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Using Gray Literature and Social Media Records to Help Identify Population Hotspots and Conservation Priorities for the Vulnerable Dugong, *Dugong dugon* (Müller, 1776) in Indonesia

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ABSTRACT

We compiled, collated, and annotated 1033 dugong records for the Indonesian archipelago for the period 2010–2022. The database comprises 337 incidental reports documented via various media sources and 696 cases based on publications and gray literature. Four of six apparent dugong hotspot areas were clustered around small archipelagos of the Banda Sea. Two others were clustered roughly 1000 km away around archipelagos at the opposite end of the Java Sea. Both Indonesian hotspot clusters were adjacent to recognized dugong hotspots located outside Indonesian waters. Notwithstanding known seagrass-dependency, documented dugong records were not significantly correlated with seagrass abundance. Seagrass was most prevalent around small sparsely populated offshore archipelagos, where riverine freshwater and sedimentation were also less. Notwithstanding seagrass presence along the west coast of Sumatra, the area had limited connectivity to other dugong hotspots and was largely devoid of dugong records. Dugong size–structure data were bimodal and dominated by larger animals, suggesting either recent immigration or recent local decline in reproductive success. Most documented mortality records were on the north-west side of the Java Sea and mainly due to entanglement bycatch. Citizen science, gray literature, and social media data have clear added value but the need for more quantitative, standardized, and reliable data are emphasized.

1 | Introduction

The dugong (*Dugong dugon*), along with three species of manatees (genus *Trichechus*), is a member of the Sirenia, the only Order of extant marine herbivorous mammals. Globally, the IUCN Red List categorizes the dugong as Vulnerable with a decreasing population trend (Marsh and Sobtzick 2019). Indonesia is recognized as a country that has a significant dugong population, as confirmed by a number of local studies, either through direct sightings or secondary sightings collected through questionnaires. The Indonesian archipelago is also centrally located in the world-wide range of the dugong and may therefore play a special role in maintaining geographic connectivity, gene flow, and genetic diversity within the species. The size of the dugong population in Indonesia has been previously estimated to have been as high as 10,000 in the 1970s and as low as 1000 in 1994 (https://www.dugongconservation.org/where-we-work/indonesia/). As of this writing, Indonesia is not signatory to the dugong MOU (UNEP-CMS 2019). However, under the Ministry of Marine Affairs and Fishery (MMAF), Indonesia has created a National Plan of Action for the "Conservation of the Dugong and Its Habitat" (KKP-DJPRL 2018). Nonetheless, the dugong's population size and dynamics in the Indonesian archipelago are poorly understood, and only a rough estimate of population size and its general distribution are presently available (Hines et al. 2012). The consensus is that the species suffers from several anthropogenic threats such as incidental and intentional killing, seagrass loss and destruction, and human-wildlife conflicts within Indonesia as well as elsewhere (Marsh and Sobtzick 2019).

Indonesia is the largest archipelagic and fifth most populous country in the world, exhibiting rapid economic and population growth (BAPPENAS 2021). Rapid coastal development can potentially affect the dugong and its habitat. As part of Indonesia's long-term development vision, 15 "Special Economic Zones" are currently being planned or developed. Among these, 12 are located in or near coastal areas. Failure to take remedial conservation action in light of anticipated developments could easily result in severe consequences for the dugong, similarly to what has happened in Eastern China, where dugongs have disappeared and are now functionally extinct (Lin et al. 2022). At the same time, the rapid increase of maritime traffic across the archipelago is becoming an emerging threat (Groom et al. 2004; Maitland et al. 2006). In parallel, habitat loss, fragmentation, and degradation exacerbate the overall pressure on the endangered dugong population (Dewi et al. 2025; Ng et al. 2022; Sjafrie et al. 2024).

In this study, our objective was to collect and analyze publicly available information on dugong occurrence within the Indonesian archipelago so as to develop a better understanding of the species' known distribution and abundance. Publicly available information shared on many different platforms can be used to consolidate knowledge about the dugong's spatial and temporal distribution across the country by means of both incidental sightings and directed studies. Panyawai and Prathep (2022) indicated that peer-reviewed publications on the dugong in the Indo-Pacific were limited. Hence, going beyond the use of formally published scientific articles might help to obtain a broader picture of dugong distribution in Indonesia. Elsewhere underutilized incidental reports have proven useful for the development of valuable insights for rare marine mammals (e.g., Choi-Lima et al. 2017; Debrot et al. 2020, 2022; Franzini et al. 2013; Nazareth et al. 2022; Pikesley et al. 2012; Sahri et al. 2020), so we used such reports for the dugong of Indonesia.

2 | Methods

We collated incidental sightings reported via the Internet and social media, as well as published accounts, for the 13-year period of 2010–2022. A dedicated team searched the Internet and downloaded available information. All records were geolocated using GPS coordinates or to the highest precision possible, based on the available location information. We grouped dugong sighting information into two broad categories: (1) the "Internet and social media" category, which consisted of any information sourced from Internet news, Instagram, Facebook, and YouTube; and (2) the "publication" category, consisting of both gray literature and formal publications. Careful, case-by-case assessments were made to avoid redundancy of incidental reports by scrutinizing similarities in images and case descriptions, and time and location of the documented records. As much as available, additional information collected included the type of record (sighting, directed takes, incidental take), the number of animals, whether they died or were actively killed, the sex (M/F), rough maturity stage (juvenile/adult), and size (total length). Direct contact with the owners of the information was established as much as possible to gain further details when necessary. However, in some cases this could not be further documented because of disconnected social media links or because the original reporters of the information could not be reached. In addition to our Internet and social media search, we used keywords in Bahasa Indonesia and major local dialects (i.e., *dugong*, *duyong*, *duyung*, *dulung*) to find additional publications and gray literature sources for the period 2010–2022. Publications or media notices about dugongs in Indonesian zoos and aquariums were excluded.

We distinguished three main types of records: (1) "stranding" records were for animals washed up on shore either dead or alive and whether or not due to entanglement in fishing gear; (2) "capture" records referred to all records in which animals were either caught passively in fishing gear or actively hunted and killed or put into captivity; and (3) "sighting" records which were reported by local fishers, nature managers, scientists, or dive operators. We further distinguished four main causes of death: (1) "entanglement bycatch and death due to stress; injury or drowning"; (2) "entanglement bycatch and purposely killed"; (3) "hunted"; and (4) "other" (e.g., suffocation due to plastic pollution, boat collisions, and "unknown"). We used the rough age groupings by Marsh and Sobtzick (2019) and Kwan (2002) to differentiate age groups: average size at maturity is 2.7 m, and for this assessment all animals $\geq$ 2.7 m were classified as adults. Neonatal size was defined as $\leq$ 1.3 m in length while animals of 1.3 $\leq$ 2.7 m were considered sub-adults.

Dugong abundance based on records was compared to the documented occurrence of seagrass. Sjafrie et al. (2018) indicate that seagrass coverage in Indonesia is minimally 293,000 ha. However, this number is considered to only represent 15%–35% of the potential seagrass beds due to limited data availability. In this assessment, we used the Allen Coral Atlas (2022), in which seagrass coverage up to 10 m depth was estimated using a combination of machine learning and composite satellite images.

2.1 | Statistical Analysis

Sex ratios in dugong records were tested for deviation from the expected ratio of 1:1 for males and females by means of the chi-squared goodness of fit test. Sizes were reported as mean ± standard deviation (SD). The Kolmogorov–Smirnov (KS) test for normality was used to examine if the size–frequency structure conformed to normality. A simple linear regression analysis of variance *F*-test was used to test for any relationship between dugong records and seagrass coverage.

3 | Results

Our compilation of dugong records for 2010–2022 amounted to 1033 cases comprising 337 incidental reports documented via the Internet and social media and 696 cases reported via scientific papers and gray literature sources. All records and supporting data are available in Supporting Information.

3.1 | Spatial Distribution

Dugong records were established for 24 of the 37 provinces of Indonesia (Figure 1). Five provinces (Sulawesi Utara, Bangka Belitung archipelago, Sulawesi Tengah, Nusa Tenggara Timur, and Riau archipelago) stood out with more than 50 reported records. Of these, Sulawesi Utara and Bangka Belitung archipelago were provinces with more than 100 records, while Sulawesi Utara had the most records (518) distributed between the two concentration areas (Figure 1, see inserts F(1) and F(2)). The high numbers of records for Sulawesi Utara and Bangka Belitung archipelago were mainly provided by Bonnet (2016), Putri et al. (2019), Septiani (2022), Suhendro et al. (2018), Supratman and Farhaby (2021), Syafutra et al. (2018), and Wilanda et al. (2021).

Figure 1 shows the distribution of documented records from the two main categories of sources (Internet and social media vs. publications and reports) across the Indonesia archipelago. Many areas can be seen to have mostly social media records, while others have mostly published records based on reports and studies. For instance, for the Bangka Belitung archipelago and Sulawesi Tengah, documented records were largely via social media, while for the Riau archipelago and Sulawesi Utara, records were largely from publications and gray literature sources. These hotspots are close to each other; thus, even relatively closely situated hotspot areas may differ greatly in the sourcing of available records. Thirteen provinces had no records available for the period considered.

Spatially, dugong records might be expected to be closely correlated with seagrass distribution as seagrass is the dugong's staple food (Budiarsa et al. 2021). Figure 2 shows reported dugong sightings and seagrass cover (ha) according to the Allen Coral Atlas (2022). There were provinces with many dugong records and little documented seagrass and those with few records and much seagrass (Figure 2).

Linear regression analysis of dugong records as a function of seagrass coverage at the province level failed to detect any simple relationship between dugong records and seagrass coverage, even after removal of an outlier value (518) for Sulawesi Utara ($F = 1.95250594$, df $= 1$, $p = 0.17$).

3.2 | Demography

Out of 1107 reported dugong sightings, 918 sightings were reported as solitary animals (89%), while 115 (11%) reports involved multiple dugongs. Of the 94 animals in which the sex was determined, 43 were females and 51 were males, which failed

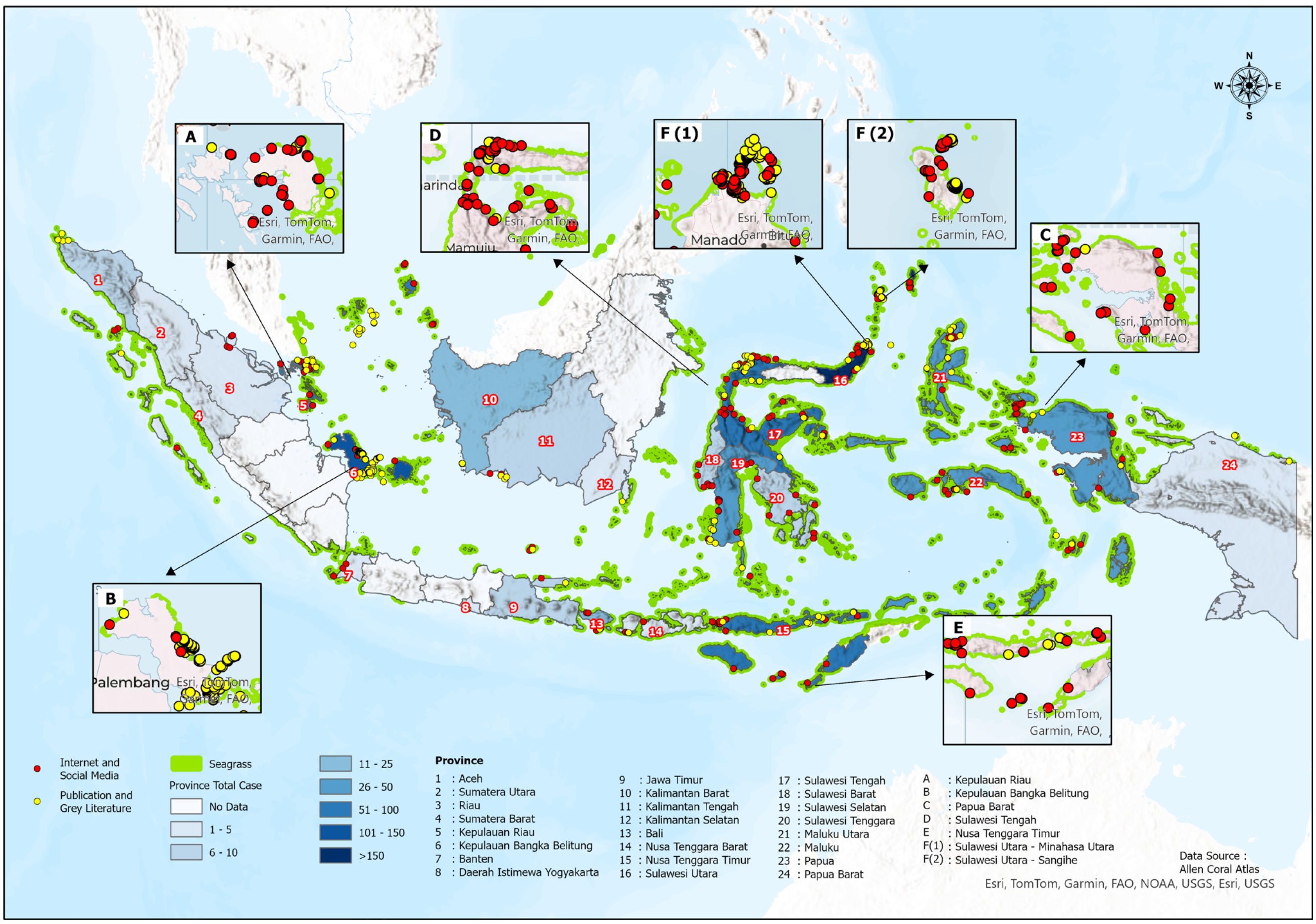

FIGURE 1 | Dugong and seagrass distribution in Indonesia based on Internet and social media (red) and publications and gray literature (yellow). Boxes A–E indicated > 50 sightings hotspots: A, Kepulauan Riau; B, Kepulauan Bangka-Belitung; C, Papua Barat; D, Sulawesi Tengah; E, Nusa Tenggara Timur; F(1) Sulawesi Utara—Minahasa Utara; F(2), Sulawesi Utara—Sangihe.

to differ significantly from the expected ratio of 1:1 ($x^2 = 0.681$, df = 1, $p \geq 0.05$).

Of the 1107 sighting reports, 110 records provided a measurement or estimate of total length (Figure 3). The average reported length of these 110 specimens was 2.15 ± 0.79 m, with a reported size range of 0.5–4.50 m. The mean length was below 2.7 m, which according to Marsh et al. (2012) is the average size at maturity. One sighting from North Sulawesi was of an animal of between 4.25 and 4.5 m, a size which is quite rare (Burnie and Wilson 2005). The size distribution showed a significant deviation from normality (KS, $p = 0.003$) with an overall tendency toward a left skew in which there were relatively fewer small animals and more large animals.

Two other features can be seen in the size–frequency data. The first is that the size estimates show an artifact typically associated with rough size estimation, namely that observers tend to truncate their estimate to fit whole numbers, leading to a seemingly staggered size structure. The second, more interesting feature is that the size structure suggests that the dugong population is composed of two disjunct size groups, one with a modal size of 1.25–1.50 m and one with a modal size at around 2.50 m.

3.3 | Reported Threats and Fatalities

In total, 307 reported dugong records (28%) involved captured (113) or stranded animals (194), while 72% were sightings of animals alive and at large (800 sightings). A total of 184 dugong records further involved dead animals (i.e., 17% of all records).

Of the 184 records of dead dugong, 130 (71%) were from unspecified causes of death, followed by 45 (24%) likely deceased due to stress, injury or drowning resulting from entanglement bycatch, 2 (1%) deceased due to purposeful killing after entanglement bycatch, and 7 (4%) killed during directed hunts (Figure 4). Further, according to record type categories, stranding records contributed 123 of the 184 death reports, capture records (also as bycatch) contributed 54 death reports and sighting records contributed seven death reports. The provinces with highest number of documented mortalities were the Bangka Belitung (22% with 41 records of dead dugong) and Riau archipelagos (17% with 31 records of dead dugong), both at the western end of the Java Sea. The main sources of Bangka Belitung archipelago mortality cases were associated with entanglement bycatch (28 cases) followed by other unknown causes (10 cases). Purposeful hunting (two cases) or killing after bycatch (one case) were

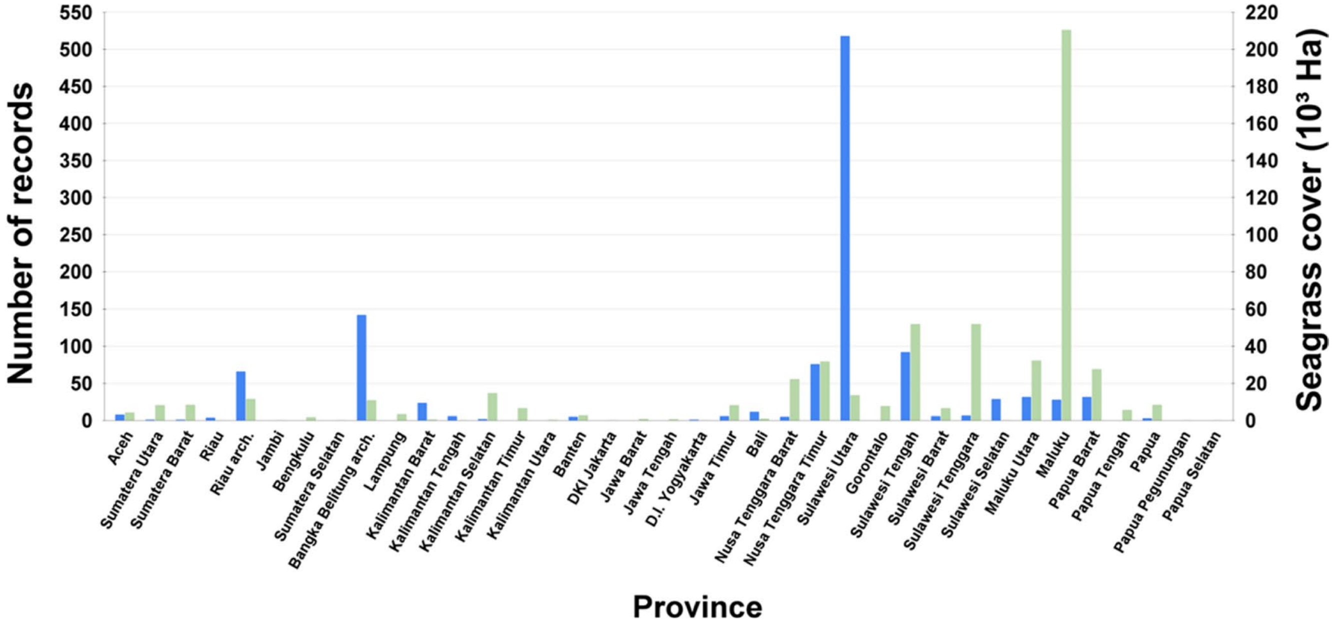

FIGURE 2 | Reported dugong records and seagrass coverage for each province (in hectares × 10^3).

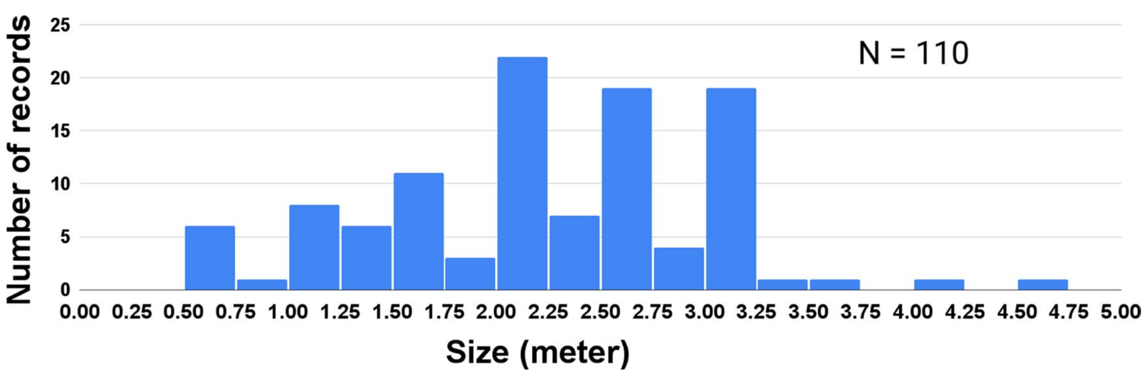

FIGURE 3 | Histogram of reported body lengths of dugong sightings. Two exceptional length reports (≥ 4 m) can be seen in the far right side of the histogram.

least important (Chairul 2020; Haryanto 2021; Pojok 2021; Putri et al. 2019; Suhendro et al. 2018; Syafutra et al. 2018; Tasmalinda 2021; TVRI Babel 2017). The main sources of Riau archipelago mortality cases were "unknown" (25 cases), followed by mortality associated with entanglement bycatch (five cases) and killing after bycatch entanglement (one case) (Figure 5).

3.4 | Specific Cases

3.4.1 | Intentional Capture and Hunting

We recorded eight intentionally captured and captive-kept dugongs within three provinces, namely: (a) Maluku Utara, (b) Papua Barat, and (c) Sulawesi Tengah. The general reason for keeping dugongs in captivity was to attract tourists from which to earn visitor fees. In two instances (Franciska 2016; Moore 2017), the dugong was tied by the tail and moved regularly to fresh seagrass. The person who captured the dugong would offer photo services and allow the visitor to touch or pet the dugong. Some of the reports mentioned injuries to the tail and body, likely due to scouring by the rope (Moore 2017). In one case (Yellu village in the province of Papua Barat), a dugong was captured and kept alive but eventually released by the authorities (Nuraini 2020).

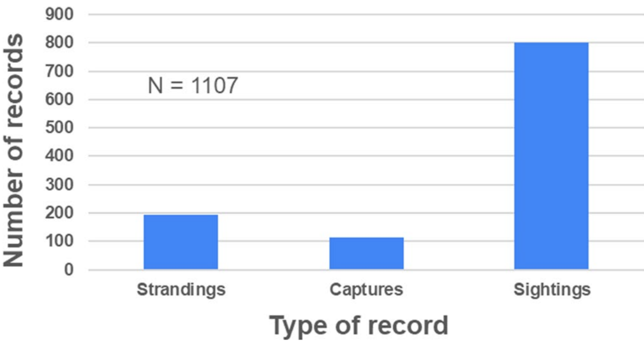

FIGURE 4 | Reported status of dugong records according to the report categories of stranding, capture, and sighting.

We recorded six cases, involving seven dugongs that were intentionally hunted, including an incident from Halmahera Timur, Maluku Utara province, in 2011 when a pregnant dugong was caught and slaughtered by fishermen while the animal was in shallow waters (Nontji 2015; Nontji et al. 2012). There were also cases where bycaught and stranded freshly dead dugongs were subsequently slaughtered for consumption by the coastal villagers if the meat was still fresh. Slaughtering of dugong (whether after intentional or non-intentional mortality) is rarely reported by the public because of its illegality and chance of penalties. Hence, the likelihood of under-reporting is high. At least 29 sightings (2017–2022) involved a single solitary male dugong, locally named Mawar, interacting with human visitors in the Selat Mantar Marine Sanctuary, Kabola Bay, East Nusa Tenggara Province (Harahap 2018). The majority of the latter sighting reports were attributable to a local boat tour operator (Fauzi 2019).

3.5 | Temporal Trends in Dugong Records

The distribution of dugong records for the 13-year period of 2010–2022 shows a general increasing trend apart from two major peaks for the year 2016 (266 records) and 2022 (243 records). This gradual increase in documented records can be attributed to mostly publications and gray literature studies ($R^2 = 0.19$) but records from Internet and social media also manifested a significant positive linear regression ($R^2 = 0.68$) over the years (Figure 6).

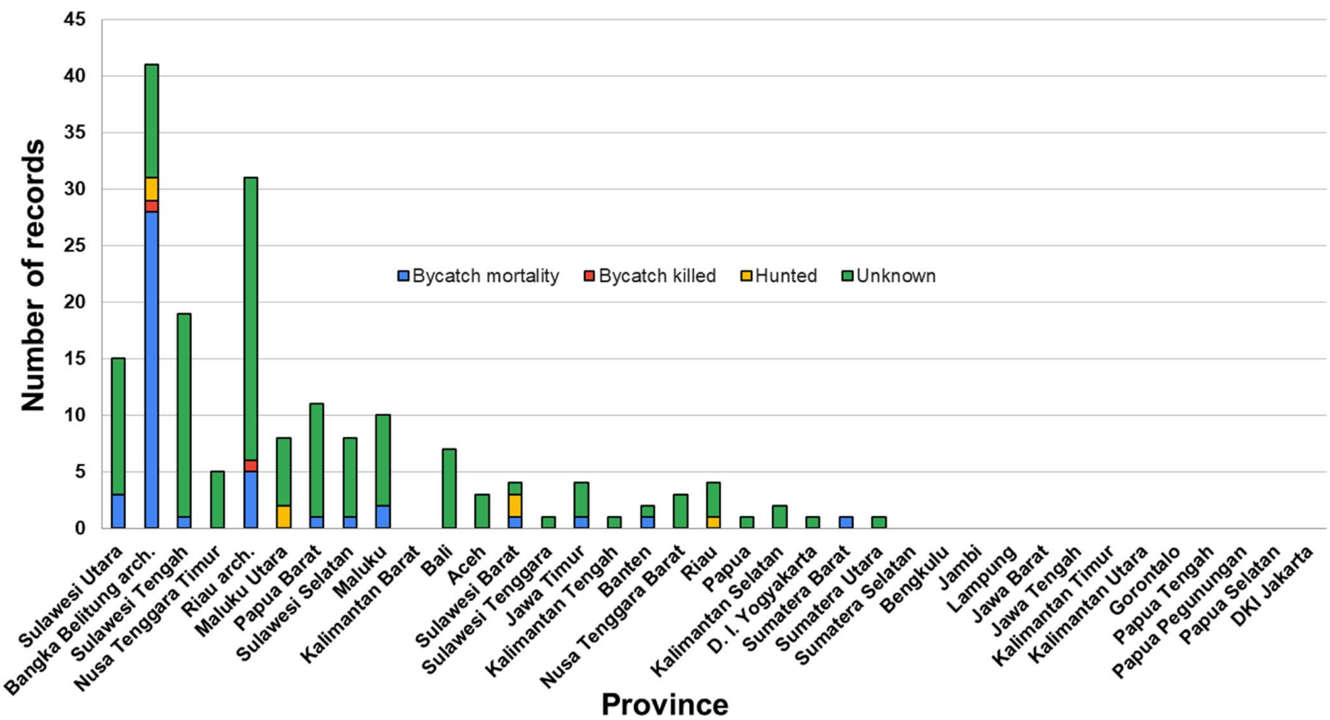

FIGURE 5 | Reported dugong source of mortality by province.

The peak in records for 2016 were sourced back to a master's thesis by Bonnet (2016) for Sulawesi Utara and a conference paper by Suhendro et al. (2018) covering widespread areas of Indonesia including a multi-institutional conservation report focused on Sulawesi Tengah. The peak in records for 2022, was sourced back to a master's thesis by Septiani (2022) for Sulawesi Utara. Both years also happen to be on record for highly extreme climatic events in southeast Asia which may have contributed to higher movement and visibility of dugongs (Trewin 2017; ABM 2022).

4 | Discussion

The compilation of 1033 dugong sighting records from 2010 to 2022 across Indonesia provides new insights into dugong distribution patterns and threats. Our findings especially underscore the urgency for more consistent and coordinated dugong ecological research and five main discussion points emerge:

4.1 | Hotspots

A number of interesting geographic distributional patterns were suggested from our assessment. Six apparent hotspots were identified, clustered into two wider regions, namely the Banda Sea region (Nusa Tenggara Timur including the Flores Sea, Timor Sea, and Celebes Sea) and the western Java Sea (Bangka Belitung and Kepuluan Riau archipelagos). The Banda Sea cluster occurred around relatively small island archipelagos, while the Bangka-Belitung and Kepulauan Riau archipelagos were the locus of the western Java Sea cluster. The Bangka-Belitung and Kepulauan Riau hotspots are closely situated to the Eastern Malaysia and Brunei dugong population "hotspots" as discussed by Ponnampalam et al. (2015) and Panyawai and Prathep (2022). In between, the Java Sea separates these two clusters by roughly 1000 km, along which there is a notable paucity of dugong records. Despite older records for North Sumatra in the Malacca straits (Allen et al. 1976), as well as anecdotal records for East Kalimantan (Allen et al. 1976; Hendrokusumo et al. 1981; Marsh et al. 2002), it appears that overall the outstretched coasts of the main islands that lack safe havens such as bays and coves and which have more riverine input (including Java, most of Sumatra, south and east Kalimantan and the Papua coast of the Arafura Sea) presently have few to almost no documented records. The findings also suggest that the Indian Ocean coast of Central and West Java almost fully lack dugongs, even though in the past the species has been recorded at Cilacap and Segara Anakan west of Yogyakarta (Allen et al. 1976; Hendrokusumo et al. 1981; Marsh et al. 2002). The remarkably low number of dugong records for the Indian Ocean shores of West Sumatra (particularly the Mentawai archipelago) is notable in that small islands and documented suitable seagrass habitat are still plentiful (Figure 1).

Proven seagrass stressors in Southeast Asia are increased nutrient loading and increased sedimentation in shallow coastal areas. Both factors are more problematic around larger islands (Short et al. 2014) as also influenced by the continued large-scale development of coastal lowland agriculture on those islands. The scarcity of records along Sumatra, Java, Kalimantan, and Papua, despite the presence of seagrass cover (Allen Coral Atlas 2022; Budiarsa et al. 2021), suggests that dugongs preferentially occur around small isolated offshore islands with (possibly) reduced disturbance and reduced sedimentation, or both. These patterns align well with previous studies that link dugong presence to small island seagrass ecosystems in Indonesia (De Iongh 1996; De Iongh et al. 1995, 1998, 2007). Even though several studies also demonstrate a tight link between seagrass and dugongs at more limited spatial scales (Cleguer et al. 2020; Cullen-Unsworth et al. 2018), the weak correlation between dugong sightings and seagrass observed in this study likely reflects both the opportunistic nature of citizen science data and incomplete seagrass coverage mapping (Allen Coral Atlas 2022; Sjafrie et al. 2018).

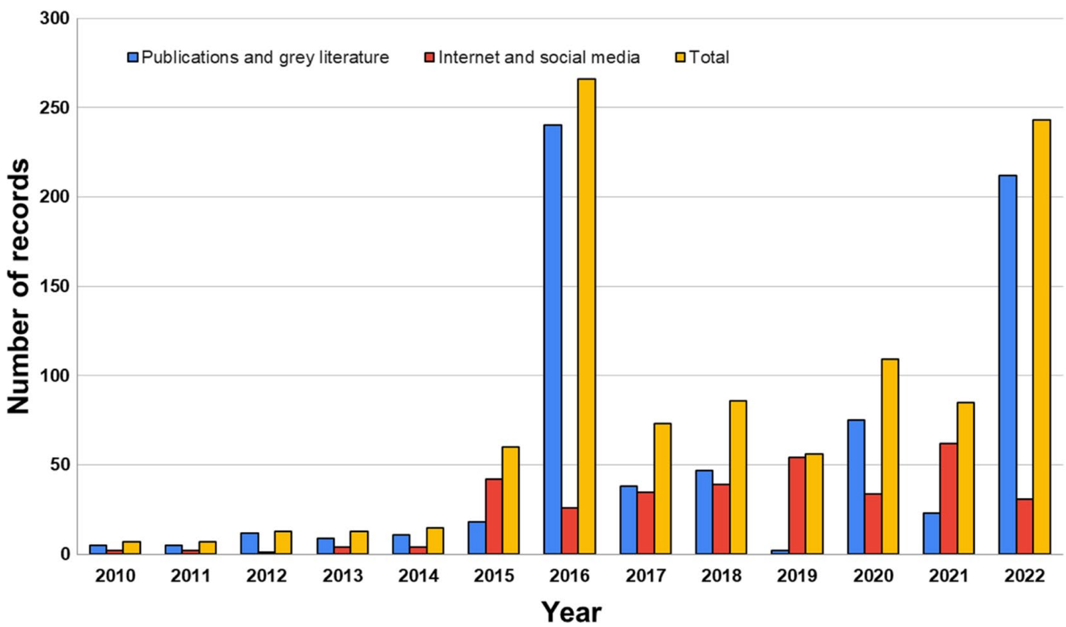

FIGURE 6 | Number of dugong sightings from 2010 to 2022 based on (1) Internet and social media, (2) scientific publications and gray literature.

4.2 | Connectivity

The large geographic separation of hotspots highlights questions of connectivity both within Indonesia and across borders. The Banda Sea cluster may connect most directly to Australia, which has the largest worldwide population of about 70,000 dugongs (Marsh and Sobtzick 2019), which would be unsurprisingly consistent with published evidence of transboundary movement (Marsh and Sobtzick 2019). Nevertheless, limited genetic barcoding from the eastern Java Sea (i.e., bordering the Banda Sea cluster of hotspots) suggests a closer association with the eastern Indo-Pacific population than with Australian dugongs (Dewi et al. 2025). Poommouang et al. (2021) have shown that the dugongs of the Banda Sea seem to be a quite diverse mix of widely dispersed lineages. In contrast, the genetic affinities of the western Java Sea cluster, situated adjacent to the Malaysian dugong concentration (Ponnampalam et al. 2015; Panyawai and Prathep 2022), remain unknown. They might represent the Malaysian/Philippine dugong lineage or could also be more related to the Andaman dugongs, which are a mixture of the Malaysian/Philippine lineage and a unique Andaman lineage (Poommouang et al. 2021). The lack of understanding of transboundary genetic connectivity and gene flow between the western Java Sea and the nearby Malaysian/Philippine and Andaman Sea dugongs (or even the more distant Banda Sea dugongs) represents a critical research gap. Poommouang et al. (2021) have further documented declining genetic diversity in dugongs from both sides of the nearby Thai peninsula. This, as well as limited gene flow and inbreeding as found for at least one Thai dugong subpopulation (Poommouang et al. 2022), could well be occurring in Indonesian dugongs but remains to be studied. Finally, while the exact causes for the apparently low presence of dugongs in the Mentawai archipelago on the west coast of Sumatra remain unknown, these islands have ample seagrass habitat and should be suitable for re-establishment of an additional hotspot for dugongs. That could not only help bolster the status of the (transboundary) Andaman dugongs (Panyawai and Prathep 2022) but also serve as a valuable stepping stone for connectivity across the Indian Ocean.

4.3 | Demography

The gradual, incremental increase in the availability of dugong records as seen in our data is not so surprising, even as the species might actually be showing long-term declines in Indonesia from within its core Banda Sea hotspots area (Cullen-Unsworth et al. 2018). Gradual increases in records of charismatic megafauna are commonly seen in other fields of conservation endeavor as the public becomes more aware and engaged, as the number of scientists continues to increase, and as the collection and spread of information via social media becomes more prevalent. Hence, it is important to understand that the gradual increase in documented records over time likely does not mean or even suggest that dugong abundance is increasing.

At the most elementary level, our data demonstrate a mix of dugong sizes, which corroborates that the species is clearly able to reproduce in Indonesia, as all size-groups were represented. A fully stable population of a long-lived species should further typically show a unimodal population structure. The dugong is a long-lived, late-maturing, low-fecundity species such that a left skew (with old animals predominating), as observed in our data, can also be expected as a normal feature of a stable population (Heide-Jørgensen and Teilmann 1994). However, superimposed upon the general left skew, the data even suggest a bimodal structure, dominated by larger adults with fewer young age/size groups. Changes in the age/size-frequency structure of a population and irregularities in population structure are often caused by perturbations and will typically also have significant impacts on population vitality (Holmes and York 2003; Jackson et al. 2020). This seemingly bimodal population structure could indicate recent immigration of adults from healthier populations (e.g., Australia) or a recently reduced reproductive success within Indonesia (Holmes and York 2003; Jackson et al. 2020). The overall average estimated size of 2.15 m falls below the maturity threshold size of 2.7 m (Marsh et al. 2012). This demographic profile emphasizes the need for standardized monitoring to clarify reproductive success and long-term developments in population viability. In our data, records of males were somewhat but not significantly more abundant than records of females. A relative "shortage" of females versus males may signal lower survival of females or possibly greater mobility (and hence visibility) of males. Therefore, important deviations from a 1:1 ratio between the sexes should always be a good reason for further research. It is also important to verify any major meteorological dynamics that might impact dugong food availability and their movement patterns. For instance, both years with exceptionally high numbers of dugong records were years associated with extreme regional meteorological upheavals known to disturb and destroy the main habitat and food source of the dugong (Collier et al. 2014; McKenna et al. 2015; Short et al. 2014). When faced with food shortages, dugongs may emigrate in large numbers from affected areas (Preen and Marsh 1995) and are well-documented to make frequent macro-scale movements in response to environmental change (Sheppard et al. 2006).

4.4 | Knowledge Gaps

Reliable population size estimates are a minimal metric required for population status assessment (Marsh and Sobtzick 2019). Despite Indonesia's importance in terms of its geographical position for dugong survival, scientific knowledge on abundance and habitat use remains extremely scarce. Much of the available information (yet available) is derived from incidental sightings or localized studies, which make robust population estimation impossible (Cleguer et al. 2020; Cullen-Unsworth et al. 2018; Sahri et al. 2020). In addition, the size/age and sex–structure of any population are also key metrics of population vitality as they represent the joint result of numerous (also historical) processes governing population growth and/or decline through time. Therefore, standardized surveys for reliable population estimation and assessment in different parts of the archipelago and genetic studies are urgently needed to assess and verify connectivity among the Indonesian subpopulations and with neighboring range states (Dewi et al. 2025; Garrigue et al. 2022; McGowan et al. 2023; Seddon et al. 2014).

4.5 | Policy Implication

Previously, Marsh and Sobtzick (2019) ranked anthropogenic dugong mortality rates in Indonesia as unsustainable which means that addressing dugong mortalities is the most pressing policy matter to address. The Bangka Belitung and Kepulauan Riau archipelagos recorded the highest record of mortality largely caused by bycatch, highlighting the urgency of effective mitigation measures, especially for these archipelagos (Marsh and Sobtzick 2019). Strengthened governance, including bycatch reduction by excluding gillnet use from dugong-sensitive areas, effective enforcement, and participation in international conservation agreements, will be crucial for sustaining Indonesia's dugong populations (Sahri et al. 2020).

The recently enacted MMAF Decree No. 79/2018 regarding a National Action Plan for marine mammal conservation offers major new perspectives for dugongs (Sahri et al. 2020). The main action points of that plan were briefly summarized by Sahri et al. (2020) as follows: (1) more ecological and socio-cultural research; (2) building a national database (for which this project may be seen as a modest start); (3) reducing fishing-related mortality (which our study identifies as a key problem for the dugong especially around the Bangka Belitung and Riau archipelagos); (4) identification and protection of main dugong hotspots (as we have explored here, but which need confirmation); (5) better valuation and community awareness of the (clearly growing) tourist economic value of dugongs at large; (6) capacity building and the establishment of a network for rescuing stranded animals; and finally, (7) limiting negative effects of coastal development. A key challenge in this all will be to address the large existing gaps in spatial jurisdiction. Of the 34 provinces of Indonesia, only 16 have some form of marine spatial planning and of the 177 widely scattered marine protected areas, only two specifically address marine mammal needs (Sahri et al. 2020).

5 | Conclusions

Indonesia occupies a central position in the dugong's extensive Indo-Pacific range and holds extensive seagrass ecosystems. Yet its dugong populations remain poorly studied (Marsh et al. 2012; Marsh and Sobtzick 2019). By collating 1033 records from gray literature, scientific papers, and social media sources, this study identified two major hotspot clusters: the Banda Sea and the western Java Sea. These findings suggest that dugongs in Indonesia are not uniformly distributed; rather, they are concentrated around small archipelagos with relatively undisturbed seagrass ecosystems (De Iongh 1996; De Iongh et al. 1995, 1998, 2007; Short et al. 2014). The first and foremost threat to address is the unsustainable level of mortality (Marsh and Sobtzick 2019), which (also based on our results) largely appears to be from bycatch in coastal gillnet fisheries taking place in dugong-sensitive areas and habitat.

While the insights provide new working hypotheses, they also expose critical knowledge gaps. The absence of reliable population size estimates, uncertainties in reproductive success, and unverified genetic connectivity between Indonesia's subpopulations and neighboring range states, particularly Malaysia and Thailand, highlight the limits of current, available knowledge (Dewi et al. 2025; Garrigue et al. 2022; Seddon et al. 2014). Our findings point to the need for standardized and consistent ecological surveys, comprehensive seagrass mapping, and genetic studies addressing subpopulation structure and connectivity (Cullen-Unsworth et al. 2018; McGowan et al. 2023; Sahri et al. 2020). Use of an online, centralized, participatory reporting platform or other low-cost interview methods (Pilcher et al. 2017); university capacity-building networks, and advanced technologies such as drone surveys and the use of artificial intelligence can be part of these efforts (Digdo et al. 2025; Rajpurkar et al. 2021).

From a management perspective, the high incidence of mortality in Bangka Belitung and Kepulauan Riau archipelagos stresses the urgency of addressing bycatch issues (Holmes and York 2003; Marsh and Sobtzick 2019). Moreover, Indonesia's absence in the UNEP-CMS Dugong MoU (UNEP-CMS 2019) limits opportunities for regional cooperation. Strengthening conservation efforts under the National Plan of Action (KKP-DJPRL 2018), while engaging international frameworks, will be essential for safeguarding dugongs across the Indonesian archipelago (Sahri et al. 2020).

Author Contributions

Akbar A. Digdo: conceptualization, validation, data curation, writing – original draft, writing – review and editing, resources, methodology, funding acquisition. **Adolphe O. Debrot:** conceptualization, writing – original draft, funding acquisition, methodology, writing – review and editing, formal analysis, data curation. **Elisabeth Astari:** data curation, validation, analysis, illustration, review. **Bella R. Arinda:** data curation, validation, analysis, illustration, review. **René J. H. G. Henkens:** conceptualization, resources, review, editing.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

References

ABM (Australia Bureau of Meteorology). 2022. *Special Climate Statement 75 – Australia's Wettest November on Record*, 23. Commonwealth of Australia, Bureau of Meteorology. http://www.bom.gov.au/climate/current/statements/scs75.pdf.

Allen Coral Atlas. 2022. *Imagery, Maps and Monitoring of the World's Tropical Coral Reefs*. Arizona State University's Center for Global

Discovery and Conservation Science. https://doi.org/10.5281/zenodo.3833242.

Allen, J. F., M. M. Lepes, I. T. Budairos, D. Sumitro, and D. Hammond. 1976. "Some Observations on the Biology of the Dugong (*Dugong dugon*) From the Waters of South Sulawesi." *Aquatic Mammals* 4, no. 2: 33–48.

BAPPENAS. 2021. *Blue Economy Development Framework for Indonesia Economic Transformation*. Ministry of National Development Planning Republic of Indonesia. https://perpustakaan.bappenas.go.id/e-library/file_upload/koleksi/dokumenbappenas/file/Blue%20Economy%20Development%20Framework%20for%20Indonesias%20Economic%20Transformation.pdf.

Bonnet, A. 2016. "Status of Dugongs in Relation to Intertidal and Shallow Subtidal Seagrass Beds and Human Induced Threats in North Sulawesi, Indonesia." Unpublished Master's Thesis, Wageningen University.

Budiarsa, A. A., H. H. De Iongh, W. Kustiawan, and P. M. van Bodegom. 2021. "Dugong Foraging Behavior on Tropical Intertidal Seagrass Meadows: The Influence of Climatic Drivers and Anthropogenic Disturbance." *Hydrobiologia* 848, no. 18: 4153–4166. https://doi.org/10.1007/s10750-021-04583-0.

Burnie, D., and D. E. Wilson, eds. 2005. *Animal: The Definitive Visual Guide to the World's Wildlife*. DK Adult.

Chairul, W. 2020. *Seekor Anak Ikan Duyung Penuh Luka Terdampar di Perairan Tanjung Ular*. WowBabel. https://www.wowbabel.com/nasional/pr-5984153787/seekor-anak-ikan-duyung-penuh-luka-terdampar-di-perairan-tanjung-ular.

Choi-Lima, K., F. T. M. Campos, A. C. O. de Meirelles, C. P. N. Silva, T. E. B. Da Costa, and D. M. De S. Abessa. 2017. "Using Traditional Ecological Knowledge to Prospect the Distribution of the Antillean Manatee *Trichechus Manatus Manatus* (Sirenia: Trichechidae) in the States of Ceará and Rio Grande Do Norte, Brazil." *Pan-American Journal of Aquatic Sciences* 12, no. 3: 234–247. https://panamjas.org/pdf_artigos/PANAMJAS_12(3)_234-247.pdf.

Cleguer, C., C. Garrigue, and H. Marsh. 2020. "Dugong (*Dugong dugon*) Movements and Habitat Use in a Coral Reef Lagoonal Ecosystem." *Endangered Species Research* 43: 167–181. https://doi.org/10.3354/esr01061.

Collier, C. J., C. Villacorta-Rath, K. J. van Dijk, M. Takahashi, and M. Waycott. 2014. "Seagrass Proliferation Precedes Mortality During Hypo-Salinity Events: A Stress-Induced Morphometric Response." *PLoS One* 9, no. 4: e94014. https://doi.org/10.1371/journal.pone.0094014.g003.

Cullen-Unsworth, L. C., B. L. Jones, R. Seary, R. Newman, and R. K. Unsworth. 2018. "Reasons for Seagrass Optimism: Local Ecological Knowledge Confirms Presence of Dugongs." *Marine Pollution Bulletin* 134: 118–122. https://doi.org/10.1016/j.marpolbul.2017.11.007.

De Iongh, H. H. 1996. "Plant-Herbivore Interactions Between Seagrasses and Dugongs in a Tropical Small Island Ecosystem." PhD Thesis, Radboud University Nijmegen, 1–205. http://hdl.handle.net/2066/146288.

De Iongh, H. H., W. Kiswara, W. Kustiawan, and P. E. Loth. 2007. "A Review of Research on the Interactions Between Dugongs (*Dugong dugong* Muller 1776) and Intertidal Seagrass Beds in Indonesia." *Hydrobiologia* 591: 73–83. https://doi.org/10.1007/s10750-007-0785-4.

De Iongh, H. H., P. Langeveld, and M. Van der Wall. 1998. "Movement and Home Ranges of Dugongs Around the Lease Islands, East Indonesia." *Marine Ecology* 19: 179–193.

De Iongh, H. H., B. J. Wenno, and E. Meelis. 1995. "Seagrass Distribution and Seasonal Biomass Changes in Relation to Dugong Grazing in the Moluccas, East Indonesia." *Aquatic Botany* 50: 1–19. https://doi.org/10.1016/0304-3770(94)00438-R.

Debrot, A. O., D. Caicedo-Herrera, I. Gomez-Camelo, et al. 2022. "The Antillean Manatee (*Trichechus manatus manatus*) Along the Caribbean Coast of Colombia: Underused Incidental Records Help Identify Present and Past Coastal-Lowland Hotspots." *Marine Mammal Science* 39: 322–337. https://doi.org/10.1111/mms.12972.

Debrot, A. O., L. Eybrecht, E. Dawson, J. Cremer, and R. Stelten. 2020. "The Antillean Manatee (*Trichechus manatus manatus*) in the Southern Caribbean: A Compilation and Review of Records for the Dutch Leeward Islands and the Central Venezuelan Coast." *Marine Mammal Science* 36, no. 1: 324–333. https://doi.org/10.1111/mms.12636.

Dewi, C. S. U., S. Wahyudi, H. Tarno, et al. 2025. "Genetic of Stranded *Dugong dugon* (Müller 1776) in the Java Sea, Indonesia, Through COX1-Based DNA Barcoding." *Biodiversitas Journal of Biological Diversity* 26, no. 2: 951–962. https://doi.org/10.13057/biodiv/d260244.

Digdo, A. A., E. Astari, B. R. Arinda, and T. Cahyono. 2025. "The Use of Drones and Artificial Intelligence for Dugong Sighting Detection in a Limited Resource Scenario." *Bio Web of Conferences* 156: 01004. https://doi.org/10.1051/bioconf/202515601004.

Fauzi, M. P. 2019. "Persahabatan Manusia dengan Ikan Duyung Jadi Atraksi Wisata di Alor." *DetikTravel*. https://travel.detik.com/travel-news/d-4451876/persahabatan-manusia-dengan-ikan-duyung-jadi-atraksi-wisata-di-alor.

Franciska, C. 2016. "Para Penyelam 'Menyelamatkan' Dugong Yang Diikat di Maluku Utara." *BBC*. https://www.bbc.com/indonesia/majalah/2016/03/160315_trensosial_dugong.

Franzini, A., D. N. Castelblanco-Martínez, F. C. W. Rosas, and V. M. F. Da Silva. 2013. "What Do Local People Know About Amazonian Manatees? Traditional Ecological Knowledge of *Trichechus inunguis* in the Oil Province of Urucu, AM, Brazil." *Brazilian Journal of Nature Conservation* 11, no. 1: 77–82. https://repositorio.inpa.gov.br/handle/1/16057.

Garrigue, C., C. D. Bonneville, C. Cleguer, and M. Oremus. 2022. "Extremely Low mtDNA Diversity and High Genetic Differentiation Reveal the Precarious Genetic Status of Dugongs in New Caledonia, South Pacific." *Journal of Heredity* 113, no. 5: 516–524. https://doi.org/10.1093/jhered/esac029.

Groom, R. A., I. R. Lawler, and H. Marsh. 2004. *The Risk to Dugongs of Vessel Strike in the Southern Bay Islands Area of Moreton Bay*, 22. James Cook University report.

Harahap, D. 2018. "'Disaat Mawar (Dugong) Sedang Bermain' Di Bawah Perahu Sambil Menyantap Lumut' Yang Menempel Di Perahu Pantai Mali, Alor, Nusa Tenggara Timur, Indonesia #akumelalak #instagram." [Photograph] Instagram.

Haryanto. 2021. "Viral, Warga Pangkalpinang Temukan Duyung Terdampar di Pantai Pasir Padi." *Sindo News*. https://daerah.sindonews.com/read/536938/174/viral-warga-pangkalpinang-temukan-duyung-terdampar-di-pantai-pasir-padi-1631254155.

Heide-Jørgensen, M. P., and J. O. N. A. S. Teilmann. 1994. "Growth, Reproduction, Age Structure and Feeding Habits of White Whales (*Delphinapterus leucas*) in West Greenland Waters." *Bioscience* 39: 195–212. https://doi.org/10.7146/mogbiosci.v39.142550.

Hendrokusumo, S., D. Sumitro, and Tas'an. 1981. "The Distribution of the Dugong in Indonesian Waters." In *The Dugong: Proceedings of a workshop Held at James Cook University of North Queensland, 8-13 May, 1979*, edited by H. Marsh, 10–18. James Cook University. https://catalogue.nla.gov.au.catalogue/10331.

Hines, E. M., K. Adulyanukosol, S. Poochaviranon, et al. 2012. "Dugongs in Asia." In *Sirenian Conservation, Issues and Strategies in Developing Countries*, edited by J. E. Reynolds III, L. V. Aragones, A. A. Mignucci-Giannoni, and M. Marmontel, 58–76. University Press of Florida. https://www.researchgate.net/profile/Lemnuel-Aragones/publication/305680895_Dugongs_in_Asia/links/57ee37fd08ae8da3ce484c87/Dugongs-in-Asia.pdf.

Holmes, E. E., and A. E. York. 2003. "Using Age Structure to Detect Impacts on Threatened Populations: A Case Study With Steller Sea

Lions." *Conservation Biology* 17, no. 6: 1794–1806. https://doi.org/10.1111/j.1523-1739.2003.00191.x.

Jackson, J., K. U. Mar, W. Htut, D. Z. Childs, and V. Lummaa. 2020. "Changes in Age-Structure Over Four Decades Were a Key Determinant of Population Growth Rate in a Long-Lived Mammal." *Journal of Animal Ecology* 89, no. 10: 2268–2278. https://doi.org/10.1111/1365-2656.13290.

KKP-DJPRL. 2018. *National Plan of Action Conservation of Dugong and Its Habitat (Seagrass) in Indonesia (Period 1: 2018–2022).* Direktorat Jenderal Pengelolaan Ruang Laut.

Kwan, D. 2002. "Towards a Sustainable Indigenous Fishery for Dugongs in Torres Strait: A Contribution of Empirical Data and Process." https://doi.org/10.25903/15wx%2Ddx52.PhD Thesis, James Cook University. Research Online@JCU

Lin, M., S. T. Turvey, C. Han, X. Huang, et al. 2022. "Functional Extinction of Dugongs in China." *Royal Society Open Science* 9, no. 8: 211994. https://doi.org/10.1098/rsos.211994.

Maitland, R. N., I. R. Lawler, and J. K. Sheppard. 2006. "Assessing the Risk of Boat Strike on Dugongs *Dugong dugon* at Burrum Heads, Queensland, Australia." *Pacific Conservation Biology* 12, no. 4: 321–326. https://doi.org/10.1071/PC060321.

Marsh, H., J. O'Shea, and J. E. Reynolds III. 2012. *Ecology and Conservation of the Sirenia: Dugongs and Manatees*. Cambridge University Press. https://doi.org/10.1017/CBO9781139013277.

Marsh, H., H. Penrose, C. Eros, and J. Hugues. 2002. *Dugong (Dugong dugon) Status Report and Action Plans for Countries and Territories*. Early Warning and Assessment Report Series, 162. UNEP.

Marsh, H., and S. Sobtzick. 2019. "*Dugong dugon* (Amended Version of 2015 Assessment). The IUCN Red List of Threatened Species 2019: e.T6909A160756767." https://doi.org/10.2305/IUCN.UK.2015-4.RLTS.T6909A160756767.en.

McGowan, A. M., J. M. Lanyon, N. Clark, et al. 2023. "Cryptic Marine Barriers to Gene Flow in a Vulnerable Coastal Species, the Dugong (*Dugong dugon*)." *Marine Mammal Science* 39, no. 3: 918–939. https://doi.org/10.1111/mms.13021.

McKenna, S., J. Jarvis, T. Sankey, C. Reason, R. Coles, and M. Rasheed. 2015. "Declines of Seagrasses in a Tropical Harbour, North Queensland, Australia, Are Not the Result of a Single Event." *Journal of Biosciences* 40: 389–398. https://doi.org/10.1007/s12038-015-9516-6.

Moore, A. 2017. ""The Lost Princess (Putri Duyung)" of the Small Islands: Dugongs Around Sulawesi in the Anthropocene." *Frontiers in Marine Science* 4, no. 284: 1–16. https://doi.org/10.3389/fmars.2017.00284.

Nazareth, E., E. D'Souza, R. Arthur, and R. W. Jabado. 2022. "Distribution of the Critically Endangered Giant Guitarfish (*Glaucostegus typus*) Based on Local Ecological Knowledge in the Andaman Islands, India." *Ocean and Coastal Management* 220: 106075. https://doi.org/10.1016/j.ocecoaman.2022.106075.

Ng, S. Z., Y. X. Ow, and Z. Jaafar. 2022. "Dugongs (*Dugong dugon*) Along Hyper-Urbanized Coastlines." *Frontiers in Marine Science* 9: 947700. https://doi.org/10.3389/fmars.2022.947700/full.

Nontji, A., K. T. Edi, and H. Errix. 2012. *National Review of Dugong and Seagrass: Indonesia*. GEF/UNEP Project on the Dugong and Seagrass Conservation.

Nontji, A. 2015. *Dugong Bukan Putri Duyung*. Oseanografi LIPI.

Nuraini, D. 2020. "KKP Bebaskan Dugong Tangkapan Nelayan di Raja Ampat." Bisnis.com. https://ekonomi.bisnis.com/read/20200328/99/1219050/kkp-bebaskan-dugong-tangkapan-nelayan-di-raja-ampat.

Panyawai, J., and A. Prathep. 2022. "A Systematic Review of the Status, Knowledge, and Research Gaps of Dugong in Southeast Asia." *Aquatic Mammals* 48, no. 3: 203–222. https://doi.org/10.1578/AM.48.3.2022.203.

Pikesley, S. K., M. J. Witt, T. Hardy, et al. 2012. "Cetacean Sightings and Strandings: Evidence for Spatial and Temporal Trends?" *Journal of the Marine Biological Association of the United Kingdom* 92, no. 8: 1809–1820. https://doi.org/10.1017/S0025315411000464.

Pilcher, N. J., K. Adulyanukosol, H. Das, et al. 2017. "A Low-Cost Solution for Documenting Distribution and Abundance of Endangered Marine Fauna and Impacts From Fisheries." *PLoS One* 12, no. 12: e0190021. https://doi.org/10.1371/journal.pone.0190021.

Pojok, B. 2021. "Seekor Dugong Terdampar Hebohkan Warga [Video]." Youtube. https://www.youtube.com/watch?v=EvJyHBmh9XA.

Ponnampalam, L. S., J. F. Izmal, K. Adulyanukosol, J. L. Ooi, and J. E. Reynolds. 2015. "Aligning Conservation and Research Priorities for Proactive Species and Habitat Management: The Case of Dugongs *Dugong dugon* in Johor, Malaysia." *Oryx* 49, no. 4: 743–749. https://doi.org/10.1017/S0030605313001580.

Poommouang, A., W. Kriangwanich, K. Buddhachat, et al. 2021. "Genetic Diversity in a Unique Population of Dugong (*Dugong dugon*) Along the Sea Coasts of Thailand." *Scientific Reports* 11, no. 1: 11624. https://doi.org/10.1038/s41598-021-90947-4.

Poommouang, A., P. Piboon, K. Buddhachat, et al. 2022. "Microsatellite Polymorphism and the Population Structure of Dugongs (*Dugong dugon*) in Thailand." *Animals* 12, no. 3: 235. https://doi.org/10.3390/ani12030235.

Preen, A., and H. Marsh. 1995. "Response of Dugongs to Large-Scale Loss of Seagrass From Hervey Bay, Queensland Australia." *Wildlife Research* 22, no. 4: 507–519.

Putri, A. W., M. M. Kamal, and F. Yulianda. 2019. "Studi Keberadaan Dugong (*Dugong dugon* Müller, 1776) dan Habitatnya di Kabupaten Bangka Selatan, Provinsi Kepulauan Bangka Belitung." Undergraduate Thesis, IPB University, IPB Repository. http://repository.ipb.ac.id/handle/123456789/102204.

Rajpurkar, S., A. Pande, S. Sharma, et al. 2021. "Light-Weight Unmanned Aerial Vehicle Surveys Detect Dugongs and Other Globally Threatened Marine Species From the Andaman and Nicobar Islands, India." *Current Science* 121, no. 2: 195–197. https://www.jstor.org/stable/27310577.

Sahri, A., P. L. K. Mustika, H. Y. Dewanto, and A. J. Murk. 2020. "A Critical Review of Marine Mammal Governance and Protection in Indonesia." *Marine Policy* 117: 103893. https://doi.org/10.1016/j.marpol.2020.103893.

Sahri, A., M. I. Putra, P. L. Mustika, and A. J. Murk. 2020. "A Treasure From the Past: Former Sperm Whale Distribution in Indonesian Waters Unveiled Using Distribution Models and Historical Whaling Data." *Journal of Biogeography* 47, no. 10: 2102–2116. https://doi.org/10.1111/jbi.13931.

Seddon, J. M., J. R. Ovenden, H. L. Sneath, D. Broderick, C. L. Dudgeon, and J. M. Lanyon. 2014. "Fine Scale Population Structure of Dugongs (*Dugong dugon*) Implies Low Gene Flow Along the Southern Queensland Coastline." *Conservation Genetics* 15: 1381–1392. https://doi.org/10.1007/s10592-014-0624-x.

Septiani, C. 2022. "Socio-Ecological Modelling on Seagrass Ecosystems in Sangihe Islands, Indonesia." Unpublished master's Thesis, New Castle University.

Sheppard, J. K., A. R. Preen, H. Marsh, I. R. Lawler, S. D. Whiting, and R. E. Jones. 2006. "Movement Heterogeneity of Dugongs, *Dugong dugon* (Müller), Over Large Spatial Scales." *Journal of Experimental Marine Biology and Ecology* 334, no. 1: 64–83. https://doi.org/10.1016/j.jembe.2006.01.011.

Short, F. T., R. Coles, M. D. Fortes, et al. 2014. "Monitoring in the Western Pacific Region Shows Evidence of Seagrass Decline in Line With Global Trends." *Marine Pollution Bulletin* 83, no. 2: 408–416. https://doi.org/10.1016/j.marpolbul.2014.03.036.

Sjafrie, N. D. M., U. E. Hernawan, B. Prayudha, et al. 2018. *Status Padang Lamun Indonesia 2018 (Ver. 02)*. Puslit Oseanografi-LIPI.

Sjafrie, N. D. M., P. Rahmadi, T. Triyono, et al. 2024. "Monetary Value of Ecosystem Services in Unhealthy Seagrass Meadows in Indonesia." *Ecosystem Services* 70: 101668. https://doi.org/10.1016/j.ecoser.2024.101668.

Suhendro, M. D., W. Adnyana, and D. Suprapti. 2018. *Kajian Awal Sebaran Temporal Dan Spasial Kejadian Dugong Terdampar di Indonesia* [Conference Presentation]. Symposium Dugong dan Lamun Indonesia. IPB University.

Supratman, O., and A. M. Farhaby. 2021. "Sebaran spasial kemunculan Dugong (*Dugong dugon*) di Pulau Bangka." *Jurnal Enggano* 6, no. 2: 309–322.

Syafutra, R., W. Adi, M. Iqbal, and I. Yustian. 2018. "Short Communication: *Dugong dugon* Müller, 1776 (Sirenia, Dugongidae) in Bangka Island, Indonesia." *Biodiversitas* 19, no. 3: 823–830.

Tasmalinda. 2021. "Dugong Ditemukan di Pantai Tanjung Bunga, Hendak Dijual Rp 5 Juta." Suara Sumsel. https://sumsel.suara.com/read/2021/09/11/074436/dugong-ditemukan-di-pantai-tanjung-bunga-hendak-dijual-rp-5-juta.

Trewin, B. 2017. *Australia's Climate in 2016 – A Year of Two Halves as El Niño Unwound*. Australian Bureau of Meteorology. https://media.bom.gov.au/social/blog/1202/australias-climate-in-2016a-year-of-two-halves-as-el-nio-unwound/#:~:text=For%20Australia%27s%20climate%2C%202016%20was,in%20northern%20and%20eastern%20Australia.

TVRI Babel. 2017. "Nelayan Tangkap Ikan Duyung." [Video] Youtube. https://www.youtube.com/watch?v=kOh1T0pFs_I.

UNEP-CMS. 2019. "Memorandum of Understanding on the Conservation and Management of Dugongs and Their Habitats (Dugong MOU)." Fact Sheets.

Wilanda, M., A. Farhaby, O. Supratman, and W. Adi. 2021. "Sebaran Spasial Kemunculan Dugong (*Dugong dugon*) Sebagai Dasar Pengelolaan Mamalia Laut di Kabupaten Bangka Tengah." *Akuatik: Jurnal Sumberdaya Perairan* 15, no. 1: 75–81.

Supporting Information

Additional supporting information can be found online in the Supporting Information section. **Data S1:** mms70110-sup-0001-supinfo.xlsx.