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Review article

The plight of dugongs in Thailand: A race against extinction

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Abstract

The dugong (*Dugong dugon*), a herbivorous marine mammal, is experiencing significant population declines in Thai waters, primarily due to habitat degradation, bycatch, and environmental changes. Here, this review aims to synthesize current knowledge on the population status, threats, and conservation efforts of dugongs in Thailand and management priorities. By summarizing recent findings from genetic, ecological, and community-based studies, this article provides an updated perspective to guide future conservation planning. Historically abundant, particularly in the Andaman Sea and the Gulf of Thailand, dugong numbers have decreased dramatically over the past few decades. Surveys from 2004 estimated approximately 250 individuals in Thailand, with the majority concentrated in Trang Province. However, by 2024, the total population was estimated at 240 individuals, with a notable shift in distribution driven by habitat loss. The total number of dugongs strandings has exhibited a concerning upward trend, increasing from 19 individuals in 2022 to 40 in 2023, and more than doubling to 46 in 2024. This sharp rise underscores the deteriorating status of the species, which is particularly vulnerable due to its low reproductive rate and limited capacity for recovery. A sharp decline in the Gulf of Thailand reduced its population to merely 18 dugongs. Despite showing temporary increases, the Andaman Sea population is threatened by seagrass degradation and mortality events. Migration patterns observed in late 2024 suggest dugongs are moving from Trang to regions like Phuket in search of viable habitats. Conservation efforts, including community-driven initiatives and establishing marine protected areas, have shown promise in mitigating threats. However, the sustainability of dugong populations in Thailand remains precarious, necessitating urgent and coordinated action to address habitat protection, reduce anthropogenic pressures, and foster long-term ecological resilience.

Keywords: Conservation, Migration, Population, Seagrass degradation, Sirenian,

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INTRODUCTION

Dugong is a Malay word meaning “lady of the sea”; the species is closely related to the manatee (*Trichechus inunguis*) and belongs to the order Sirenia. Manatee comes from the Latin manatus, which means “having hands.” They are collectively called sea cows. Dugongs and manatees are believed to have inspired the legend of mermaids. These marine mammals have been associated with mermaid myths in various cultures long before European colonial exploration. This connection can be found in Neolithic cave paintings depicting dugongs, discovered in the Tambun Cave in Ipoh, Malaysia, dating back approximately 5,000 years.

The taxonomic classification of the dugong has undergone several revisions since its initial description. In 1776, Philipp Ludwig Statius Müller, a German zoologist, and entomologist, published a supplement to his translation of Carl Linnaeus's Natursystem (Müller, 1776; Domning, 1996). In that work, Müller provided the first scientific description of the dugong, assigning it the binomial name *Trichechus dugon* (Domning, 1996). However, it is essential to note that this initial classification placed the dugong in the same genus as manatees, which was later recognized as incorrect (Domning, 1996). The current taxonomic classification of the dugong established through subsequent research and revisions today is *Dugong dugon*, belonging to the order Sirenia, family Dugongidae, and genus *Dugong* (Domning, 2018). Its chromosome count includes 23 pairs of autosomes and one pair of sex chromosomes (Baker et al., 2024), similar to the manatee (Kellogg et al. , 2007). The species is the sole extant member of its genus and family. This modern classification reflects a more accurate understanding of the dugong's evolutionary relationships and distinguishes it from manatees (Domning, 2018). While there are three other living species in the order Sirenia, the dugong is the only one that inhabits the waters of the Indo-Pacific Ocean (Domning, 2018; Marsh, 2012).

Dugongs inhabit coastal and island waters ranging from shallow to medium depths, thriving in areas supported by tropical and subtropical seagrass species (Marsh et al., 2018; Panyawai and Prathep, 2025). Geographically, their range spans from East Africa to New Caledonia longitudinally and from Okinawa Island, Japan, to Australia latitudinally (Marsh, 2012; Marsh and Sobtzick, 2019). This vast range encompasses 41 countries (Marsh and Sobtzick, 2019). This range includes the Gulf of Thailand and the Thai Andaman Sea, where the first information of dugong was recorded in 1979 (Boonprakob, 1983). The largest dugong population, estimated at approximately 10,000 individuals, resides in the waters of northern Australia and Papua New Guinea (Marsh and Sobtzick, 2019). The second-largest population, numbering around 6,000 individuals, is found in the waters of Bahrain, Qatar, and the United Arab Emirates (Al-Abdulrazzak and Pauly, 2017; Marshall et al., 2018). The third-largest population, estimated at 2,000 dugongs, inhabits the Red Sea (Marsh et al., 2015). In Southeast Asia, the dugong population is estimated at 1,000 individuals (Hines, 2002; Marsh, et al., 2002; Rajamani, 2009). Other significant populations include approximately 898 dugongs off New Caledonia (Cleguer et al., 2017) and around 300 individuals off Mozambique (Marsh et al., 2015). The species have been listed as Vulnerable on the IUCN Red List of Threatened Species since 1982, with East Africa and New Caledonia populations considered Critically Endangered and Endangered, respectively.

In Thailand, dugongs hold both ecological and cultural significance, yet recent strandings and habitat loss highlight their growing vulnerability (Panyawai and Prathep 2022; Panyawai and Prathep 2025). Despite scattered reports and studies, there has been no comprehensive synthesis of the current population trends, genetic diversity, and conservation challenges. Thus, in this review, we aim to summarize the current state of dugong populations in Thailand, identify key drivers of decline, and evaluate the effectiveness of ongoing conservation initiatives. The goal is to provide a scientific basis for improving region-specific management and policy strategies for long-term dugong conservation.

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BIOLOGY OF THE DUGONG

The dugong is the only strictly herbivorous marine mammal, feeding primarily on seagrass in shallow coastal ecosystems (Domning, 2018; McDonald, 2005). Its strong dependence on seagrass meadows makes it highly sensitive to habitat degradation and coastal disturbance. As seagrass distribution determines dugong foraging grounds, changes in water quality, turbidity, or coastal development can directly affect their survival (Marsh et al., 2022). Dugong has smooth, gray skin, a mouth that opens ventrally under a muzzle, a downturned snout, short flippers lacking nail, and dolphin-like tails; only males have tusks. It has a small brain compared to the size of its body (Marsh et al., 2002; McDonald, 2005). The animal can weigh 400 kg and reach lengths of 3.5 m (Marsh et al., 2002; McDonald, 2005). The size of dugongs varies across regions due to differences in food availability and habitat conditions. For instance, a study of skeletal remains in Thailand revealed that dugongs inhabiting the Andaman Sea are, on average, larger than those found in the Gulf of Thailand (Nganvongpanit et al., 2017a; Nganvongpanit et al., 2017b; Nganvongpanit et al., 2020). This difference underscores the influence of environmental factors on dugong growth and development.

The dugong has a slow reproductive rate and long lifespan (Heinsohn et al., 2004), contributing to the slow recovery of populations from hunting practices of previous centuries (McDonald, 2005). Dugongs reach sexual maturity between 9-10 years of age (Marsh et al., 1984) or at a body length of 240 cm. (Burgess et al., 2012b). They reach adulthood at about 20 years of age (Cherdsukjai et al., 2020) or over 250 cm in body length (Lanyon et al., 2005). Various studies describe different ages at which females can give birth between 6 and 17 years of age (Perrin et al., 2009), highlighting the paucity of information on the species. In a study by Burgess et al. (2012a), the smallest female identified as pregnant was 253 cm in body length, although most (90%) were larger than 260 cm. Gestation ranges between 13 and 15 months, with females usually giving birth to only one calf (Marsh et al., 1984; Boyd et al., 1999; Kwan, 2002). Estimates of calving intervals range from 3 to 7 years (Marsh et al., 1984). Young are large at birth, measuring 1-1.3 m long and weighing 20-35 kg. Calves remain with their mothers, nursing, for up to 1.5 years (Marsh et al., 1984). The oldest dugong was reported to be 73 years of age (Kayanne et al., 2021).

Dugongs exhibit diverse mating strategies, demonstrating remarkable adaptability to local environmental conditions. In Western Australia, they engage in a lek-like system where males gather in traditional areas to perform competitive displays for female selection (Preen, 1989). Conversely, in Moreton Bay, Queensland, more aggressive competition is observed, with males engaging in physical confrontations and displays such as splashing and tail thrashing to gain access to females in estrus (Preen, 1989; Lanyon et al., 2019). Some populations form mating herds, characterized by multiple males pursuing a single female through following, fighting, and mounting (Marsh et al., 1984). In Thailand, behaviors such as splashing, fighting, or rushing at the water surface were not observed during mating activities (Infantes et al., 2020). In addition, mature male dugongs in Moreton Bay showed spring (September–October) elevations in fecal testosterone four times higher than in all other months, suggesting that male dugongs in this region are seasonal breeders (Lanyon, 2003; Burgess et al., 2012b). These varied reproductive behaviors underscore the importance of understanding dugong mating systems for effective conservation, as they provide crucial insights into population dynamics and reproductive success across different habitats.

DUGONG POPULATIONS IN THAILAND

Estimating the population size of dugongs in their natural habitats presents significant challenges due to limitations, including the vastness of the distribution areas, constraints on survey efforts, and the animals' behavior, such as diving and swimming patterns and avoidance of survey boats or aircraft. Consequently,

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population assessments rely on statistical methods to approximate the population size as closely as possible. A commonly used metric is abundance, which is defined as the total number of individuals within a study area. This metric serves as a minimum estimate of the population, calculated by multiplying the average density of dugongs (number of individuals per unit area) by the size of the surveyed area (Hines et al., 2005b; Marine and Coastal Resources Survey Information and Technology Division, 2024).

In Thailand, the Department of Marine and Coastal Resources (DMCR) has a protocol to estimate dugong numbers (Marine and Coastal Resources Survey Information and Technology Division, 2024, Hines et al., 2005b). However, given the expansive range of dugong habitats, conducting comprehensive surveys across the entire area has proven difficult. Instead, DMCR employs sampling techniques within smaller sub-areas where the number of dugongs can be counted more feasible by boat-based and aerial survey (Hines et al., 2005b; Adulyanukosol and Poovachiranon, 2006). These smaller areas are assumed to be representative of the larger distribution area. In Thailand, both line- and strip-transect methods have been used to survey marine mammals (Hines et al., 2005b; Hines et al. 2015). However, line-transect sampling is less suitable for dugongs due to their solitary behavior, brief surfacing time, and the turbid coastal waters they inhabit. Therefore, strip- or fixed-width transect techniques are generally preferred for aerial surveys.

Over the years, methods for estimating dugong populations have evolved significantly, incorporating technological advancements to improve accuracy and efficiency. More than a decade ago, researchers primarily relied on traditional approaches such as interview surveys, land-based observations, and boat surveys to assess dugong numbers (Hines et al., 2005b). Nevertheless, these survey techniques are subject to several limitations. Sampling errors and detection biases can influence population estimates, particularly in regions with variable water clarity and sea conditions. For instance, aerial transect surveys may underestimate abundance due to two main types of bias: perception bias when animals visible at the surface are overlooked by observers and availability bias when animals remain undetected because of environmental factors such as turbidity, sea state, depth, or diving behavior. Along the Andaman coast, high turbidity during spring tides, when water depth exceeds approximately 3.5 m, often prevents the detection of submerged animals, leading to underestimation of true abundance (Hines et al., 2005b). However, contemporary techniques now include advanced methods such as aerial surveys using drones and unmanned aerial vehicles (UAVs), offering more precise and comprehensive data collection (Infantes et al., 2020; Yamato et al., 2021). These innovations enhance the reliability of population estimates and reduce potential animal disturbances, contributing to more effective conservation efforts.

Dugongs are distributed along both coastlines of Thailand - the Andaman Sea (Ranong, Phang-nga, Phuket, Krabi Trang and Satun) and the Gulf of Thailand (Chanthaburi, Chonburi, Rayong, Trat, Chumphon, Nakhon Si Thammarat, Songkhla, Surat Thani and Pattani) (Adulyanukosol et al., 1997; Adulyanukosol 1999; Hines et al., 2005b; Kittiwattanawong, 2024). The population in the Andaman Sea is particularly important due to its genetic diversity and ecological uniqueness compared to that in the Gulf of Thailand (Poommouang et al., 2021; Poommouang et al. 2022). This diversity includes three of unique haplotypes, the distinct maternal lineage from the other regions in the world, reflecting evolutionary adaptations specific to the Thai Andaman (Poommouang et al., 2021). Historically, the largest population was found in Trang province, potentially representing the highest concentration in Southeast Asia during the early 2000s (Adulyanukosol, 1999; Hines et al., 2005b). The dugong population in Trang Province, specifically around Libong to Muk Islands, was estimated at 123 individuals during 2000–2001, with the largest group sizes recorded as 30 in 2000 and 53 in 2001 (Hines et al., 2005b). Based on an aerial survey conducted in 2004, the overall estimated dugong population in Thai waters was approximately 200 in the Andaman Sea, of which 126 animals found in Trang Province, while fewer than 50 animals remained in the

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Gulf of Thailand (Adulyanukosol, 2004; Adulyanukosol et al., 2009; Hines et al., 2012). However, no population estimates were reported between 2005 and 2016.

Between 2017 and 2023, the estimated dugong population in Thai waters showed a generally increasing trend, rising from 221 individuals in 2017 to a peak of 282 in 2023 (Department of Marine and Coastal Resources, 2018; Kittiwattanawong 2024) (Figure 1). In 2017, dugongs in Thai waters was estimated to be around 30 animals in the Gulf of Thailand and 191 individuals in the Andaman Sea (Figure 1), while the population in Trang was estimated at 154 individuals (Department of Marine and Coastal Resources, 2018). Notable increases were observed between 2017 and 2018 (from 221 to 250) and again from 2021 to 2022 (from 261 to 273), with 188 individuals observed in Trang (Figure 1). Although a slight decline occurred in 2020 (from 261 in 2019 to 255), the population rebounded in subsequent years. By 2023, the population reached to a peak, comprising 32 in the Gulf of Thailand and 250 in the Andaman Sea which include 194 individuals of Trang population (Kittiwattanawong, 2024). However, in 2024, a sharp decline was recorded, with the population dropping to 240 individuals, 18 in the Gulf of Thailand and 222 in the Andaman Sea, a reduction of 42 individuals from the previous year (Kittiwattanawong, 2024). These recent trends reveal differing regional dynamics. While the Andaman Sea population experienced a modest net increase over the seven-year period, followed by decline in the most recent year, the Gulf of Thailand population remained relatively stable until 2024, when it later declined sharply. A genetic study using microsatellite loci by Poommouang et al. (2022) also revealed that, over a 26-year period from 1994 to 2019, inbreeding levels in Thai dugongs increased, as indicated by the inbreeding coefficient. This finding may suggest limited gene flow or a lack of new individuals or herds migrating from other areas to maintain genetic diversity. These sudden declines and low genetic diversity reflect the growing vulnerability of local dugong populations, potentially accelerating their risk of extinction, and highlight the urgent need for region-specific conservation strategies.

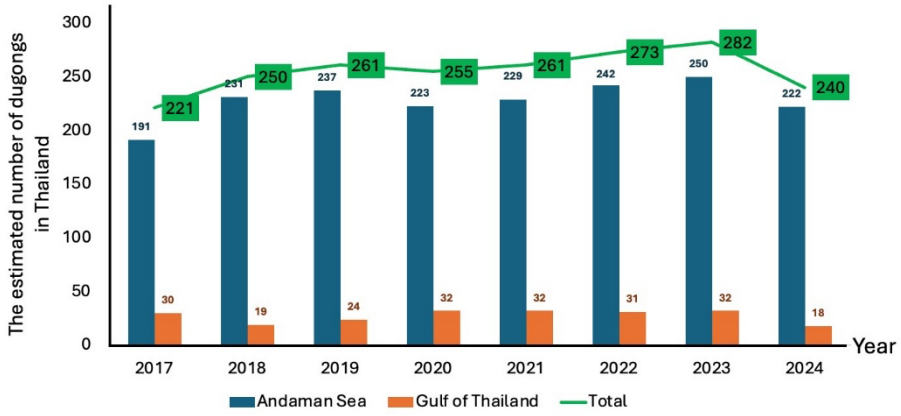

Figure 1 The estimated number of dugongs from a survey by the Department of Marine and Coastal Resources from 2017-2024 (Kittiwattanawong 2024).

It is important to note that, the estimated population numbers are based primarily on surveys and may not accurately reflect the actual population size. Nonetheless, a total of 40 and 46 dugong strandings were reported in 2023 and 2024, respectively (Kittiwattanawong, 2024). Although these figures should not be directly subtracted from the estimated population, the increasing number of mortalities suggests a concerning downward trend and highlights the growing vulnerability of Thai dugong populations in both the Gulf of Thailand and the Andaman Sea. By late 2024, a significant migration of dugongs from Trang Province to other regions was observed, leading to a noticeable decline in the population (BBC Thai, 2024). The migration is believed to be driven by the

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degradation of seagrass meadows, the primary food source for dugongs (BBC Thai, 2024). Interestingly, up to 18 dugongs were reported along the eastern coastline of Phuket Province in Ao Tang Khen (Figures 2a-2d), a region with historically low dugong sightings (Manager Online, 2024). It is hypothesized that these dugongs migrated from the waters of Trang and Krabi provinces in search of better habitats. Due to the species' low reproductive rate and limited annual calf production, dugong populations are particularly susceptible to decline. Consequently, the actual population in Thai waters may be considerably lower than survey estimates indicate, underscoring the critical need for enhanced conservation measures to protect this vulnerable species.

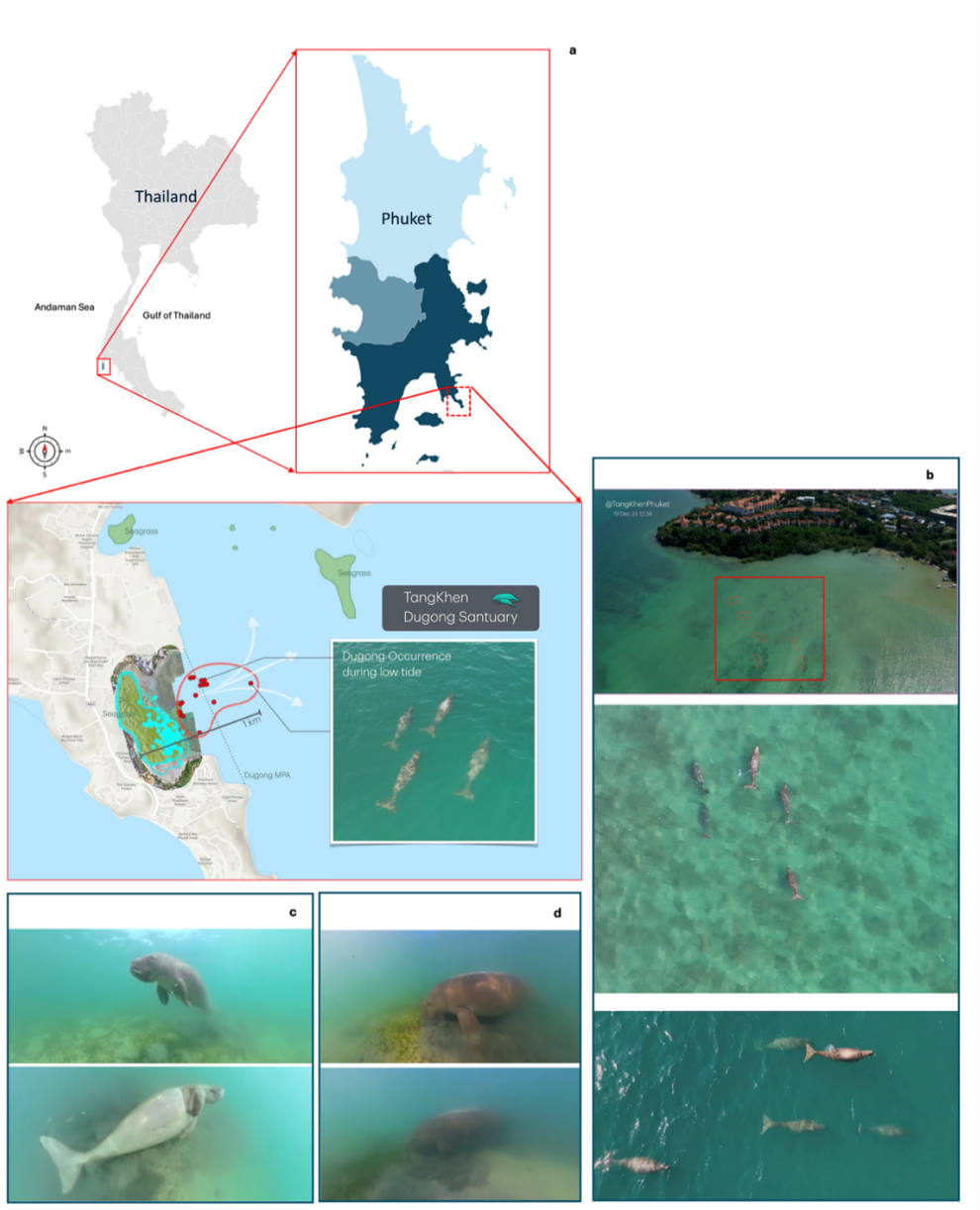

Figure 2 A new population of dugongs was observed in Thailand at the end of 2024, with up to 18 individuals observed in Ao Tang Khen, Phuket (a). A herd of up to five dugongs was identified in the area (b). One female dugong frequently exhibited rolling behavior (c), while another was documented grazing on seagrass (d). Photo credits: Kongkiat Kittiwattanawong and Theerasak Saksritawee. The map was created using Microsoft® Excel for Mac, Version 16.92 (24120731), under a Microsoft 365 Subscription from Chiang Mai University.

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A DRAMATIC DECLINE

Revered for its cultural significance and ecological importance, the dugong is now facing an alarming decline in its population. Once commonly sighted in the seagrass meadows along the Andaman Sea and the Gulf of Thailand, dugong numbers are now critically low. Historically, dugongs were hunted for meat, medicaments, leather, oil, amulets, and charcoal from their bones. However, most countries have banned the hunting of dugongs (Marsh et al., 2002; McDonald, 2005), including in Thailand through the passage of the Fisheries Acts of B.E. 2490 (1947) (Adulyanukosol, 1999; Saranakomkul, 2002; Adulyanukosol, 2004, Adulyanukosol and Poovachiranon, 2006). Today, main threats include degradation and loss of habitat, especially the destruction of seagrass ecosystems due to coastal clearing, trawling, boat propellers, mining, and dredging that can affect plant growth by reducing light intensity (Marsh et al., 2002; McDonald, 2005). Artisanal and industrial fisheries pose significant threats due to accidental entangling in gill nets (Marsh et al., 2002; McDonald, 2005). Additionally, sound waves from human activities can interfere with natural communication signals and cause ear damage and behavioral changes (Marsh et al., 2002; McDonald, 2005). Finally, dugongs are susceptible to parasitic diseases (protozoans, helminths, etc.) and other infections (Marsh et al., 2002; McDonald, 2005). These factors could influence population dynamics by reducing connectivity among subpopulations. Habitat fragmentation and increased mortality from fishing gear may limit dispersal and recruitment, contributing to reduced gene flow and increased inbreeding observed in recent years (Poommouang et al., 2022). These cumulative pressures may reduce reproductive success, and hinder recovery, especially in small or isolated populations. If urgent conservation actions are not implemented, this iconic species may vanish entirely from Thai waters.

Stranded dugongs have been reported across several provinces in Thailand, including Chanthaburi, Chonburi, Rayong, Trat, Chumphon, Nakhon Si Thammarat, Songkhla, Surat Thani and Pattani in the area of the Gulf of Thailand and Ranong, Phang-nga, Phuket, Krabi, Satun and Trang in the area of Andaman Sea (Table 1). A study by Adulyanukosol et al. (2009) reported 282 stranded dugongs in Thai waters between 1962 and February 2008 (Figure 3a). Of these, 202 cases were from the Andaman Sea and 80 from the Gulf of Thailand with gillnets identified as the main known cause of death (Adulyanukosol et al., 2009). The highest number of strandings in a single year was recorded in 1996, with 24 dugongs (Adulyanukosol et al., 2009). Between 2006 and 2015, 103 dugongs were found stranded in Thailand (average 10 per year), of which 12 were alive (Pradip Na Thalang et al., 2023). From 2009 to 2019 (Department of Marine and Coastal Resources, 2019a; Department of Marine and Coastal Resources, 2019b), 142 dugong strandings were recorded (average 12 per year). In a more recent study (Daochai et al., 2024), 132 dugongs were found stranded between 2018 and 2023 (average 22 dugongs per year); 125 died after live stranding, and seven returned to the sea. Examining data from the past 12 years (2013-2024) (Kittiwattanawong, 2024), a total of 238 dugong strandings have been reported, averaging 20 cases per year (Figures 3b and 4). However, in that study, no reports of stranded dugongs were reported for five of the provinces from the Gulf of Thailand: Chanthaburi, Nakhon Si Thammarat, Pattani, Songkhla, and Trat (Figure 3b). The number of strandings in 2024 was increased compared to 2022 and 2023. Moreover, there have been reports of two stranded dugongs in Langkawi and one in Penang, Malaysia, where dugong strandings had not been documented in over 15 years (Saif and Apandi, 2009). It is plausible that some dugongs migrated from Trang to these areas, as the dugong population in Trang has shown a dramatic decline. Concurrently, dugongs have been observed in increased numbers in other provinces, such as Phuket, suggesting potential shifts in distribution driven by environmental changes or habitat degradation in Trang (Manager Online, 2024).

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Table 1 Summary of reported dugong strandings in Thai waters from 1996 to 2024.

Year	Duration (year)	Stranded (individual)	Stranded/year	Reference
1996-2008	13	282	21.7	Adulyanukosol et al., 2009
2006-2015	10	103	10.3	Pradip Na Thalang et al., 2023
2009-2019	11	142	12.9	DMCR2019a-b
2018-2023	6	132	22.0	Daochai et al., 2024
2013-2024	12	238	19.8	Kittiwattanawong 2024

Figure 3 The number of stranded dugongs recorded during two time periods: 1962–2002 (a) and 2013–2024 (b). The figure was created using Microsoft® Excel for Mac, Version 16.92 (24120731), under a Microsoft 365 Subscription from Chiang Mai University. The data for (a) was obtained from (Adulyanukosol et al. 2009), while the data for (b) was sourced from (Kittiwattanawong 2024).

It can be difficult to identify the cause of death or reason for stranding. (Adulyanukosol et al., 2009) reported many (44%) died of unidentified causes. That study classified the cause of stranding into five categories: gillnets, trawlers, stationary traps, other fishing gear, and nonfishing gear such as boat strikes and shark attacks. Of those, the highest proportion of deaths was caused by gillnets. A later study (Daochai et al., 2024) reported on the causes of death in 125 dugongs in the Andaman Sea between 2018-2023 and found eight were anthropogenic, 34 were non-anthropogenic, and 83 died from unidentified causes. Anthropogenic causes included ship collisions (n=6) and interaction with fishing activities (n=2); nonanthropogenic causes included pathology associated with significant cachexia (n=6), pathology associated with non-cachexia (n=23), perinatal pathology (n=1), and intra or interspecific traumatic interactions (n=4). In that study of 139 stranded dugongs, 119 were dead strandings, 13 were live strandings, and seven died after live stranding (Daochai et al., 2024).

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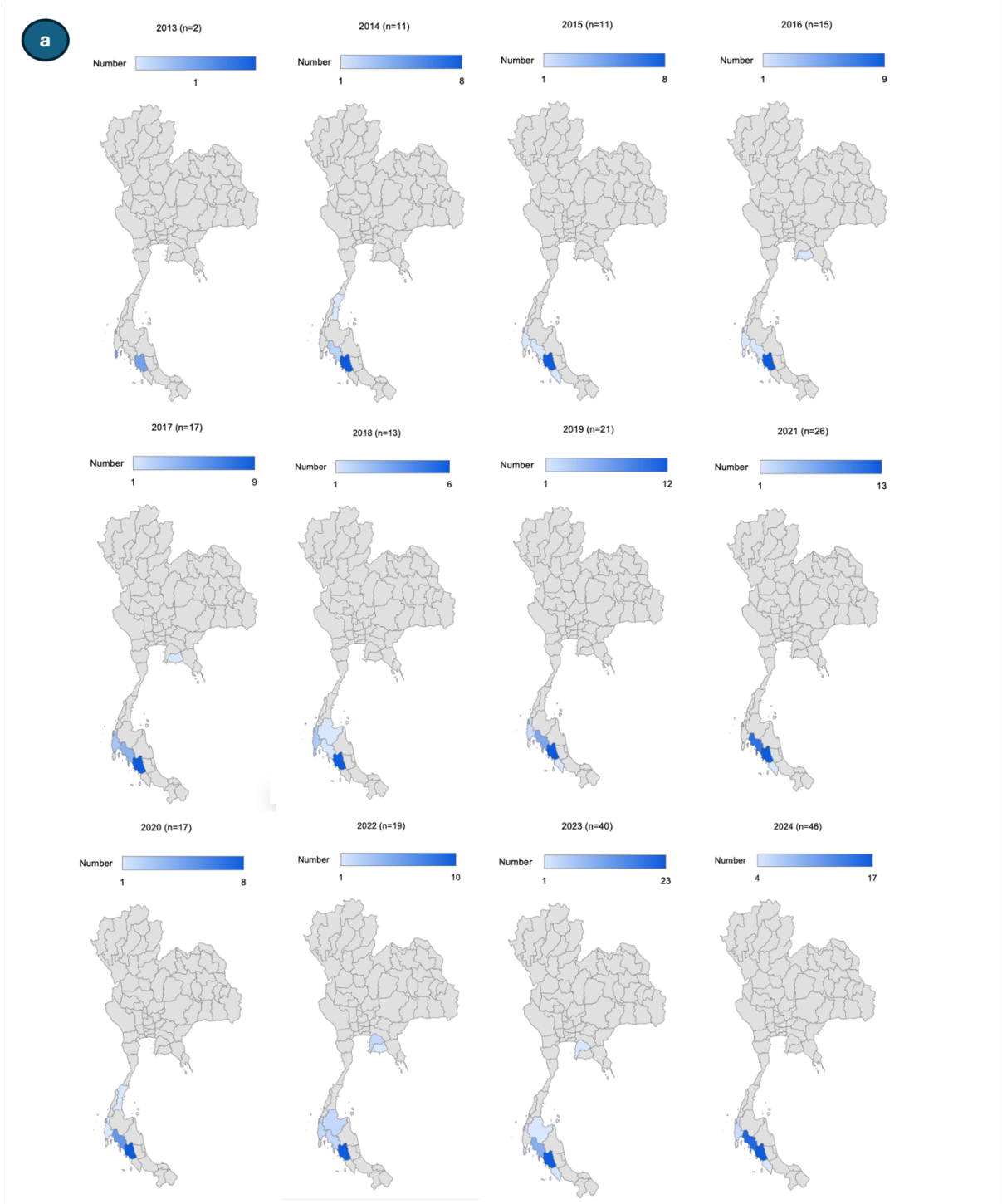

Figure 4 The number of stranded dugongs/carcasses between 2013-2024 by province (a) and separated between the Andaman Sea and the Gulf of Thailand by year (b). The figure was created using Microsoft® Excel for Mac, Version 16.92 (24120731), under a Microsoft 365 Subscription from Chiang Mai University, the data from (Kittiwattanawong 2024).

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Finally, between October 2022 and September 2023, there were 36 reported cases of stranded dugongs (Figure 5a-5n) (Kittiwattanawong, 2024). Of these, 32 cases (89%) involved dead dugongs. Of the live strandings (11%), three dugongs (75%) were successfully rescued and released back into the wild. Among the total strandings, cause of death in 11 cases (31%) could not be established due to the advanced decomposition of the carcasses, while 25 cases (69%) had identifiable causes. Of the cases with known causes, the majority were due to illness, accounting for eight cases (32%). Accidents at sea were responsible for five cases (20%), while five cases (20%) involved dugongs that were sick and had ingested marine debris. Additionally, there were two cases (8%) of dugongs becoming stranded due to disorientation and five (20%) attributed to other causes. The rate of strandings caused by illness has shown an increasing trend compared to 2022. Thus, mitigation of these threats is needed to avoid the species becoming locally extinct.

THE ROLE OF SEAGRASS MEADOWS

Dugongs depend entirely on seagrass for their survival. These underwater meadows provide their primary food source, making them crucial for the species' existence. Unfortunately, seagrass habitats in Thailand are being degraded by coastal development, destructive fishing practices, and sedimentation from land-based activities. Losing these critical habitats directly impacts dugong populations, pushing them closer to extinction.

Thirteen seagrass species from seven genera and two families have been documented along the coastlines of both the Andaman Sea and the Gulf of Thailand. These species include; *Halophila ovalis*, *Halophila major, Halophila minor, Halophila decipiens, Halophila beccarii, Cymodocea rotundata, Cymodocea serrulata, Halodule uninervis, Halodule pinifolia, Enhalus acoroides, Thalassia hemprichii, Syringodium isoetifolium,* and *Ruppia maritima* (Lewmanomont, 1991; Aryuthaka et al., 1992; Aryuthaka and Poovachiranon, 1994; Chansang and Poovachiranoon, 1994; Lewmanomont et al., 1996; Poovachiranon et al., 2006). All of these species are present in both regions, except for *R. maritima*, which has not been recorded along the Andaman coast. The most extensive seagrass beds, with the highest species diversity (11 species), are found around Libong Island in Trang Province (Chansang and Poovachiranoon, 1994; Poovachiranon et al., 2006). In this area, the highest frequency of dugong feeding trails was observed in seagrass meadows dominated by *Halophila ovalis* (Panyawai and Prathep, 2025). These seagrass beds, along with those near Muk Island, serve as critical feeding, nursery, and reproductive grounds for dugongs. Aerial surveys have proven to be a practical method for studying seagrass distribution in areas characterized by mangroves, river mouths, beaches, and island-dotted coastlines (Poovachiranon and Adulyanukosol, 1999).

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Figure 5 The causes of dugong mortality in the Andaman Sea are diverse, and it is often challenging to determine the exact cause. A stranded female dugong was rescued in Ao Maya, Ao Nang Subdistrict, Mueang Krabi District, Krabi Province (a). This individual had injuries on its back resembling cuts from sharp objects and evidence of severe blunt force trauma (b). After its death, a CT scan revealed eight fractured ribs (c). Another stranded dugong was found dead on Nopparat Thara Beach, Ao Nang Subdistrict, Mueang Krabi District, Krabi Province. This individual had two relatively fresh wounds on the head and neck, resembling cuts from a sharp object (d). A stranded female dugong was discovered in Ao Yamu, Pa Khlok Subdistrict, Thalang District, Phuket Province. This individual had five deep, chronic wounds on the head and neck, extending to the skull (e, f). Necropsies of stranded dugongs frequently reveal remnants of fishing nets or fishing lines in their gastrointestinal tracts (g, h, i). A male dugong, measuring 1.98 meters in length, was found stranded near Ban Bo Mamuang Pier, Sai Khao Subdistrict, Khlong Thom District, Krabi Province. This dugong exhibited extensive barnacle attachment along its body (j, k, l), suggesting poor health and reduced mobility, which allowed barnacles to attach. A live stranded dugong of unknown sex was discovered at Laem Ju Hoi, Ko Libong, Ko Libong Subdistrict, Kantang District, Trang Province (m). This individual had a chronic wound at the base of its tail caused by entanglement with fishing gear (n). Photo credits: Piyarat Khumraksa and Patcharaporn Kaewmong.

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In 2017, Khogkhao et al. (2017) investigated the spatial patterns of seagrass species composition, biomass, and their relationships with physical factors such as salinity, mean sea level, light extinction coefficient, temperature, grain size (gravel, coarse sand, fine sand, clay), and soil organic matter across dry and rainy seasons in the Trang River mouth gradient near Libong Island, Trang Province. During the dry season, 10 seagrass species were identified across an area of 6,100 hectares, while only eight species were observed over 2,400 hectares in the rainy season. *H. decipiens* Ostenfeld was the dominant species, covering 2,900 hectares in the dry season. *E. acoroides* and *H. ovalis* also occupied extensive areas. However, density, coverage, and biomass of most species declined during the rainy season. Seasonal variations were evident in both the physical and chemical parameters and in seagrass species composition, biomass, and reproduction. Water depth and light availability were identified as critical limiting factors affecting species composition, biomass, and reproductive success (Khogkhao et al., 2017).

Nearly two decades ago, the total seagrass coverage area was reported to be 14,937 hectares: 9,448 hectares in the Andaman Sea and 5,489 hectares in the Gulf of Thailand (Poovachiranon et al., 2006). At that time, the status of seagrass beds along the Andaman coast was categorized as 40% in good condition, 30% in fair condition, and 10% in poor condition, but habitat quality has declined since then. For example, the loss of seagrass habitats in Trang Province has been ongoing across various areas since 2020 (Wirachwong, 2021). At Libong Island, approximately 300 hectares of seagrass were destroyed, and an additional 900 hectares deteriorated due to sand deposition resulting from dredging activities for the maintenance of shipping channels (Wirachwong, 2021). Only 1,200 hectares of seagrass remained unaffected. The deposition of sand transformed the seabed, originally a mixture of sand and mud, into predominant sand (Figure 6). This alteration led to increased water evaporation during low tide, causing the seagrass to dry out. Consequently, *E. acoroides* leaves were reduced to a length of just 10 cm, exhibiting signs of degradation. Between January and October 2023 Wirachwong (2021), approximately 720 hectares of seagrass at Muk Island was lost. In this area, *E. acoroides*, the dominant species in the middle to lower intertidal and subtidal zones, experienced significant leaf shortening to 7–10 cm due to grazing by green turtles (*Chelonia mydas*) (Figure 7). Unlike leaves damaged by drying, which turn yellow or brown, the grazed leaves retained a bright green color. In August 2023 (Wirachwong, 2021), about 272 hectares of seagrass were lost at Ao Kham. Similarly, the dominant *E. acoroides* in the middle and lower intertidal to subtidal zones experienced leaf shortening to 7–10 cm, attributed to grazing by green turtles, with the grazed leaves remaining green. In November 2023 (Wirachwong, 2021), further losses were documented at Ban Pak Klong, with 128 hectares of seagrass affected. The dominant *E. acoroides* in this region also exhibited leaf shortening to 7–10 cm due to grazing by green turtles, and the leaves maintained a healthy green appearance (Wirachwong, 2021). Additionally, 320 hectares of seagrass in the same area were similarly impacted, with *E. acoroides* showing identical patterns of grazing and leaf reduction.

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Figure 6 The seagrass meadows at Libong Island (a, b) remain relatively pristine, while degraded Enhalus acoroides beds (c, d, e) exhibit shortened leaves with yellow or brown coloration (f, g), attributed to sand deposition. This sediment accumulation alters the seabed, leading to exposure and drying of seagrass during low tide. Photo credit: Ponthep Wirachwong.

Figure 7 The seagrass meadows at Muk Island, Ao Kham, Ban Pak Klong, and Ban Laem Sai (a, b) display a different pattern of loss. Here, *Enhalus acoroides* leaves are shortened but retain a vibrant green color (c, d, e), primarily due to grazing by green turtles (*Chelonia mydas*). This grazing activity is a key driver of seagrass degradation in these regions. Photo credit: Ponthep Wirachwong.

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Global climate change, characterized by unpredictable local seasonal climates, poses a significant threat to tropical seagrasses in estuarine environments (Khogkhao et al. 2017; Edwards 2021). Reduced light availability, driven by increased freshwater runoff, is a critical factor influencing the survival of these seagrasses, whereas salinity appears to have a lesser impact (Khogkhao et al., 2017). In regions with intensive coastal development, such unpredictable conditions may lead to substantial sediment runoff, which could become a major constraint on the growth and reproduction of seagrasses (Khogkhao et al., 2017).

The rapid decline and poor condition of these sea grasses has a direct impact on the dugongs that live there (Panyawai and Prathep, 2025), and is a major cause of dugong migration to other areas with greater sea grass abundance. As a result, in 2024 dugongs are currently found in very few numbers around Libong Island. According to estimates from locals living around Libong Island, presently there are no more than 10 dugongs left around the island. In general, the seagrass beds along the Andaman coast are more abundant than those in the Gulf of Thailand. However, the degradation of these habitats is primarily driven by human activities, including sedimentation from coastal construction, fisheries, and illegal fishing practices. Additionally, seasonal monsoons contribute to localized changes in some areas. This change affects not only the dugong but other animals that live in the seagrass beds, resulting in changes in coastal ecosystems.

THE IMPACT OF LOCAL COMMUNITIES – LIBONG ISLAND AS A MODEL

In Thailand, a successful protocol has been implemented to mitigate the illegal hunting of dugongs. This approach integrates multiple strategies, including enforcement of legal measures and community education, to foster awareness about the importance of dugongs in the local ecosystem (Rojchanaprasart et al., 2015; Hines et al., 2002; Supholdhavanij, 2022). Efforts have also been made to incorporate dugongs into the cultural identity of the community, highlighting their role in sustainable ecotourism and providing income from observing dugongs in their natural habitat (Hines et al., 2002; Rojchanaprasart et al., 2014; Rojchanaprasart et al., 2015). Furthermore, social engagement has been enhanced through meetings, conferences, media coverage, and social media platforms to promote conservation awareness and community participation.

The Libong Island in Trang Province, Thailand, have become a focal point for innovative efforts in dugong conservation through community engagement (Rojchanaprasart et al., 2015). These islands, located within a region historically known for its rich marine biodiversity, are home to significant populations of dugongs, a vulnerable species reliant on healthy seagrass meadows. The breakthrough involved empowering local communities to take an active role in conservation initiatives. Efforts included training residents to monitor dugong populations, restore seagrass habitats, and reduce threats such as fishing gear entanglement and habitat destruction (Supholdhavanij, 2022). Additionally, education campaigns raised awareness about the ecological importance of dugongs, emphasizing their role in maintaining healthy marine ecosystems (Rojchanaprasart et al., 2014; Supholdhavanij, 2022). Collaborative approaches, including partnerships between government agencies, non-governmental organizations, and local leaders, played a pivotal role in this success. By integrating traditional knowledge with scientific methods, the community has contributed to dugong conservation and strengthened their livelihoods through sustainable eco-tourism and marine stewardship (Rojchanaprasart et al., 2015).

The community of Libong Island, located in Trang Province, Thailand, serves as an exemplary model for promoting community participation in the conservation of dugongs, which the locals call ‘duyong’ (Hines et al., 2005a, Adulyanukosol et al., 2010). The involvement of these residents is critical as they become more closely connected to these marine mammals. When the community

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recognizes the significance of conservation efforts, tangible success can be achieved (Hines et al., 2005a; Adulyanukosol et al., 2010). Historically, prior to the declaration of dugongs as protected species under the Wildlife Preservation and Protection Act B.E. 2535 (1992), Libong Island harbored a substantial dugong population due to its diverse ecosystems, particularly its extensive seagrass meadows, which serve as both a food source and habitat for these marine herbivores (Adulyanukosol et al., 2010). Consequently, Libong Island earned the moniker "the capital of dugongs".

The close relationship between the community and dugongs has persisted for generations, with dugongs becoming an integral part of local life. Most Libong Island residents are engaged in fishing as their primary livelihood. However, traditional fishing practices often inadvertently harmed dugongs, particularly when destructive fishing gear damaged seagrass beds or ensnared dugongs. In the past, it was reported that for every ten fishing expeditions, approximately two dugongs were incidentally caught, often already deceased. Dugong meat was consumed locally, shared with neighbors, or sold, while their bones and tusks were sold at high prices for use as amulets, leading to deliberate hunting (Adulyanukosol et al., 2010). The slow reproductive rate of dugongs, combined with destructive fishing practices, significantly reduced their numbers. The situation was exacerbated by the use of highly destructive fishing equipment such as push nets, trawl nets, explosives, and poison, often introduced illegally into coastal waters. These practices not only endangered dugongs but also damaged local fishing gear, disrupting livelihoods. The saying, "If dugongs cannot survive, neither can the villagers," emerged to underscore the interdependence between dugong conservation and community well-being.

In 1994, Libong Island residents began organizing conservation efforts, driven by a shared understanding of dugong importance (Adulyanukosol and Poovachiranon, 2006). These efforts included collaborative actions involving governmental and private organizations as well as the local community. Initial strategies focused on social measures, such as academic research on dugongs and seagrass, which provided essential knowledge shared with the community to foster awareness of the ecological value of seagrass meadows. These meadows not only support immature marine organisms but also economically significant species like sea cucumbers, conch, and abalone. Public forums were organized to gather community input on local issues, strengthen cooperation, and develop solutions. Awareness campaigns, local school curricula on dugongs and seagrass, and other educational activities helped shift local attitudes. Villagers gradually stopped using destructive fishing gear, consuming dugong meat, or neglecting stranded dugongs. Instead, they actively participated in rescues, with some residents prioritizing saving dugongs over economic gains. For instance, villagers would abandon fishing and shell collection activities to assist stranded dugongs (Saranakomkul, 2002; Adulyanukosol and Poovachiranon, 2006; Rojchanaprasart et al., 2014; Supholdhavanij, 2022).

In 2003, tourism activities focused on dugong observation began, further motivating the community to protect these animals. A dugong death now evokes collective sorrow, akin to losing a fellow villager, reflecting their deep emotional bond with these animals. To support conservation, the "Duyong Conservation Volunteers" group was established in 2011, uniting community leaders, residents, and youth to protect dugongs and seagrass in collaboration with national and international organizations. Beyond social initiatives, the Libong Island community has also adhered to governmental policies and regulations aimed at dugong conservation. Key measures include the designation of Libong Island as a wildlife sanctuary in 1979, the classification of dugongs as protected animals in 1992, and provincial regulations in 1992 prohibiting harmful fishing practices. Subsequent bans on trawling and other destructive fishing methods were enacted in 2001 and 2007 (Saranakomkul, 2002; Adulyanukosol and Poovachiranon, 2006; Rojchanaprasart et al., 2014; Supholdhavanij, 2022). In 2021, safe zones for

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dugong feeding and habitation were established through collaborative discussions among fishers, conservation groups, and community leaders. Regulations were introduced to restrict harmful fishing gear, manage vessel operations, and ensure tourism activities minimize disturbances to dugongs. The community actively monitors and reports illegal fishing activities to authorities (Supholdhavanij, 2022).

Before a sharp decline in 2024 (Kittiwattanawong, 2024), the dugong population increased from approximately 123 individuals in 2000–2001 (Hines et al., 2005b) to 194 individuals in 2023. This population trend before the dramatic decline serves as a key performance indicator of community-driven conservation efforts and highlights both their success and the need for continued monitoring and adaptive management in Trang province. The Libong Island community has long been central to dugong conservation in Thailand. While dugongs were once abundant in the area, the habitat degradation previously led to population decline. In response, local residents, supported by government agencies, established community-based conservation measures, including the designation of seagrass protection zones and restrictions on destructive fishing gear. These efforts, grounded in cultural values and traditional stewardship, have fostered strong cooperation among stakeholders and produced measurable outcomes.

CONSERVATION CHALEENGES

Preventing the extinction of dugongs in Thailand requires a comprehensive and coordinated strategy that integrates habitat protection, sustainable practices, education, research, and community involvement (Adulyanukosol and Poovachiranon, 2006). Efforts to protect dugongs in Thailand face several challenges. One major obstacle is the lack of public awareness, as many people remain unaware of the dugong's plight and its ecological importance. In addition, economic activities such as coastal tourism and industrial development often take priority over conservation efforts, disrupting dugong habitats and natural behaviors (Figure 8). Moreover, conservation programs these days often face resource limitations, including insufficient funding and manpower. Although collaborative initiatives among government agencies, NGOs, researchers, and local communities once demonstrated the success of dugong management in Thailand (Adulyanukosol and Poovachiranon, 2006), renewed and strengthened efforts are now needed to sustain and restore that success. Public education campaigns must highlight the ecological importance of dugongs and the challenges they face, fostering broader societal support for their conservation. Scientific research should focus on monitoring dugong populations and their habitats, particularly areas containing seagrass meadows, providing critical data to guide conservation planning and engaging local communities as active participants in protecting coastal ecosystems is crucial for ensuring the long-term success of conservation efforts. Other than that, basic research such as histological studies of dugong organs can enhance understanding of normal anatomy and provide valuable insights for pathological investigations, as demonstrated by Kaewmong et al. (2023).

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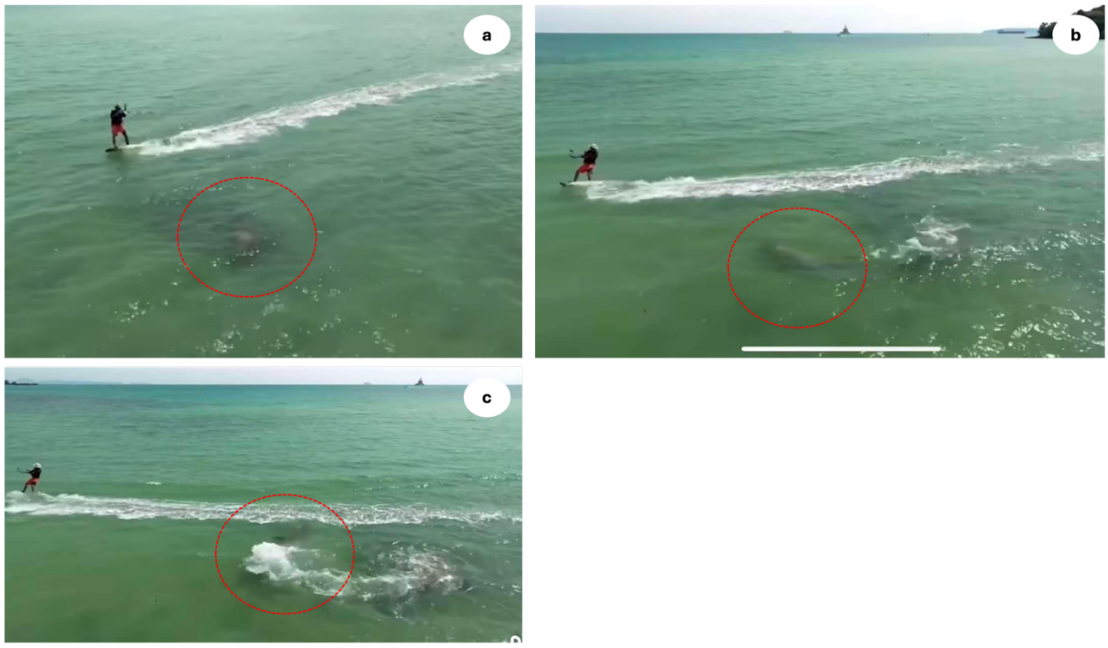

Figure 8 Human activities in the ocean disrupt the feeding behavior of dugongs. Jet skiers passing near feeding dugong (a) can startle them (b), causing the dugong to flee quickly (c). This sudden movement may lead to physical injuries or discourage the dugong from returning to the area to feed, even if seagrass, a vital food source is abundant. Photo credit: Theerasak Saksritawee.

In addition, rising sea temperatures and ocean acidification caused by climate change pose significant threats to seagrass meadows, which are critical to dugong survival. Although these problems cannot be fully resolved, research into methods for cultivating seagrass or enhancing its resilience to higher temperatures could help mitigate these impacts. Thus, the establishment and strict enforcement of marine protected areas (MPAs) are also essential to safeguarding seagrass meadows, the primary habitat for dugongs. Equally important is the adoption of sustainable fishing practices, such as the use of dugong-safe fishing gear, to reduce bycatch and other anthropogenic threats.

Beyond the population decline and habitat degradation, the rescue and rehabilitation of stranded dugongs pose additional challenges that highlight the vulnerability of the species and the limitations of current conservation approaches. Between 1979 and 2019, at least 15 dugong calves were either caught, rescued from fishing gear, or found washed ashore in Thai waters (Panyawai and Prathep, 2022). However, dugongs are highly sensitive animals and successfully keeping them in captivity poses significant challenges. The primary challenges in caring for dugongs in captivity include providing appropriate nutrition, such as milk replacement for calves and fresh seagrass for older individuals, as well as ensuring suitable enclosure conditions. Additional stressors include injuries sustained during capture and transportation and a high susceptibility to diseases (Boonprakob, 1983; Adulyanukosol and Patiyasawee, 1994; Adulyanukosol, 1996; Adulyanukosol, 2002). Furthermore, the survival prospects of rescued calves after release into the wild appear limited. Young calves often struggle to adapt to their new environment, lacking essential survival skills such as foraging and avoiding predators. These deficiencies significantly reduce their chances of survival in the wild.

In 2019, two young calves, Marium and Jamil, were rescued in April and July (Figure 9). Marium was an 8-month-old female stranded on Poda Island in Krabi. After being rescued, she was released back to the sea after 2 days. However, she returned to the shore. DMCR then moved her to a dugong habitat near Libong Island in Trang to forage naturally. However, she died after 114 days from a blood

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infection and gastrointestinal disorders (Central Database System and Data Standard for Marine and Coastal Resources, 2020b). The other calf, Jamil was a 3-month-old female dugong stranded on Krabi. She was moved to the Marine and Coastal Resources Research and Development Center, Phuket. However, she died after 53 days from septic shock (Central Database System and Data Standard for Marine and Coastal Resources, 2020a). Thus, the rehabilitation and release of dugongs, particularly young calves, presents significant challenges. The complexities of providing appropriate care in captivity, combined with the difficulties these animals face upon reintroduction to the wild, underscore the critical importance of protecting dugong populations in their natural habitats. The cases of Marium and Jamil highlight the vulnerability of rescued calves and the need for advanced, specialized care protocols. These experiences emphasize the necessity of focusing conservation efforts on preserving dugong habitats and preventing incidents that lead to stranding, rather than relying solely on rescue and rehabilitation strategies.

Figure 9 The calves were rescued from the Andaman Sea, Marium the eight-month-old dugong rescued in April 2019 and Jamil, a three-month-old rescued in July 2019. Photo credit: Patcharaporn Kaewmong.

CONCLUSIONS

Thailand's Andaman Sea coast is a vital habitat for dugongs, but their dramatic decline serves as a stark reminder of the urgent need for marine conservation. Without immediate action, this iconic species could vanish within our generation. By protecting seagrass habitats, minimizing human-induced threats, and fostering public awareness, we can give dugongs a fighting chance. Time is of the essence our collective actions today will determine the future of this species. Presently, dugongs have become locally extinct from some region such as in Taiwan (Hines et al., 2012). Urgent and comprehensive efforts are needed to protect dugongs in Thailand to prevent the country from being added to the growing list of nations where dugongs have become extinct.

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AUTHOR CONTRIBUTIONS

Patcharaporn Kaewmong: conceptualization (lead), data curation (equal), investigation (lead), validation (lead), resources (lead), writing – original draft (equal). Kongkiat Kittiwattanawong: data curation (supporting), investigation (supporting), resources (lead), validation (supporting). Janine L. Brown: supervision (equal), validation (equal), writing – review and editing (equal). Piyarat Khumraks: data curation (supporting), investigation (supporting), resources (lead), validation (supporting). Kanokrat Rattanapan: data curation (supporting), investigation (supporting), resources (lead), validation (supporting). Ponthep Wirachwong: data curation (supporting), investigation (supporting), resources (lead), validation (supporting). Wen-Ying Chen: supervision (equal). Korakot Nganvongpanit: data curation (supporting), investigation (supporting), validation (supporting), writing – original draft (equal), writing – review and editing (equal). Promporn Piboon: conceptualization (equal), project administration (equal), supervision (equal), validation (equal), writing – review and editing (equal).

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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