on seafood as their major or only source of protein and 41% of households directly dependent on marine and coastal resources for their primary income (Cullen et al., 2007). Despite representing only a small percentage of the population in the WNP, Bajo people account for approximately 50% of fishers and have a high level of marine ecological knowledge (Clifton et al., 2010; Cullen et al., 2007; Pilgrim et al., 2008).

Household surveys conducted in the WNP (Unsworth et al., 2014) confirm that there is a high reliance on seagrass meadows for both income and food security, with all age groups of the community taking part in invertebrate gleaning in intertidal seagrass areas at low tide as well as seagrass areas being used for fin fisheries and seaweed cultivation (Cullen-Unsworth et al., 2014). This regular and close interaction with seagrass habitat is likely to create a wealth of knowledge of dugong population ecology within relevant stakeholder groups active in the WNP. At present only anecdotal information is used to note the presence of *D. dugon* in WNP. While the presence of the species has been historically noted in the WNP, no formal data is available on its current status.

2.2. Investigation of dugong presence through semi-structured interviews

Research was conducted between July 2012 and January 2013. A total of 109 semi-structured household interviews were completed. Households were selected at random from largely fishing villages. Both Bajo (31 interviews) and Pulo (78 interviews) were included. Interviews were conducted on all 4 major islands within the WNP; Kaledupa, Binongko, Tomia and Wangi-Wangi and across a total of 35 villages and sub villages. Interviews were conducted face to face either in Indonesian (Bahasa Indonesia) or Bajo (Bahasa Bajo) through a local translator. Interviewees were verbally introduced to the study, its aims and objectives and asked if they would like to participate (giving verbal consent). Questions were designed to determine dugong presence in the park and perceptions of trends in population changes over time. Respondents were asked if they had ever seen a dugong in the park,

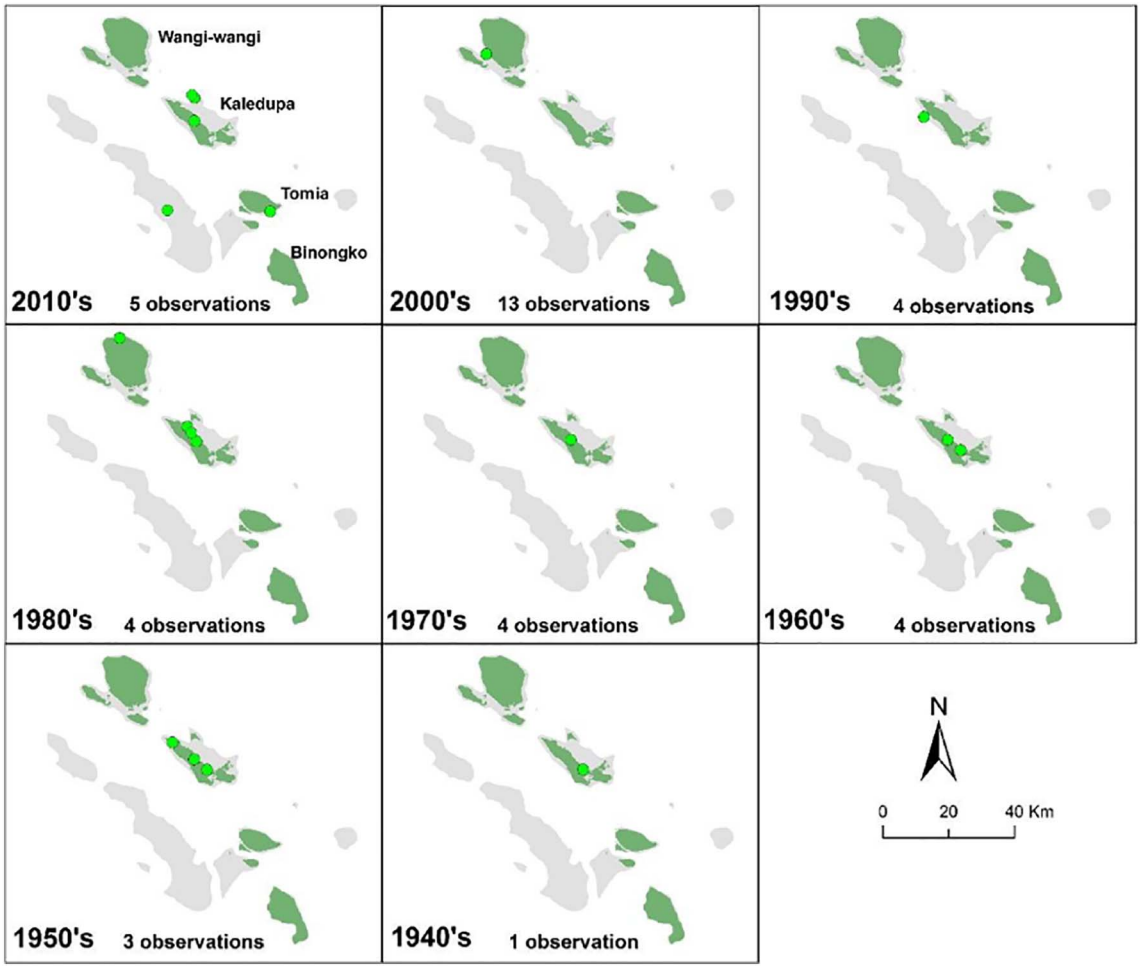

Fig. 1. Decadal dugong observations in the Wakatobi National Park, SE Sulawesi, Indonesia. Green dots indicate locations of dugong observations. Note: Several observations included more than one dugong sighting and multiple observations were made at some locations. Green areas are islands while grey areas represent intertidal to subtidal seagrass and coral. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

when their sightings were (year) and the specific location of their sighting. They were also asked what happened to the dugong they saw. Questions on seagrass knowledge, including perceptions of its importance, were also included. The locations of dugong sightings were usually given as named fishing grounds which were also pinpointed on a map of the Wakatobi. Seventy-seven of the respondents were fishers and ten respondents participated in other sea-based occupations (e.g. seaweed cultivation and marine transportation), while the remaining 22 respondents undertook non sea-based occupations but spent recreational or travel time on or near the water.

3. Results

A total of 99 sightings of *D. dugon* individuals were reported across a time frame ranging from 1942 to 2012, with 10 sightings being recorded as within the previous two years (2010 – 2012), and a total of 48 sightings within the previous 10 years (2002 – 2012) (Fig. 1).

Of 109 respondents, 87 individuals (79.82%) reported to have seen or eaten a dugong in the area, of which 85 individuals had seen a dugong and two individuals had eaten dugong but not seen the animal in the wild. Individuals from all four islands as well as Bajo respondents reported to have seen a dugong, this included 15 of 49 respondents from Wangi-Wangi, Tomia and Binongko, 47 out of the 63 respondents from Kaledupa and 25 of the 31 Bajo respondents.

When asked what happened to the dugongs that were sighted 64 respondents chose to provide additional detail. Of these, 26.98% reported that the dugong had been captured but that their fate was unknown, 26.98% specified that dugong had been captured but later released, 23.81% reported that the animal had been captured and eaten, 14.29% reported that they had watched a dugong just passing by in the water, 3.17% that the animal had been killed by bomb fishing, 3.17% that they were stranded on a beach and 1.59% that the dugong had been discarded dead (see Table 1).

Seventeen Bajo individuals made additional comments on the current state of the dugong population within the Wakatobi National Park (WNP). Despite these respondents having recorded a dugong sighting between 1990 and 2012, the comments consistently expressed the opinion that although dugongs are present, they are rarer in the area now than in the past. Respondents suggested that dugongs have either

Table 1
Nature of dugong encounters where details were provided. The result of 64 sightings were provided, for the remaining 36 sightings, respondents chose not to elaborate on the result of their dugong encounter.

Result of dugong sighting	Percentage of detailed sightings[a]
Captured (purpose not specified)	26.98
Captured and released	26.98
Captured and eaten	23.81
Observed passing by in the water	14.29
Stranded on a beach	3.17
Killed by bomb fishing	3.17
Caught and discarded dead	1.59

[a] Percentages are shown for those sightings where further details were available.

moved elsewhere and only occasionally enter the WNP, or that the Wakatobi population has become reduced, with one fisherman, who reported having captured seven dugongs in the past, expressing that dugongs are “running out”. Another respondent stated that “Dugong tusks used to be very expensive, so there were many fishermen who caught dugongs for that reason. Now dugongs are in danger of extinction”.

4. Discussion

Through the engagement of local stakeholders in population assessments, Local Ecological Knowledge (LEK) has proved a valuable resource to investigate population ecology in fellow sirenians; the Amazonian manatee *Trichechus inunguis* (Franzini et al., 2013; Sousa et al., 2013), Antillean manatee *Trichechus manatus* (Arevalo-Gonzalez et al., 2014) and West African manatee *Trichechus senegalensis* (Mayaka et al., 2013). LEK has also been used to examine the presence of *D. dugon* populations across their range in developing countries such as Malaysia (Rajamani, 2013; Rojchanaprasart et al., 2014), Myanmar (Ilangakoon and Tun, 2007) and Mayotte Island (Pusineri et al., 2013). However, there remain extensive areas within the known distribution of dugongs where population data is lacking. There is an urgent need for conservation but limited resources available.

The present study aimed to demonstrate the potential value of LEK in the Wakatobi National Park (WNP), to confirm the presence of *D. dugon* in the park. Not only did it confirm presence but provided some indication of potential population changes which highlights that action is urgently required. It is likely that hunting has impacted dugong populations but habitat degradation may also have had an impact (Cullen-Unsworth and Unsworth, 2013a; De Iongh et al., 2009). This is a significant consideration with further cooperative investigation required to evidence the causes of decline.

In the WNP, LEK confirms the continuing presence of a vulnerable species, *D. dugon*. Local stakeholders appear knowledgeable regarding some of the anthropogenic impacts threatening *D. dugon* in the area, in regards to hunting and the indirect effects of fishing, and it is evident that although there remains a resident population, the population of *D. dugon* has been reduced within the lifespan of several respondents. The importance of seagrass meadows is well appreciated in terms of the ecosystem services that seagrass meadows provide across the park (Unsworth et al., 2014), particularly its value as a fishing habitat, but the links to dugong populations are not well acknowledged.

In its capacity as a World Biosphere Reserve, the engagement of resource users, particularly fishers, is an essential element for the Wakatobi and clearly an aspiration of local stakeholders as stated in the reserve outline (UNESCO, 2012). Given the desire to become a learning laboratory as a world biosphere reserve and the enthusiasm of local stakeholders (e.g. FORKANI a Kaledupa based environmental NGO) to integrate LEK and scientific methods towards securing the park as a sustainable system, there are clear pathways for knowledge contribution and integration. One specific example of this is the contribution of LEK concerning the presence, distribution and population changes of dugongs in the park, where accepted scientific methods could be used to investigate reasons for decline.

For a given ecosystem to be the focus of policy and become a target for regulation, its value needs to be established (von Heland and Clifton, 2015). With the recognition of dugong persistence in the Wakatobi National Park, but acknowledgement of the potential decline in numbers this needs to be put into context of the status of the seagrass habitat on which the dugong depends. This is particularly relevant given the diverse range of known local threats to these seagrass meadows (Cullen-Unsworth and Unsworth, 2013b). Demonstrating a clear coupling of this system supports a renewed call for the protection of seagrass for the suite of ecosystem services that it provides, including biodiversity support. De Iongh et al. (2007) suggest that the protection of intertidal *Halodule unnerves* meadows in Indonesian coastal waters may be an important conservation measure for dugong populations.

Further study is required to quantify the *D. dugon* population in the WNP, but evidence of their presence, and stakeholder perceptions of decline could be used to support a renewed call to protect both the dugongs and the seagrass meadows on which they depend. Due to the close coupling of the social-ecological system in the WNP (Cullen-Unsworth et al., 2014) and the status of a declining habitat, this close interaction and co-dependence on seagrass meadows may also create conflicts of use between local communities and any resident dugong populations. However, using the evidence presented here may provide some insight for the potential rezoning of WNP to accommodate the multi-species uses. For any management strategy to be successful, however, it is essential that where LEK is used in ecological monitoring, it can be a tool to inform understanding of the coupled social-ecological system and should be included in the development of appropriate action plans. Here, LEK confirms the presence of dugongs and further implies changes in population numbers, this information has the potential to guide further scientific study and conservation efforts for the protection of both an endangered species and its habitat.

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