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Research article

Epidemiological situation of dugong stranding in the Andaman Sea of Thailand, 2019 –2024

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Abstract

Dugongs *(Dugong dugon)*, as strictly herbivorous marine mammals, play a crucial ecological role dependent on seagrass ecosystems. This cross-sectional study examined the epidemiological situation of dugong strandings across six provinces in the Andaman Sea of Thailand (Ranong, Phang Nga, Phuket, Krabi, Trang, and Satun) from January 2019 to December 2024. Data from the Department of Marine and Coastal Resources (DMCR) database were analyzed using descriptive statistics and chi-square tests. Thailand's dugong population is estimated at approximately 240 individuals, mostly residing in the Andaman Sea. Over the six-year period, 161 strandings were reported, detected by government officers and public notifications. Temporal trends revealed a seasonal pattern peaking in the monsoon season, particularly from 2023–2024. Findings showed an alarming increase in emaciated dugongs (underweight, with stomach contents <3% body weight), likely linked to the degradation of local seagrass beds since 2019. This study enhances understanding of stranding detection and management within the current system. However, to fully evaluate the causes and develop effective surveillance and solutions, the current reporting system must clearly identify the gaps in the documented causes of dugong strandings and their associated factors.

Keywords: Andaman Sea of Thailand, Dugong stranding detection, Epidemiology.

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INTRODUCTION

Dugongs *(Dugong dugon)* are primarily herbivorous marine mammals that depend on seagrass meadows for survival and play an important ecological role in coastal marine ecosystems (Marsh, 1984; Marsh et al., 2019). In Thailand, dugongs are legally protected under the Wild Animal Conservation and Protection Act B.E. 2562. All forms of harm, hunting, possession, or trade of dugongs are strictly prohibited under the Act, which provides the legal basis for protecting the species, conserving their habitats, and prosecuting violations such as boat strikes or fishing gear entanglement (Thailand, 2019). The latest survey in Thailand estimates the population at 267 (Report on the Status of Endangered Marine Animals by the Department of Marine and Coastal Resources, Fiscal Year 2024.). Their distribution spans both coastal areas along the Gulf of Thailand and the Andaman Sea (Poommouang et al., 2021; Poommouang et al. 2022). The larger population is found in the Andaman Sea, estimated to be around 222 individuals, coinciding with the location of the largest seagrass beds in Thailand's waters (Adulyanukosol et al., 2009).

Seagrass meadows provide crucial services, such as habitat for diverse marine life, carbon sequestration, and coastal protection (Orth et al., 2006; Fourqurean et al., 2012; Duarte et al., 2013). Dugongs are vital to seagrass by maintaining healthy and resilient seagrass meadows through grazing. Sustained dugong grazing prevents seagrass detrital buildup and reduces shoot density, while promoting the growth of new shoots and seed dispersal (Preen 1995; Aragones and Marsh 2000; Marsh et al. 2011). Dugongs serve as indicators of the health of marine biodiversity, as their presence and population status can reflect the condition of seagrass habitats and overall marine ecosystem health (Marsh et al., 2011). Dugongs hold significant cultural value for many coastal communities, particularly in regions such as the Indian Ocean and Pacific Islands. They are often featured in local traditions, folklore, and rituals, symbolizing a connection to the sea and marine life (Marsh et al., 2011). Their protection is tied to preserving these cultural practices and heritage. Dugongs also have economic and tourism value. Their presence can attract ecotourism, offering opportunities for wildlife watching and educational experiences. This can provide income and employment for local communities (Marsh et al., 2011). Additionally, healthy seagrass meadows, supported by dugongs, enhance fishery resources and contribute to sustainable marine economies (Marsh et al., 2011).

A stranded dugong refers to animals on the shore that are unable to return to the water under their own power, those in the water that cannot return to their own natural habitat, or dead animals on the beach or in the water. The number of stranded dugongs in the Andaman Sea of Thailand has averaged 23 per year over the past five years of data collection (2019–2024) (Department of Marine and Coastal Resources, 2024). Threats to dugong population loss are classified into three categories: dugong health, human activities, and environment. All three factors contribute to dugong stranding, for example, natural disease, habitat loss, and anthropogenic injuries (Muir et al., 2003). However, the cause of death for the majority of dugong strandings recorded in Thailand remains unclear, largely due to the advanced state of decomposition in many carcasses and the limited availability of fresh specimens for comprehensive necropsy. This is largely due to delays and limitations in the current stranding surveillance and response system, which often prevent the timely retrieval of carcasses and result in many being found in advanced stages of decomposition. These gaps highlight the need for a more comprehensive understanding of the epidemiological patterns of dugong strandings in Thailand, including spatial and temporal trends, carcass condition, potential contributing factors, and limitations in current data collection systems. Such information is essential for identifying emerging threats, guiding conservation planning, and strengthening national response capacity for marine mammal health surveillance.

Therefore, this study aimed to describe the epidemiological situation of dugong strandings in the Andaman Sea from 2019 to 2024, focusing on (1) distribution patterns, (2) health condition and potential causes of death in stranded dugongs, and (3) gaps in the current dugong stranding data system. Improving understanding of these factors will support earlier detection of unusual mortality events, inform evidence-based management interventions, and ultimately enhance the protection and long-term viability of dugong populations in Thailand. The objectives of this study were to describe the epidemiological distribution of dugong stranding detection (DSD) events, including their spatial and temporal patterns, and to assess the health conditions of stranded dugongs in order to identify potential causes associated with dugong stranding detection (DSD).

MATERIALS AND METHODS

Study Design

A cross-sectional study was conducted to describe dugong strandings in the Andaman Sea of Thailand. The unit of interest was an individual dugong reported as stranded. A DSD was defined as any report of a live or dead dugong found ashore or in nearshore waters within the Andaman Sea. All events were reported to the Department of Marine and Coastal Resources (DMCR) through a 24-hour hotline (1362), social media channels, or the Line application. The study period spanned from 1 January 2019 to 31 December 2024, as earlier records lacked consistent detail and standardization; therefore, this timeframe was selected because it corresponds to the period in which systematic data collection began and coincides with documented seagrass degradation in the Andaman Sea, allowing for more reliable epidemiological analysis.

Study Area

The study area covered six Andaman Sea provinces—Ranong, Phang Nga, Phuket, Krabi, Trang, and Satun (Figure 1). These provinces contain Thailand's largest seagrass meadows and represent the main distribution range of dugongs in the country. Analyses focused on identifying spatial and temporal patterns of strandings and their relationship with environmental factors and anthropogenic pressures.

Data Sources and Collection Procedures

Stranded dugongs were reported to the DMCR through the 24-hour hotline (1362) or the official Line application, with most initial detections made by local residents, fishermen, tourists, or government officers. Once notified, the hierarchical stranding surveillance system (Figure 2) was activated. This system involves field-level detection, local response, regional verification, and central-level reporting within DMCR's endangered marine animal rescue network. Upon notification, trained DMCR officers conducted on-site investigations to verify and document each event. Standardized field data collected included the date of detection, GPS coordinates, carcass decomposition code, estimated age class, sex, body length, external injuries, body condition score (BCS), stomach content weight, and the suspected cause of death. All verified records were uploaded to and securely archived in the Marine Endangered Species Unit of DMCR database.

For stranded individuals with suitable carcass condition (Code 1–3), necropsies were performed following DMCR protocols and international marine mammal post-mortem guidelines (Geraci and Lounsbury, 2005; Pugliares et al., 2007). Necropsy results—including gross findings, histopathology, parasitology, and other laboratory analyses—were incorporated when available to improve diagnostic accuracy. In addition to biological data, environmental variables relevant to dugong ecology were obtained from the marine ecosystem group in the DMCR, including seagrass coverage data and seawater quality parameters (e.g., temperature, salinity, and pH). These combined datasets formed the basis of all analyses conducted for the study period between January 2019 and December 2024.

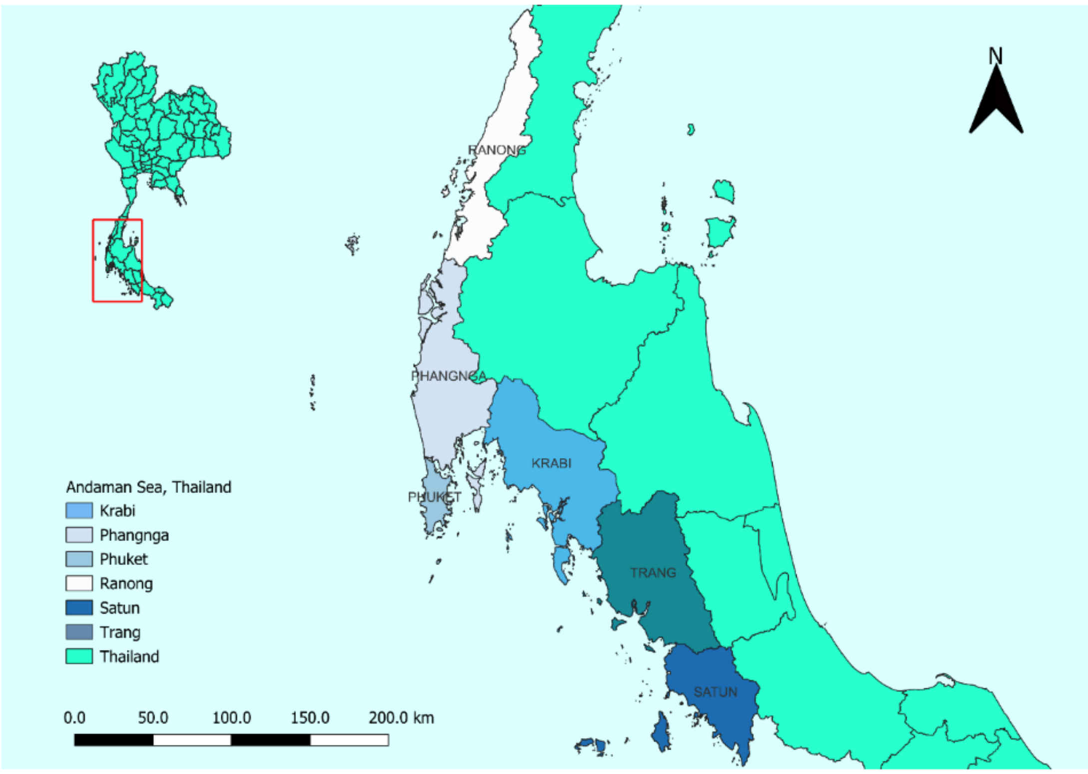

Figure 1 Geographical Distribution of the Six Provinces Covered in the Dugong Stranding Study, Andaman Sea, Thailand (Ranong, Phang Nga, Phuket, Krabi, Trang, and Satun).

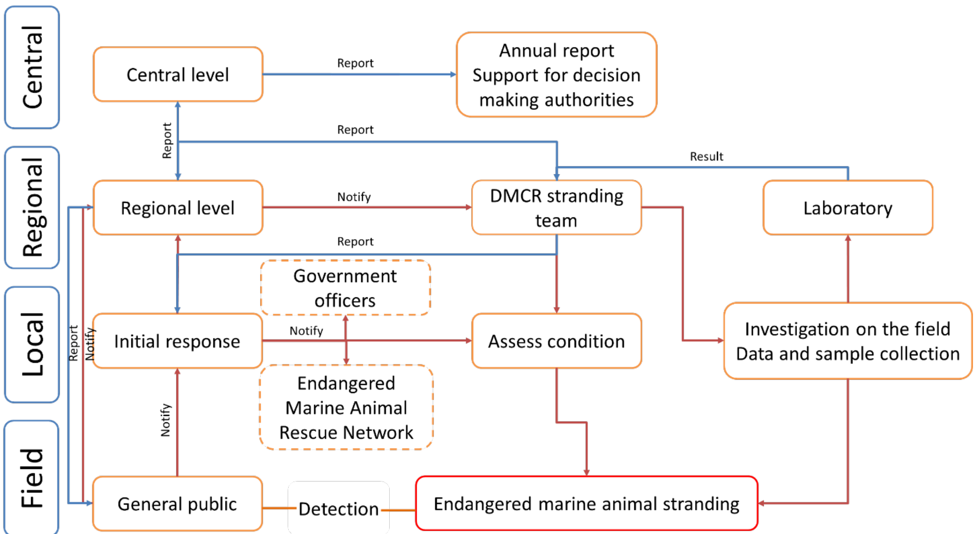

Figure 2 Flowchart Illustrating the Hierarchical Structure of the Endangered Marine Animal Stranding Surveillance and Management System in Thailand, Detailing the Interplay Between Field Detection, Local Response, Regional Investigation, and Central Reporting.

Data Extraction, Cleaning, and Processing

All dugong stranding records from January 2019 to December 2024 were extracted from the DMCR database, which serves as the official repository for verified stranding reports. Each extracted entry contained information across several domains—identification, animal characteristics, temporal variables, geographic attributes, pathological findings, and laboratory data—as outlined in Table 1.

Table 1 Data types and their sources included in this study.

Data	Variable	Sources
Identification	Event id	Marine animal stranding reporting system, Marine and Coastal Resources Research Center (Upper and Lower Andaman Sea), DMCR
Animal	Age class, sex, percentage of feeding intake, body condition score (BCS), carcass condition	
Time	Detection date, seasonal, month, year	
Place	GPS coordinates, province, detection areas	
Environmental data	Coverage of seagrass beds	
Pathological data	Suspected cause of death/stranding	Necropsy report, Marine animal stranding reporting system, Marine and Coastal Resources Research Center (Upper and Lower Andaman Sea), DMCR
Laboratory data	Type of collected sample, sample submission date, histopathological results	Laboratory report, Veterinary Diagnostic Center, Prince of Songkla University, Kasetsart University Veterinary Diagnostic Laboratory

Records were reviewed for completeness and internal consistency before inclusion in the dataset. Entries lacking essential epidemiological variables—specifically detection date, geographic location, decomposition code, or an identifiable carcass ID—were excluded because such omissions prevented reliable temporal, spatial, or diagnostic analysis. All remaining records were compiled into a consolidated database and cleaned to remove duplicates, correct inconsistent GPS coordinates, and standardize categorical variables.

Following data cleaning, variables were organized into analytical groups corresponding to the five major components reported in the Results section.

General information and demographics

Variables included age class (calf, subadult, adult), sex (male, female, undetermined), percentage of feeding intake, BCS (1–5), and carcass condition (Code 1–5), as defined in Table 1.

Temporal patterns

Temporal variables included detection date, month, year, and seasonal classification. Seasons followed regional climatology, with the monsoon season defined as May–October and the non-monsoon season as November–April.

Geographical patterns

Spatial variables included GPS coordinates, province, and type of detection area (marine protected area vs. public/private areas). All spatial data were re-projected to the WGS84 coordinate system for spatial mapping and hotspot analysis.

Health status and carcass condition

Variables included BCS, decomposition code (Geraci & Lounsbury), presence of external injuries, stomach content weight (converted to % body weight when available), necropsy findings, and seagrass coverage estimates within a defined 20-km buffer around each stranding site (Preen, 1995; Sheppard et al., 2006; Marsh et al., 2011).

Suspected causes of stranding

Records were categorized into natural causes (e.g., disease, nutritional issues), anthropogenic causes (e.g., boat strike, fishing gear interaction), or unknown causes, based on field assessments, necropsy reports, and laboratory findings.

Data Analysis

Descriptive Statistics

Frequencies, percentages, means, standard deviations (SD), medians, and ranges were calculated for age class, sex, decomposition code, body condition score (BCS), stomach content values, and suspected causes of death. Annual and monthly counts were summarized to illustrate temporal patterns. All descriptive analyses were conducted in Microsoft Excel.

Temporal Patterns

Temporal analysis included monthly, annual, and seasonal summaries based on detection date. Seasons were categorized as monsoon (May–October) and non-monsoon (November–April). No statistical hypothesis testing was applied to temporal data; instead, trends were interpreted descriptively because the study objective was to characterize rather than model temporal variation in stranding events.

Spatial Analysis

Spatial mapping was performed using QGIS version 3.34.9. All stranding coordinates were projected in WGS84 and plotted as point features. Choropleth maps were used to display provincial and subdistrict variation in stranding frequency, and point distribution mapping was used to visualize spatial clustering. Hotspot areas were identified based on visually apparent concentrations of strandings rather than formal spatial statistics, consistent with the descriptive nature of the study.

Health and Carcass Condition Analysis

Health-related variables—including body condition scores (BCS), carcass decomposition code, external injury patterns, stomach content weight (expressed as % body weight), and necropsy findings—were summarized descriptively to characterize the physiological status of stranded dugongs. BCS was evaluated using a standardized five-level scale (1 = emaciated to 5 = obese), adapted from established marine mammal health assessment frameworks and DMCR criteria (Department of Marine and Coastal Resources, 2013). Stomach content data were used to calculate feeding intake relative to body weight, and dugongs were classified as underfeeding (<3% BW) or optimal feeding (≥3% BW).

Feeding intake values were compared across years to identify broad temporal patterns, with particular emphasis on changes observed after 2021. To explore potential relationships among categorical health indicators, Chi-square tests were applied only when assumptions were met. These tests examined associations between (1) BCS and feeding intake category, (2) BCS and suspected cause of death, and (3) suspected cause of death and detection area.

Environmental Associations

Seagrass coverage estimates within a 20-km buffer surrounding stranding locations were compared with annual stranding counts. Because the sample consisted of six annual observations, Spearman's rank correlation was used to describe the direction and strength of the relationship between seagrass decline and stranding frequency.

Justification of Analytical Approach

The analyses were designed to align with the descriptive nature of the dataset and the study objective, which was to characterize epidemiological patterns rather than develop predictive models. Therefore, descriptive statistics and non-parametric tests were selected as the most appropriate and robust analytical methods given data structure, variable types, and sample size.

RESULTS

General information and dugong demographics

A total of 161 dugong stranding detections (DSD) were recorded along the Andaman Sea coastline between January 2019 and December 2024. The incident detectors included government officers (DMCR, Department of National Parks, Wildlife and Plant Conservation (DNP), and Department of Fisheries (DOF)), villagers, fishermen, and tourists. The most common type of DSD (92%) were dead strandings (n = 161, Figure 3a). We classified age classes into 3 groups. Adult (2.2 to 4 meters in length), subadult (1.8 to 2.2 meters), and calf (0.80 to 1.00 meters in length) (Marsh et al. (2011). Age classes can be determined in 158 DSD (Figure 3b); of these 44% were adult (n = 70), 28% were subadult (n = 34), and 28% were calf (n = 44). Among 142 DSD sex was determined, males represented 58% (n = 83), and 42% (n = 59) were females (Figure 3c).

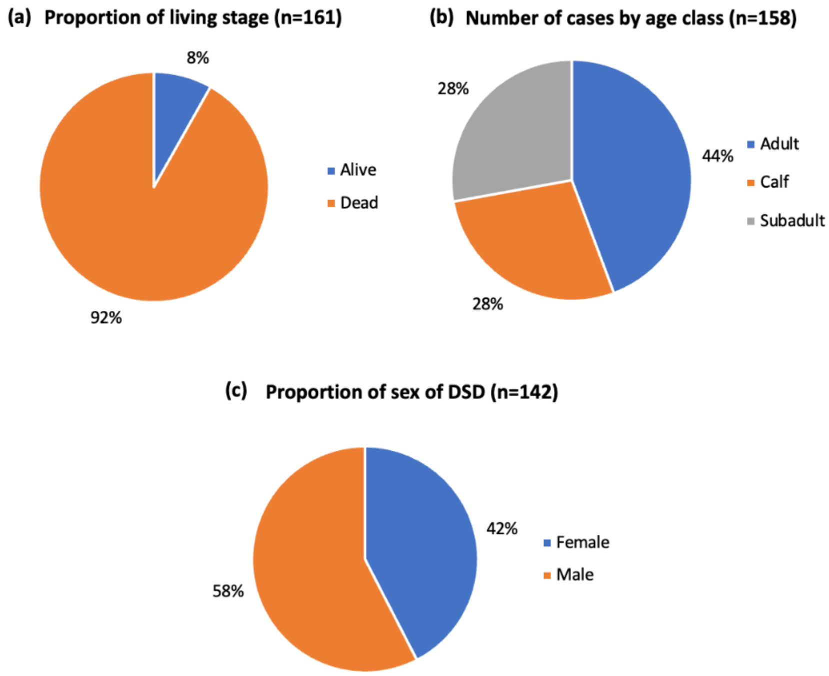

Figure 3 The proportion of dugong stranding detection (DSD) in the Andaman Sea from January 2019 to December 2024 by types of living condition (a), age classes (b), and sex (c).

Temporal patterns of dugong strandings

Yearly trends

A total of 161 DSD were recorded in the Andaman Sea between January 2019 and December 2024. Annual stranding numbers showed substantial interannual variation but an overall increasing trend, with a mean of 23 ± 9.30 DSD per year (Table 2). Annual detections ranged from a minimum of 14 cases in 2022 to a maximum of 46 cases in 2024, the highest yearly total reported during the study period (Figure 4). The most pronounced monthly peaks were observed in October and December 2024 (10 cases each), followed by August 2021 (8 cases)—all occurring during the monsoon season. From 2019 to 2022, the average monthly detection rate remained relatively stable at 1.3–2.2 DSD per month, but this rate increased to more than 3 cases per month in 2023–2024, indicating a clear upward shift in reported strandings.

Missing demographic data were due to limitations in carcass condition. Age class could not be determined in 3 cases because carcasses were too decomposed to measure reliably or were partially missing. Sex could not be identified in 13 cases due to advanced decomposition, loss of external genital structures, or incomplete remains.

Table 2 Monthly of dugong stranding detection (DSD) per year during January 2019 – December 2024 (n=161)

Year	Month												Total	Mean	SD
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec			
2019	1	1	3	1	2	1	5	3	2	0	1	1	21	1.8	1.4
2020	1	0	0	0	2	2	1	0	2	3	2	3	16	1.3	1.2
2021	3	1	2	2	1	1	1	8	1	1	3	2	26	2.2	2.0
2022	0	2	2	1	1	2	0	1	1	1	2	1	14	1.3	0.6
2023	3	2	2	4	3	3	1	3	5	5	3	4	38	3.2	1.2
2024	2	0	2	2	4	2	1	4	4	10	5	10	46	3.8	3.2
Overall (2019-2024)													161	23.0	9.3

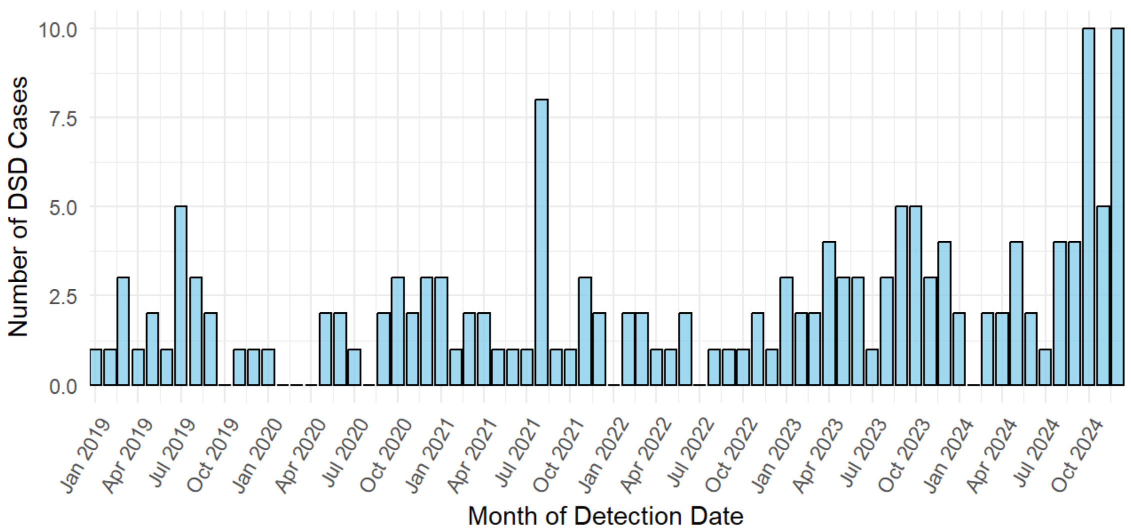

Figure 4 Distribution of dugongs stranding detections (DSD) by month in the Andaman Sea were recorded from January 2019 to December 2024.

Monthly and seasonal patterns

Monthly patterns revealed consistent seasonal peaks in dugong strandings. Strandings most frequently occurred during the monsoon season (May–October), with notable spikes in July 2019, August 2021, October 2023, 2024, and December 2024 (Figure 4). Monthly mean values were highest in August, October, and December (Figure 5b), and median monthly values across 2019–2024 also showed a clear annual peak in August, followed by persistently elevated detections extending through December (Figure 5c). While monthly detections remained relatively stable during the non-monsoon months across all years, stranding numbers increased markedly during monsoon seasons in 2023–2024 (Figure 5d).

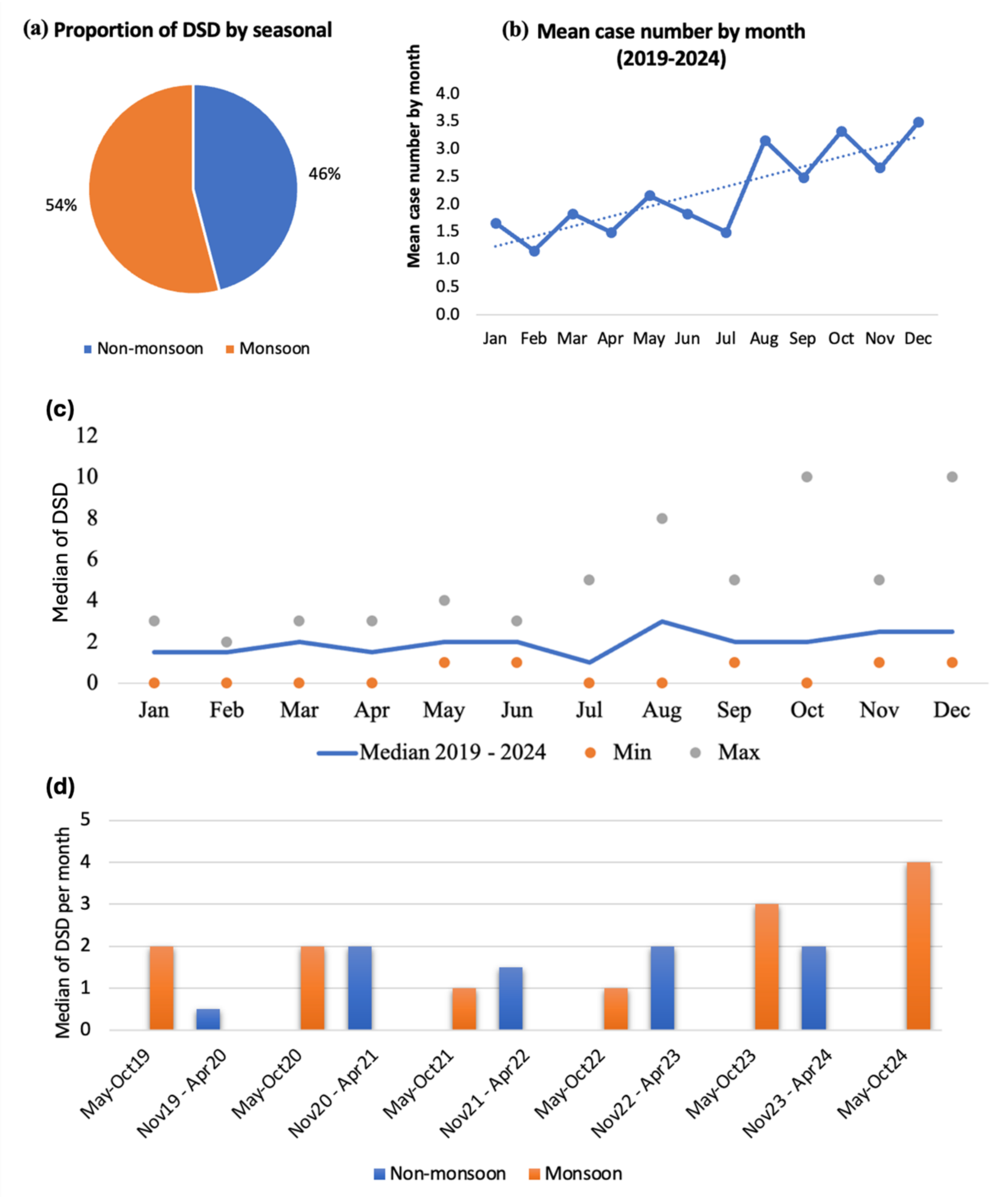

Figure 5 Monthly/seasonal distribution of dugongs stranding detections (DSD). Proportion of DSD by seasons (a), and monthly of DSD during 2019 – 2024 (b). Five-year median of dugong stranding detection between 2019 and 2024, incorporated by maximum and minimum values by months (c) and median number of DSD per month by seasons for each year in the Andaman Sea from January 2019 to October 2024 (d)

Weekdays versus weekends

For this analysis, weekends were defined strictly as Saturday and Sunday; government holidays were excluded. Over the six-year period, 1,433 weekdays accounted for 104 DSD (0.07 per day), while 726 weekend days accounted for 57 DSD (0.08 per day). Although more absolute strandings occurred on weekends (Figure 6a), adjustment for the number of available days showed that daily detection rates were comparable between weekdays and weekends (Figure 6b).

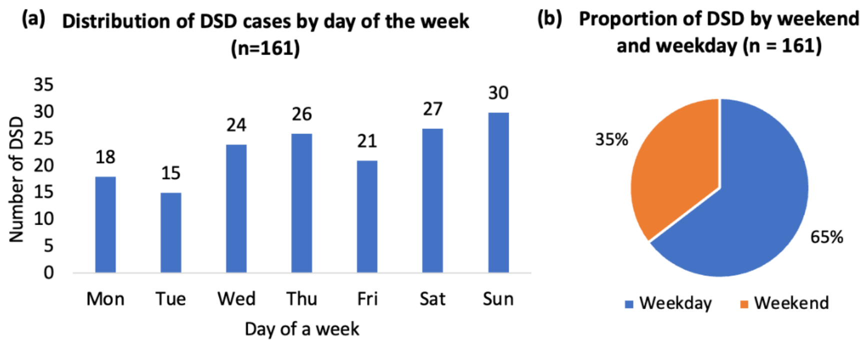

Figure 6 Distribution of dugong stranding detection (DSD) by the day of a week (a), and between weekday and weekend (b).

Geographical patterns of dugong strandings

Geographical distribution of strandings varied considerably across provinces. More than half of all detections occurred in Trang Province (83/161; 51.6%), followed by Krabi (50/161; 31.1%), Phang Nga (11/161; 6.8%), Phuket (9/161; 5.6%), Satun (7/161; 4.3%), and Ranong (1/161; 0.6%). Spatial hotspot analysis identified Koh Mook and Koh Libong in Trang Province as the areas with the highest concentrations of strandings, with intensities of 8–14 DSDs per 10 km² during 2019–2024. These hotspots were illustrated as shown in Figure 7, highlighting regions that were of high priority for conservation and further investigation.

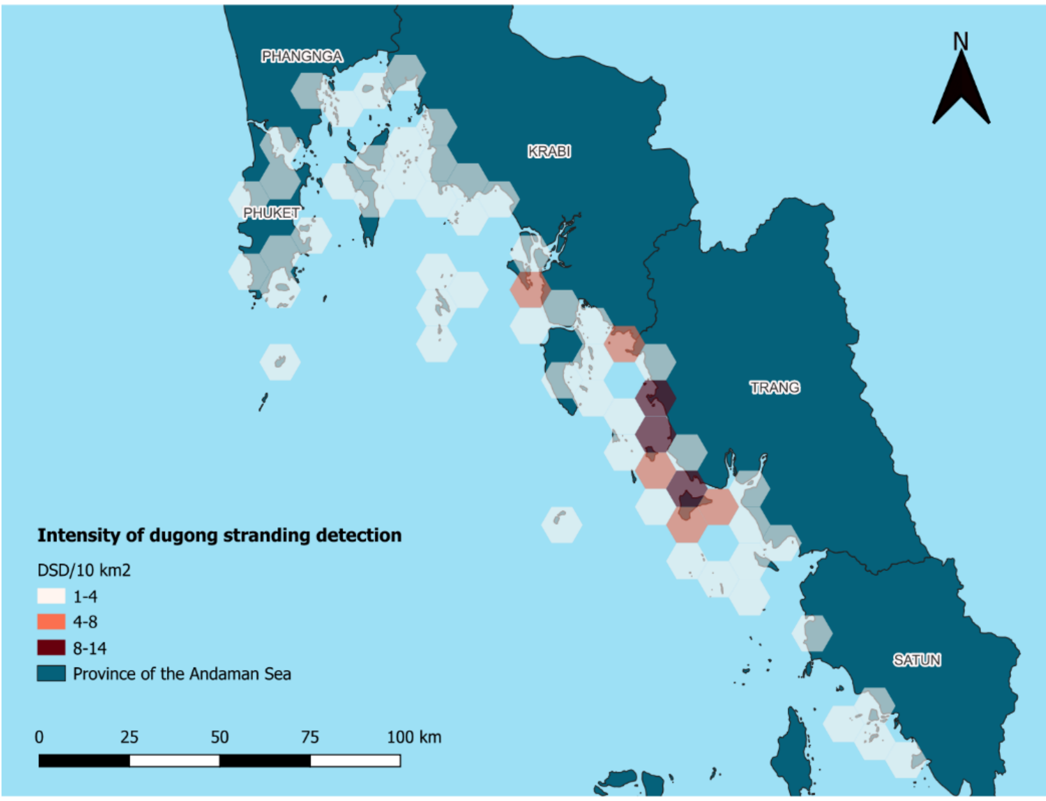

Figure 7 Map of the Andaman Sea indicated the hotspot areas of dugong stranding detection (DSD) from January 2019 to December 2024.

Carcass condition and health status of dugong strandings

Carcass condition at the time of detection was categorized into three major groups: (1) alive at detection; (2) dead, assigned to decomposition Code 1–5 following Geraci and Lounsbury (1993, 2005); and (3) loss upon investigation, when a carcass disappeared before assessment. Code ranged from fresh (Code 1–2) to moderate decomposition (Code 3), advanced decomposition (Code 4), and mummified or skeletal remains (Code 5). Fresh carcasses allowed comprehensive necropsy, whereas some laboratory analyses (e.g., heavy metals and DNA) could still be performed on advanced carcasses (Code 4–5).

Overall carcass condition

Across all detections, advanced decomposition (Code 4) accounted for the largest proportion of cases (45.3%; 73/161), followed by fresh carcasses (Code 2; 25.5%) and moderate decomposition (Code 3; 14.9%). Twelve animals (7.5%) were detected alive, and 10 (6.2%) were alive but died shortly after detection (Code 1). One case (0.6%) was lost before evaluation (Figure 8). Although detections of fresh carcasses increased toward 2024, decomposed carcasses (Code 3–4) consistently comprised more than 40% of annual detections throughout the study period (Figure 9). Most strandings (61.5%; 99/161) occurred within marine protected areas, with fewer detected in public or privately managed locations (38.5%; Figure 10; Table 3).

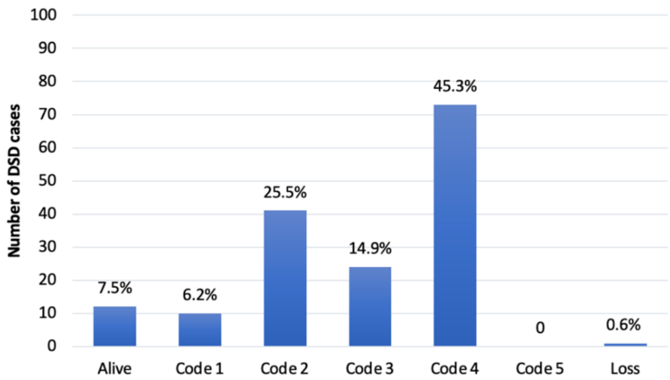

Figure 8 Percentage of dugong stranding conditions (n=161) based on the dugong stranding detection (DSD) Examination Code in the Andaman Sea of Thailand, from January 2019 to December 2024.

Table 3 Number of dugong stranding detection in the Andaman Sea based on condition of examination by detection area between January 2019 – December 2024 (n=161)

Detection area	n	%	Alive	Code 1 - 2	Code 3 - 4	Loss
Marine protected area	99	61.5	10	37	52	0
Public/private area	62	38.5	2	14	45	1
Total	161	100	12	51	97	1

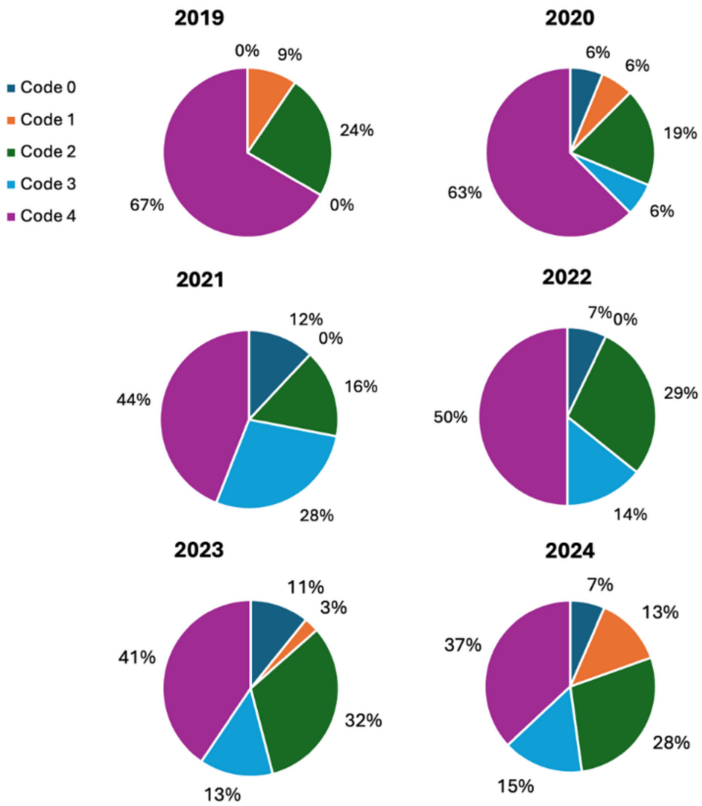

Figure 9 Proportion of condition of dugong stranding examination code, in the Andaman Sea of Thailand from January 2019 to December 2024.

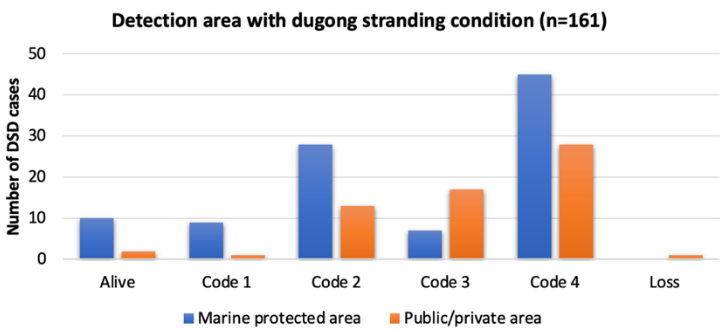

Figure 10 Number of dugong stranding detection (DSD) of the Andaman Sea by detection area and condition of dugong stranded.

Body condition and feeding intake

Body condition scores (BCS), based on external appearance, were categorized into five levels: 1 for emaciation, 2 for thinness, 3 for fair or good condition, 4 for overweight, and 5 for obesity; representative examples of each category are illustrated in Figure 11. Between January 2019 and December 2024, the prevalence of dugong strandings with low body condition scores (BCS 1–2) increased, with a notable rise observed from 2021 onward. In 2024, 14 out of 26 dugongs (54%) with assessed BCS were classified as emaciated (BCS 1), representing the highest proportion recorded during the study period

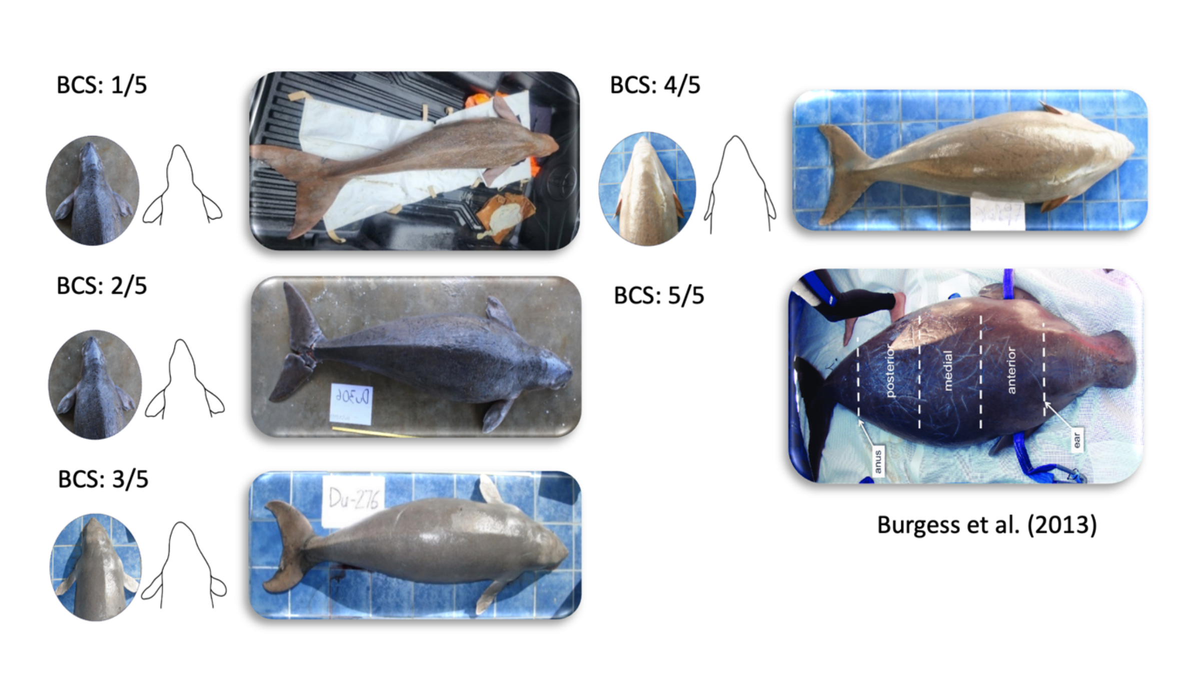

Figure 11 Classification of dugong body condition score (BCS) on a five-point scale, ranging from emaciated (BCS 1/5) to obese (BCS 5/5), used for assessing the nutritional status of stranded dugongs.

For epidemiological analysis, body condition scores 1 and 2 were grouped into an underweight category, which demonstrated an increasing trend in strandings in both 2021 and 2024, as shown in the line graph (Figure 12a). Additionally, an assessment of the stomach contents of stranded dugongs allowed for the calculation of the percentage of feeding intake relative to body weight (BW). Feeding conditions were categorized as underfeeding (defined as a mean intake of less than 3% of BW) or optimal feeding (defined as a mean intake greater than or equal to 3% of BW). Our findings revealed that the mean percentage of feeding intake for stranded dugongs was consistently below 3% of BW and showed a downward trend from 2022 to 2024, indicating a significant decline in feeding intake over time (Figure 12b).

Proportion of body condition of dugong stranding detection with an average of feeding intake (%BW) indicating all of condition has a declining trend (Figure 13). The underfeeding found in underweight is the highest of body condition (26/30; 87%), followed by fair (24/30; 80%) and overweight (8/12; 67%) (Table 4). Analysis of body condition score of dugongs stranding detection with feed intake showed that there was no association ($\chi 2 = 0.64856$, $n = 72$, $p > 0.05$), similar to body condition score of dugongs stranding detection with suspected causes of sickness and other causes ($\chi 2 = 3.10655$, $n = 60$, $p > 0.05$) (Table 5). Analysis of suspected causes of dugong stranding detection with feed intake showed that there was no association ($\chi 2 = 3.10655$, $n = 60$, $p > 0.05$), similar to detection area ($\chi 2 = 0.36592$, $n = 116$, $p > 0.05$) (Table 6).

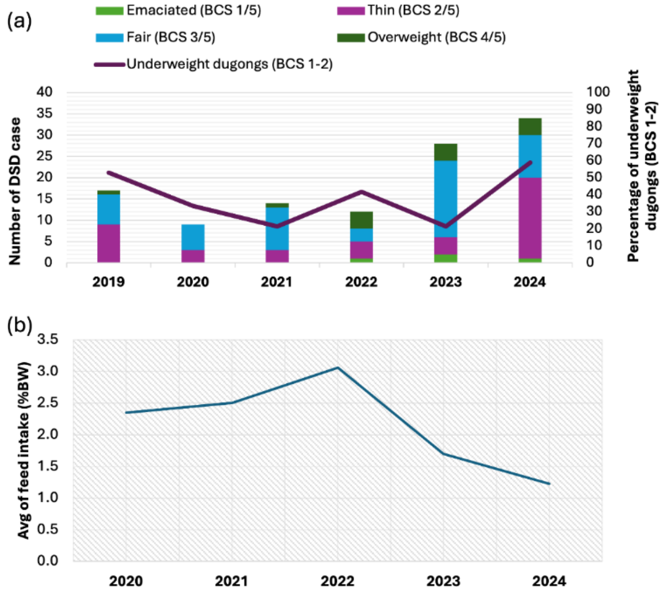

Figure 12 Number of dugongs stranding detection (DSD) with body condition score (BCS), and trend of underweight dugong group (BCS 1 – 2) from January 2019 to December 2024 (a). Percentage of body weight from stomach content of dugong stranding in the Andaman Sea between January 2019 – December 2024 (b).

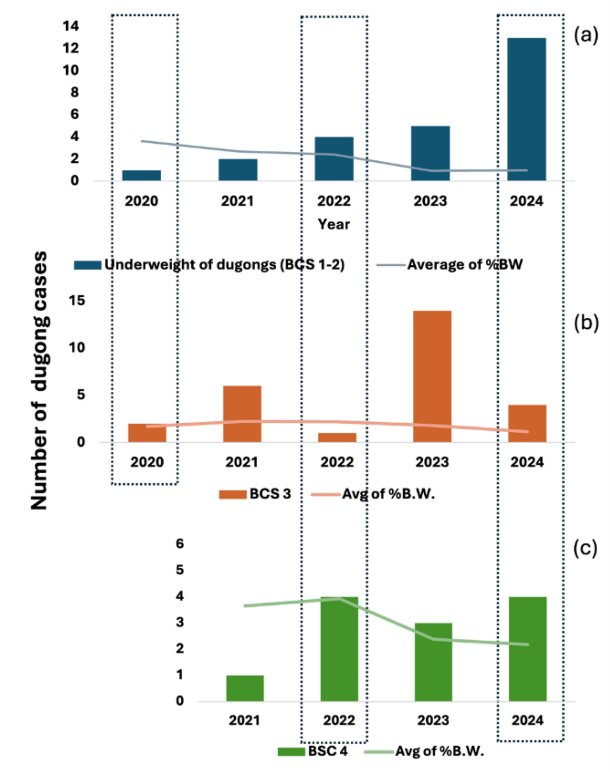

Figure 13 Percentage of body weight from stomach content of underweight (a) fair (b) and overweight (c) dugongs stranding detection (DSD).

Table 4 Proportion of feeding intake compare with the BCS of dugong stranding detection.

Body evaluation	n	Number (%)		
		Assessed for feed intake	Underfeeding	Optimal feeding
Underweight (BCS 1-2)	46	30 (65)	26 (87)	4 (13)
Fair (BCS 3)	54	30 (56)	24 (80)	6 (20)
Overweight (BCS 4)	14	12 (86)	8 (67)	4 (33)
Total	114	72 (63)	58 (81)	14 (19)

*Underfeeding: Dugong consumed less than 3% body weight.
Optimal feeding: Dugong consumed a sufficient amount of feed relative to its body weight (≥ 3% body weight).

Table 5 Body condition score (BCS) of dugong stranding detection (DSD) with feed intake and causes of dugong stranding detection.

Condition		Number			χ2	P-value
		Thin (BCS 1-2)	Not thin (BCS 3 - 4)	Total		
Feed intake (n=72)	Underfeeding (<3%bw)	26	32	58	0.64856	0.42063
	Optimal feeding (≥3%bw)	4	10	14		
Suspected causes (n=60)	Sickness	34	7	41	3.10655	0.07798
	Other causes	11	8	19		

Table 6 Suspected causes of dugong stranding detection (DSD) with feed intake and detection area.

Suspected causes		Number			χ2	P-value
		Sickness	Other causes	Total		
Feed intake (n=60)	Underfeeding (<3%bw)	34	11	45	3.10655	0.07798
	Optimal feeding (≥3%bw)	7	8	15		
Detection area (n=116)	Marine protected area	43	26	69	0.36592	0.54524
	Public area	26	11	37		

Seagrass coverage and stranding patterns

In light of the observed increase in underweight and underfed dugong strandings, we further examined whether recent deterioration of seagrass habitats may be contributing to these patterns. Koh Libong in Trang Province was selected as a representative site because it contains the largest and most historically continuous seagrass meadow in Thailand, and annual seagrass monitoring data were available for the past five years. A 20-km buffer was applied to represent the approximate home range of dugongs in this region (Figure 14; Table 7). Within this zone, seagrass coverage declined sharply from 34% in 2019 to 9.58% in 2024, while annual dugong strandings in the same area increased from 9 to 46 cases over the corresponding period. These opposing trends are illustrated by the decreasing seagrass coverage line and the increasing stranding detection line (Figure 15).

To assess the strength of the relationship between seagrass coverage and stranding numbers, a Spearman's rank correlation analysis was conducted. The analysis indicated a moderately negative correlation ($\rho = -0.6927$), suggesting that years with lower seagrass coverage tended to coincide with higher numbers of strandings. However, this association was not statistically significant ($p > 0.05$). This means that although a negative trend is apparent, the available data do not provide strong enough statistical evidence to confirm a reliable or meaningful relationship. The lack of significance is likely influenced by the very small number of annual observations, natural interannual ecological variability, and the relatively short monitoring timeframe, all of which reduce statistical power.

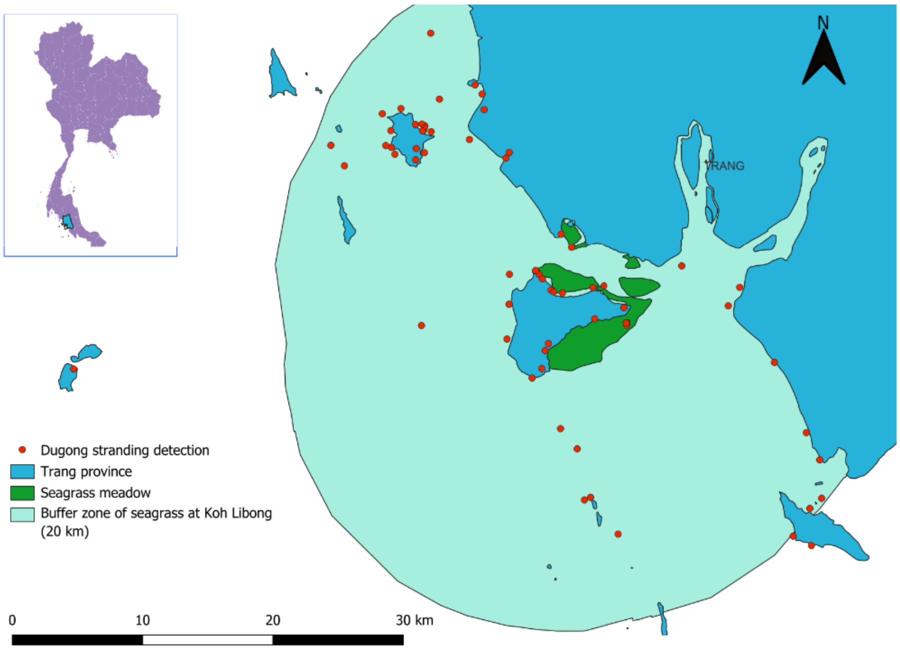

Figure 14 Map of buffer zone of seagrass area and dugongs stranding detection at Koh Libong, Trang province).

Table 7 The number of dugongs stranding detection (DSD)with percentage coverage of seagrass in Koh Libong, Trang Province.

Year	Number of DSD cases (N)	Coverage of seagrass (%)
2019	9	34.0
2020	6	32.2
2021	9	19.7
2022	8	18.7
2023	20	9.6

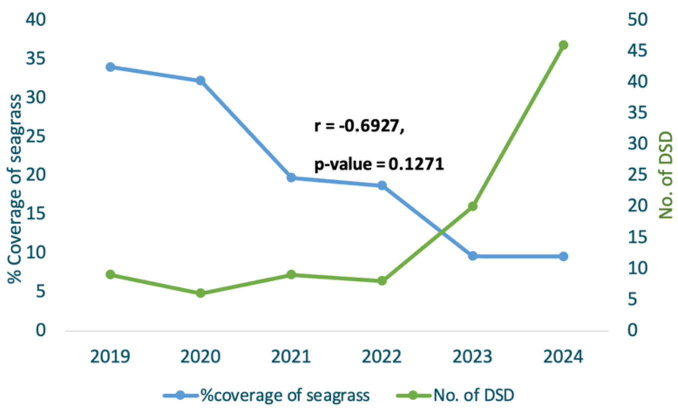

Figure 15 Negative correlation between the number of dugongs stranding detection (DSD) and percentage of coverage of seagrass, where a decline in seagrass coverage might be associated with an increase in dugong strandings.

Suspected causes of dugong strandings

Among all 161 detections, natural causes were the most frequently reported category, followed by unknown and anthropogenic causes (Figure 16). Within natural causes, sickness accounted for the majority (81%; 80 cases). Among anthropogenic cases (n = 16), incidental entanglement in fishing gear (50%) and vessel collisions (44%) represented the leading contributors. These findings demonstrate the combined impacts of disease, environmental stress, and human activities on dugong mortality in the Andaman Sea.

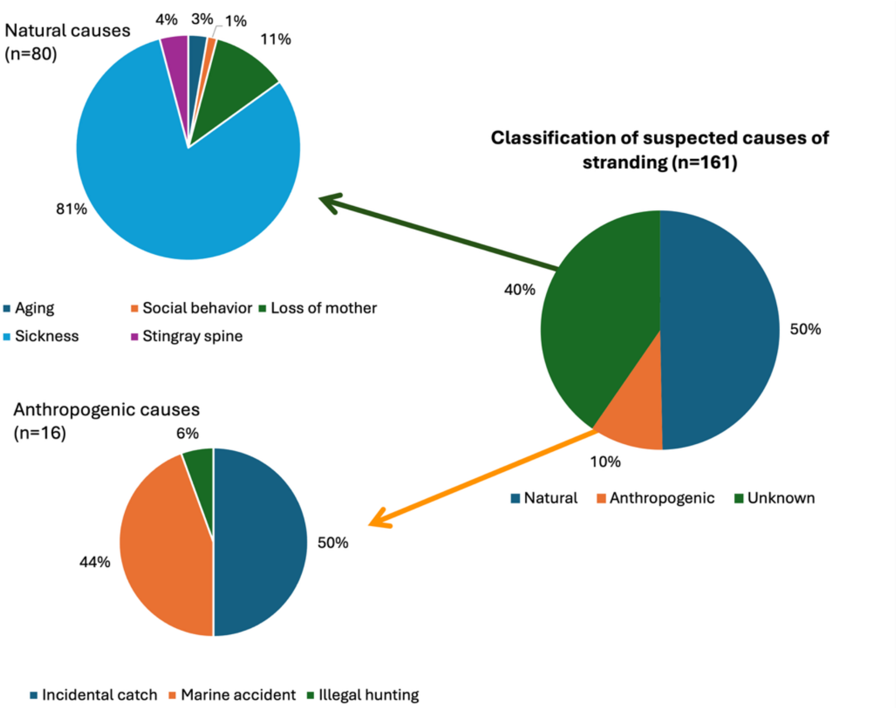

Figure 16 Classification of suspected causes of dugong stranding detection (DSD), including the proportional distribution of natural, anthropogenic, and unknown causes, with a detailed breakdown of natural and anthropogenic causes.

DISCUSSION

Trends in Dugong Stranding Frequency

The increasing trend in dugong strandings observed from 2019–2024, particularly the sharp rise in 2023–2024, suggests a growing level of physiological or environmental stress experienced by dugong populations in the Andaman Sea. Similar increases in strandings have been reported in other parts of Southeast Asia and Australia and are often interpreted as indicators of broader ecological or anthropogenic pressures (e.g., Hines et al., 2020; Marsh et al., 2011). While improvements in reporting systems and community participation may partly explain higher detection frequencies in recent years, the magnitude of increase—more than double compared with early-study years—indicates that actual mortality or morbidity levels are likely rising.

Dugongs are highly sensitive to changes in seagrass availability and habitat quality. Declines in seagrass meadows due to coastal development, eutrophication, sediment runoff, and climate-driven stressors (e.g., extreme rainfall, heatwaves, sea-level fluctuations) have been widely linked to increased mortality and reduced reproductive success in Sirenia populations (Waycott et al., 2009;

Sobtzick et al., 2017). The temporal alignment between decreasing seagrass coverage (2019–2024) and increasing strandings in the Andaman Sea is consistent with these patterns, suggesting that reduced food availability may be contributing to elevated physiological stress and mortality. Episodes of unusually high strandings—such as the peaks in August 2021 and late 2024—may further reflect acute environmental disturbances, including extreme monsoon conditions or short-term declines in seagrass productivity.

However, although the observed negative trend between seagrass coverage and stranding frequency is ecologically plausible, it should be interpreted with caution. The correlation analysis did not reach statistical significance, likely due to the small number of annual data points, the short duration of available habitat records, and the high interannual variability characteristic of seagrass ecosystems. Therefore, while the pattern supports a biologically meaningful hypothesis warranting further investigation, the findings cannot be taken as conclusive evidence of a causal link between seagrass loss and increased dugong strandings. Continued long-term monitoring of both seagrass dynamics and dugong health indicators will be essential for validating and refining this interpretation.

Seasonal Variation in Dugong Strandings

The consistently higher number of strandings during the monsoon season is consistent with regional hydrodynamic and ecological processes. Previous studies have noted that strong monsoonal currents increase the likelihood of carcasses drifting toward shore (Adulyanukosol and Poovachiranon, 2019). However, environmental stressors associated with monsoon conditions—such as turbidity, decreased salinity, and sediment deposition—can also directly impair seagrass health and dugong foraging behavior (Ray et al., 2014). Thus, elevated strandings during the monsoon likely reflect both detection bias (increased carcass drift) and potential physiological stress during periods of reduced food availability or habitat instability.

The seasonal consistency observed across years suggests that monsoon-associated pressures are a recurring feature affecting dugong ecology in the Andaman Sea. However, the amplified seasonal signal observed in 2023–2024 could indicate increasing environmental instability or cumulative impacts on dugong health.

Carcass Condition and Its Implications

The predominance of carcasses in advanced decomposition (Code 4–5) complicates assessments of mortality causes and limits diagnostic value. Similar challenges have been reported in marine mammal stranding programs worldwide (Geraci and Lounsbury, 2005). Environmental factors such as high temperatures, delayed reporting, and logistical constraints in remote coastal areas accelerate carcass degradation, reducing opportunities for thorough necropsy.

The gradual increase in detections of fresh carcasses (Code 1–3) in recent years may reflect improved community engagement and faster response times—an encouraging development for conservation efforts. High-quality necropsies are essential for identifying emerging threats, such as novel pathogens, harmful algal blooms, or contaminants. The continued dominance of decomposed carcasses underscores the need for stronger rapid-response networks and sustained local participation.

Health Indicators and Body Condition Scores

The increasing proportion of thin or emaciated dugongs, especially in 2024, is a concerning signal of deteriorating nutritional health in the population. In marine herbivores, declining body condition is frequently associated with seagrass depletion, poor forage quality, or increased energetic demands due to habitat fragmentation (Sheppard et al., 2006; Milena et al., 2019). The observed rise in underweight individuals aligns with the documented reduction in seagrass coverage around Koh Libong, suggesting a dietary deficit at the population level.

Poor body condition has been shown to reduce reproductive success and increase susceptibility to disease in dugongs and manatees (Marsh et al., 2011). Thus, deteriorating BCS trends may have long-term demographic implications, potentially reducing population resilience to environmental disturbances.

Feeding Intake and Underfeeding Trends

The marked decline in feeding intake (<3% BW) from 2022–2024 further supports a hypothesis of nutritional stress. Although the correlation between seagrass coverage and stranding frequency was not statistically significant—likely due to the small dataset—the strong negative trend is biologically plausible. Reduced seagrass availability may require dugongs to travel farther or forage longer, resulting in net energy loss and, eventually, malnutrition. Similar patterns have been documented in northern Queensland dugongs following major seagrass die-off events.

Environmental disturbances that impair seagrass growth—such as sedimentation, pollution, or rising sea temperature—could be contributing to this decline in feeding efficiency. As reduced feeding intake precedes declines in body condition, monitoring stomach content and nutritional biomarkers offers a valuable early-warning tool for population health assessment.

Spatial Distribution of Dugong Strandings

The concentration of strandings in Trang Province, particularly around Koh Mook and Koh Libong, reflects both ecological and geographic factors. These areas encompass some of the largest and historically most productive seagrass meadows in Thailand, making them prime feeding grounds for dugongs. High local densities of dugongs naturally increase the likelihood of strandings being reported in these areas (Nakaoka et al., 2014).

However, spatial clustering may also reflect localized pressures such as boat traffic, fishing gear, or habitat degradation. Previous studies have shown that areas with intense human use often overlap with key dugong habitats, elevating the risk of anthropogenic mortality (Hines et al., 2005). The finding that most strandings were detected within marine protected areas reflects the fact that MPAs cover core dugong habitats and are more frequently monitored, rather than indicating that mortality risk is greater within MPAs. Drift modeling and carcass backtracking studies would be valuable in distinguishing the true locations of mortality from detection sites.

Implications for Conservation and Management

The predominance of natural causes—particularly suspected sickness—combined with the large proportion of unknown cases reflects limitations in carcass condition and diagnostic capability. Nonetheless, the combination of increasing mortality, declining body condition, and decreasing seagrass coverage points toward ecosystem-level stress that warrants urgent intervention.

Effective conservation strategies should prioritize:

• Rapid-response stranding networks to improve carcass condition data and diagnostic accuracy

• Seagrass restoration and protection, especially in high-use dugong feeding areas

• Regulation of boat traffic and fishing activity in core habitats

• Long-term ecological monitoring integrating water quality, climate variables, and seagrass dynamics

• Community-based surveillance programs, which have proven effective in Thailand and other dugong range countries

Given the longevity and slow reproductive rate of dugongs, even modest increases in adult mortality can have profound population-level consequences.

Strengthening integration between stranding data, environmental monitoring, and policy implementation is therefore critical to sustaining dugong populations in the Andaman Sea.

Limitations and Future Research Directions

This study is constrained by several limitations, including potential detection bias, uneven reporting effort, and a high proportion of decomposed carcasses. The limited temporal coverage of seagrass data also restricts the ability to firmly link habitat decline with stranding patterns. Future research should include:

- Standardized necropsy and pathology protocols to improve cause-of-death determination
- Comprehensive disease surveillance, including virology, bacteriology, and toxin screening
- Longer-term seagrass monitoring using remote sensing and in situ surveys
- Behavioral and movement studies, potentially using satellite telemetry, to identify at-risk habitats
- Modeling to trace carcass drift and estimate true mortality locations
- Socio-ecological studies examining local fisheries, boat use, and community interactions

Together, these approaches will enable a more complete understanding of the drivers of dugong mortality and support more targeted and effective conservation strategies.

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AUTHOR CONTRIBUTIONS

Piyarat Khumraksa: Conceptualization, Methodology, Data Curation, Formal Analysis, Writing – Original Draft, Visualization, Resources, Investigation, Validation.
Paisin Lekcharoen: Supervision, Methodology, Writing—Review & Editing, Validation.
Pongpon Homkong: Supervision, Methodology, Writing – Review & Editing, Validation.
Kongkiat Kittiwattanawong: Supervision, Writing – Review & Editing.
Santi Ninwat: Resources (supporting), Investigation (supporting).
Patcharaporn Kaewmong: Resources (supporting), Investigation (supporting).

REFERENCES

Alcorn, J.F., 2020. IL-22 plays a critical role in maintaining epithelial integrity during pulmonary infection. Front. Immunol. 11, 1160.

Al-Qahtani, A.A., Alhamlan, F.S., Al-Qahtani, A.A., 2024. Pro-inflammatory and anti-inflammatory interleukins in infectious diseases: a comprehensive review. Trop. Med. Infect. Dis. 9, 13.

Barone, F., Nayara, S., Camposa, J., Cloakea, T., Withers, D.R., Toellner, K.M., Zhang, Y., Fouser, L., Fisher, B., Bowman, S., Rangel-Moreno, J., De La Garcia-Hernandez, M.L., Randall, T.D., Lucchesi, D., Bombardieri, M., Pitzalis, C., Luther, S.A., Buckley, C.D., 2015. IL-22 regulates lymphoid chemokine production and assembly of tertiary lymphoid organs. Proc. Natl. Acad. Sci. U.S.A. 112, 11024–11029.

Blake, D.P., Billington, K.J., Copestake, S.L., Oakes, R.D., Quail, M.A., Wan, K.L., Shirley, M.W., Smith, A.L., 2011. Genetic mapping identifies novel highly protective antigens for an apicomplexan parasite. PLoS Pathog. 7, e1001279.

Castro, F., Cardoso, A.P., Gonçalves, R.M., Serre, K., Oliveira, M.J., 2018. Interferon-gamma at the crossroads of tumor immune surveillance or evasion. Front. Immunol. 9, 847.

Conway, D.P., McKenzie, M.E., 2008. Poultry coccidiosis: diagnostic and testing procedures, 3rd edition. Wiley-Blackwell, Ames, Iowa.

Cronkite, D.A., Strutt, T.M., 2018. The regulation of inflammation by innate and adaptive lymphocytes. J. Immunol. Res. 2018, 1467538.

Dalloul, R.A., Lillehoj, H.S., 2006. Poultry coccidiosis: recent advancements in control measures and vaccine development. Expert Rev. Vaccines. 5, 143–163.

Djeraba, A., Musset, E., Lowenthal, J.W., Boyle, D.B., Chaussé, A.M., Péloille, M., Quéré, P., 2002. Protective effect of avian myelomonocytic growth factor in infection with Marek's disease virus. J. Virol. 76, 1062–1070.

Eyerich, K., Dimartino, V., Cavani, A., 2017. IL-17 and IL-22 in immunity: driving protection and pathology. Eur. J. Immunol. 47, 607–614.

Fries-Craft, K.A., et al., 2023. Implementing real-time immunometabolic assays and immune profiling during Eimeria maxima challenge in poultry. Front. Vet. Sci. 10, 1179198.

Ho T.D., Nguyen T.H., Nguyen T.T., Le D.P., & Pham H.S.H., 2023. The effects of infectious dosages on endogenous phage and the excretion of Eimeria tenella oocysts of infected chicken. Vet. Integra. Sci. 22(1), 161–170.

Ho, D.T., Pham, H.H.S., Aota, W., Matsubayashi, M., Tsuji, N., Hatabu, T., 2021. Reduction of macrophages by carrageenan decreases oocyst output and modifies local immune reaction in chick cecum with Eimeria tenella. Res. Vet. Sci. 139, 59–66.

Hong, Y.H., Lillehoj, H.S., Lillehoj, E.P., Lee, S.H., 2006. Changes in immune-related gene expression and intestinal lymphocyte subpopulations following Eimeria maxima infection of chickens. Vet. Immunol. Immunopathol. 114, 259–272.

Huang, J., Yin, H., Zhang, Y., Qiao, H., Su, L., Wang, J., 2022. Expression of TGF-β/Smads in cecum and spleen of chicken infected with Eimeria tenella. Braz. J. Poult. Sci. 24, eRBCA-2021-1446.

Hughes, S., Bumstead, N., 2000. The gene encoding the chicken chemokine K60 maps to chromosome 4. Anim. Genet. 31, 418–419.

Ihim, S.A., Abubakar, S.D., Zian, Z., Sasaki, T., Saffarioun, M., Maleknia, S., Azizi, G., 2022. Interleukin-18 cytokine in immunity, inflammation, and autoimmunity: biological role in induction, regulation, and treatment. Front. Immunol. 13, 919973.

Iyer, S.S., Cheng, G., 2012. Role of interleukin-10 transcriptional regulation in inflammation and autoimmune disease. Crit. Rev. Immunol. 32, 23–63.

Kaiser, P., Poh, T.Y., Rothwell, L., Avery, S., Balu, S., Pathania, U.S., Hughes, S., Goodchild, M., Morrell, S., Watson, M., Bumstead, N., Kaufman, J., Young, J.R., 2005. A genomic analysis of chicken cytokines and chemokines. J. Interferon Cytokine Res. 25, 467–484.
Kaňková, Z., Zeman, M., Schwarz, S., Kaspers, B., 2016. Preliminary results on intersexual differences in gene expression of chemokine K203 in mononuclear cells of chicken. Acta Vet. Hung. 64, 54–64.
Kim, W.H., Chaudhari, A.A., Lillehoj, H.S., 2019. Involvement of T cell immunity in avian coccidiosis. Front. Immunol. 10, 2732.
Lee, J.J., Kim, D.H., Lim, J.J., Kim, D.G., Min, W., Kim, G.S., Lee, H.J., Rhee, M.H., Park, H., Kim, S.C., Chang, H.H., Kim, S., 2012. Anticoccidial effect of supplemental dietary Galla Rhois against infection with Eimeria tenella in chickens. Avian Pathol. 41, 403–407.
Lillehoj, H.S., Erik, P.L., 2000. Avian coccidiosis: a review of acquired intestinal immunity and vaccination strategies. Avian Dis. 44, 408–425.
Livak, K.J., Schmittgen, T.D., 2001. Analysis of relative gene expression data using real-time quantitative PCR and the 2−ΔΔCT method. Methods. 25, 402–408.
López-Osorio, S., Chaparro-Gutiérrez, J.J., Gómez-Osorio, L.M., 2020. Overview of poultry Eimeria life cycle and host-parasite interactions. Front. Vet. Sci. 7, 384.
Luckheeram, R.V., Zhou, R., Verma, A.D., Xia, B., 2012. CD4+ T cells: differentiation and functions. Clin. Dev. Immunol. 2012, 925135.
Menon, A.P., Moreno, B., Meraviglia-Crivelli, D., Nonatelli, F., Villanueva, H., Barainka, M., Zheleva, A., van Santen, H.M., Pastor, F., 2023. Modulating T cell responses by targeting CD3. Cancers (Basel). 15, 1189.
Min, W., Lillehoj, H.S., 2004. Identification and characterization of chicken interleukin-16 cDNA. Dev. Comp. Immunol. 28, 153–162.
Min, W., Lillehoj, H.S., 2002. Isolation and characterization of chicken interleukin-17 cDNA. J. Interferon Cytokine Res. 22, 1123–1128.
Obeagu, E.I., 2024. Role of cytokines in immunomodulation during malaria clearance. Ann. Med. Surg. 86, 2873.
Ouyang, W., Valdez, P., 2008. IL-22 in mucosal immunity. Mucosal Immunol. 1, 335–338.
Pham, H.H.S., Hatabu, T., 2021. Eimeria tenella infection modulates the expression levels of intestinal epithelial barrier-related genes in chicken. J. Environ. Sci. Sustain. Soc. 10, 13–16.
Pham, H.H.S., Matsubayashi, M., Tsuji, N., Hatabu, T., 2021. Relationship between Eimeria tenella-associated early clinical signs and molecular changes in intestinal barrier function. Vet. Immunol. Immunopathol. 240, 110321.
Powell, M.D., Read, K.A., Sreekumar, B.K., Jones, D.M., Oestreich, K.J., 2019. IL-12 signaling drives the differentiation and function of a TH1-derived TFH1-like cell population. Sci. Rep. 9, 50614.
Rasquinha, M.T., Sur, M., Lasrado, N., Reddy, J., 2021. IL-10 as a Th2 cytokine: differences between mice and humans. J. Immunol. 207, 2205–2215.
Read, L.R., Cumberbatch, J.A., Buhr, M.M., Bendall, A.J., Sharif, S., 2005. Cloning and characterization of chicken stromal cell derived factor-1. Dev. Comp. Immunol. 29, 143–152.
Rothwell, L., Young, J.R., Zoorob, R., Whittaker, C.A., Hesketh, P., Archer, A., Smith, A.L., Kaiser, P., 2004. Cloning and characterization of chicken IL-10 and its role in the immune response to Eimeria maxima. J. Immunol. 173, 2675–2682.
Sanjabi, S., Oh, S.A., Li, M.O., 2017. Regulation of the immune response by TGF-β: from conception to autoimmunity and infection. Cold Spring Harb. Perspect. Biol. 9, a022236.
Sanjabi, S., Zenewicz, L.A., Kamanaka, M., Flavell, R.A., 2009. Anti- and pro-inflammatory roles of TGF-β, IL-10, and IL-22 in immunity and autoimmunity. Curr. Opin. Pharmacol. 9, 447–453.

Schneider, K., Puehler, F., Baeuerle, D., Elvers, S., Staeheli, P., Kaspers, B., Weining, K.C., 2004. cDNA cloning of biologically active chicken interleukin-18. J. Interferon Cytokine Res. 20, 879–883.
Shini, S., Huff, G.R., Shini, A., Kaiser, P., 2010. Understanding stress-induced immunosuppression: exploration of cytokine and chemokine gene profiles in chicken peripheral leukocytes. Poult. Sci. 89, 841–851.
Sick, C., Schneider, K., Staeheli, P., Weining, K.C., 2000. Novel chicken CXC and CC chemokines. Cytokine. 12, 181–186.
Skovdahl, H.K., Damås, J.K., Granlund, A.B., Østvik, A.E., Doseth, B., Bruland, T., Mollnes, T.E., Sandvik, A.K., 2018. C-C motif ligand 20 (CCL20) and C-C motif chemokine receptor 6 (CCR6) in human peripheral blood mononuclear cells: dysregulated in ulcerative colitis and a potential role for CCL20 in IL-1β release. Int. J. Mol. Sci. 19, 3257.
Varmuzova, K., Faldyna, M., Havlickova, H., 2016. Immune protection of chickens conferred by a vaccine: aerosol vaccination stimulates systemic immunity, oral vaccination stimulates local gut immunity. Vet. Res. 47, 1–12.
Venkatas, J., Adeleke, M.A., 2019. A review of Eimeria antigen identification for the development of novel anticoccidial vaccines. Parasitol. Res. 118, 1701–1710.
Yun, C.H., Lillehoj, H.S., Lillehoj, E.P., 2000. Intestinal immune responses to coccidiosis. Dev. Comp. Immunol. 24, 303–324.

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