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Evaluation of sea turtle handling methods in a captive facility in Nipah, Indonesia

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Abstract. *Syaputra M, Wahyuningsih E, Suparyana PK, Lestari AT, Setiawan B, Ritonga FN. 2025. Evaluation of sea turtle handling methods in a captive facility in Nipah, Indonesia. Biodiversitas 26: 5626-5637.* Animal welfare is crucial for sea turtles in captivity and is guided by several principles: freedom from hunger and thirst; freedom from discomfort; freedom from pain, injury, or disease; freedom from fear and stress; and freedom to express natural behavior. The United States Department of the Interior (USDI) Fish and Wildlife Service has issued standard guidelines for handling sea turtles in captivity. This study aimed to evaluate sea turtle conservation efforts through ex-situ strategies by fostering populations in controlled environments. The research was conducted at the sea turtle captive facility on Nipah Beach, Malaka Village, North Lombok District, West Nusa Tenggara, Indonesia, which consists of five rearing ponds and associated facilities where at the time of the research there were 566 individual sea turtles of three species: the olive ridley turtle (*Lepidochelys olivacea*), hawksbill turtle (*Eretmochelys imbricata*), and green turtle (*Chelonia mydas*). Sea turtle handling in captivity was assessed using a scoring method, complemented by observation, measurement, interviews, and laboratory analysis, based on a modified version of the 2019 Captive Sea Turtle Standards issued by the USDI Fish and Wildlife Service, and the key aspects and optimization steps of the captivity were analyzed using Analytic Hierarchy Process (AHP). In conclusion, the management of captive sea turtles achieved an overall score of 369 out of 459 (80.39%), indicating very good conditions. Pond management constitutes the primary determinant in sea turtle captivity, with a value of 0.3049. The priority order of management actions required to optimize sea turtle captivity practices from highest to lowest are: providing pond shading, conducting daily health inspections, regulating pond lighting in accordance with natural daylight cycles, constructing pond edges, and equipping pond lights with covers. Another thing to note is to ensure that there is no overcrowding in the pond. The absence of nationally recognized welfare standards in Indonesia highlights the need for policymakers to establish comprehensive guidelines for sea turtle captivity to ensure consistent and sustainable management practices.

Keywords: Animal welfare, ex-situ, sea turtle, wildlife, USDI

INTRODUCTION

The coastal forest in the Nipah area of Malaka Village, North Lombok District, West Nusa Tenggara Province, Indonesia, lies within the delineated boundaries of the Rinjani Geopark (Nurhanifa et al. 2019) and supports rich biodiversity (Shepherd et al. 2020; Nursan et al. 2022; Wahyudin et al. 2023). This biodiversity includes wildlife species of high conservation value, notably sea turtles (Syaputra et al. 2023b). To support sea turtle conservation efforts, the Malaka Village community independently established the Turtle Conservation Community (TCC) in 2018. The TCC was formally designated by the Regent of North Lombok through Decree No. 372/52/DLH-PKP/2019 as the Sea Turtle Corridor Essential Ecosystem Area.

Sea turtles have long received conservation attention in Indonesia (Sani et al. 2024), particularly within the forestry sector (Nijman and Shepherd 2022). The Indonesian Minister of Environment and Forestry has designated sea turtles as protected and as National Priority Species. According to the Indonesian Regulation of the Director General of Natural Resources and Ecosystem Conservation (KSDAE), the national population of these species must increase by 10%. Currently, sea turtle populations in the wild are at an alarming level and continue to decline due to habitat loss, coastal forest conversion, hunting, and trade, all of which pose significant threats and increase their risk of extinction (IUCN 2023).

Olive ridley turtles (*Lepidochelys olivacea*), hawksbill turtles (*Eretmochelys imbricata*), and green turtles (*Chelonia mydas*) are the three species found in the study area each has the status: vulnerable, critically endangered, and endangered based on the status of the International Union for Conservation of Nature and Natural Resources (Syaputra et al. 2024). According to Jemarut et al. (2021), olive ridley turtles have a natural distribution in East Java, Bali, and Nusa Tenggara. Hawksbill turtles occur throughout Indonesian waters, particularly in the Java Sea, Riau Islands, Flores Sea, Makassar Strait, Karimata Strait, Bali, East Nusa Tenggara, and Papua. Green turtles are

distributed across the waters of Western Indonesia (Aceh, West Sumatra, Riau Islands, Bangka Belitung), Central Indonesia (Seribu Islands, West Java, Karimun Jawa, West Kalimantan, East Kalimantan, East Java), and Eastern Indonesia (Sulawesi, Bali, East Nusa Tenggara, West Nusa Tenggara, Maluku, Papua).

According to Escobedo-Bonilla et al. (2022), all sea turtle species share the same life cycle, characterized by slow growth and requiring several decades to reach reproductive maturity (Robinson et al. 2023). Adult sea turtles may reside in a single location for years before migrating long distances from feeding grounds to nesting beaches to reproduce (Tanabe et al. 2023). Mating typically occurs offshore one to two months before the first nesting event of the season (Christiaanse et al. 2024), and both males and females may have multiple mating partners (Topping and Valenzuela 2021). Males generally return to their feeding grounds after females complete a biweekly egg-laying period on the beach. When ready to nest, females emerge from the sea and use their front flippers to drag their bodies onto the nesting beach (Figure 2) (Dethmers et al. 2010; SCS 2021).

Research evaluating sea turtle management methods in captivity remains scarce, primarily due to the limited availability of reference materials that could serve as standardized guidelines. National standards for sea turtle conservation have not been established by the Indonesian government or relevant authorities. The existing Regulation of the Director General of Animal Welfare (No. P.9/IV-SET/2011) addresses ethics and welfare for animals in ex-situ institutions but is general in scope for all species and requires further interpretation for application to sea turtles.

The concept of animal welfare encompasses five principles intended to ensure the well-being of captive species (Fischer and Romero 2019; Esteban-Sánchez et al. 2024). The United States Department of the Interior (USDI) Fish and Wildlife Service, an agency dedicated to managing wildlife, fish, and natural habitats (USDI-Fish and Wildlife Service 2019), collaborates with various stakeholders to conserve, protect, and enhance the quality of these resources for sustainable benefits. Its guidelines are designed to ensure that facilities for sea turtle care and handling comply with standards for proper care and management. By referring to widely recognized international guidelines, relevant stakeholders in Indonesia may be encouraged to develop similar, applicable standards. The findings of this study are expected to serve as a reference model for establishing national standards for sea turtle management, particularly in captivity.

Despite the existence of international guidelines, studies evaluating sea turtle handling methods in captivity remain limited (Syaputra et al. 2023a). The scarcity of reference materials, coupled with the absence of national standards for sea turtle captivity in Indonesia, presents current challenges (Hamann et al. 2010). Therefore, this study aimed to investigate sea turtle conservation efforts through both in situ approaches—such as direct protection and rescue within their natural habitats and ex-situ strategies, including population maintenance in artificial or controlled environments.

MATERIALS AND METHODS

Study area

This study was conducted from April to September 2024 at the Nipah Sea Turtle Captive Facility (8º26'03.38"S, 116º02'42.27"E), located in Malaka Village, Pemenang Sub-district, North Lombok District, West Nusa Tenggara Province, Indonesia (Figure 1).

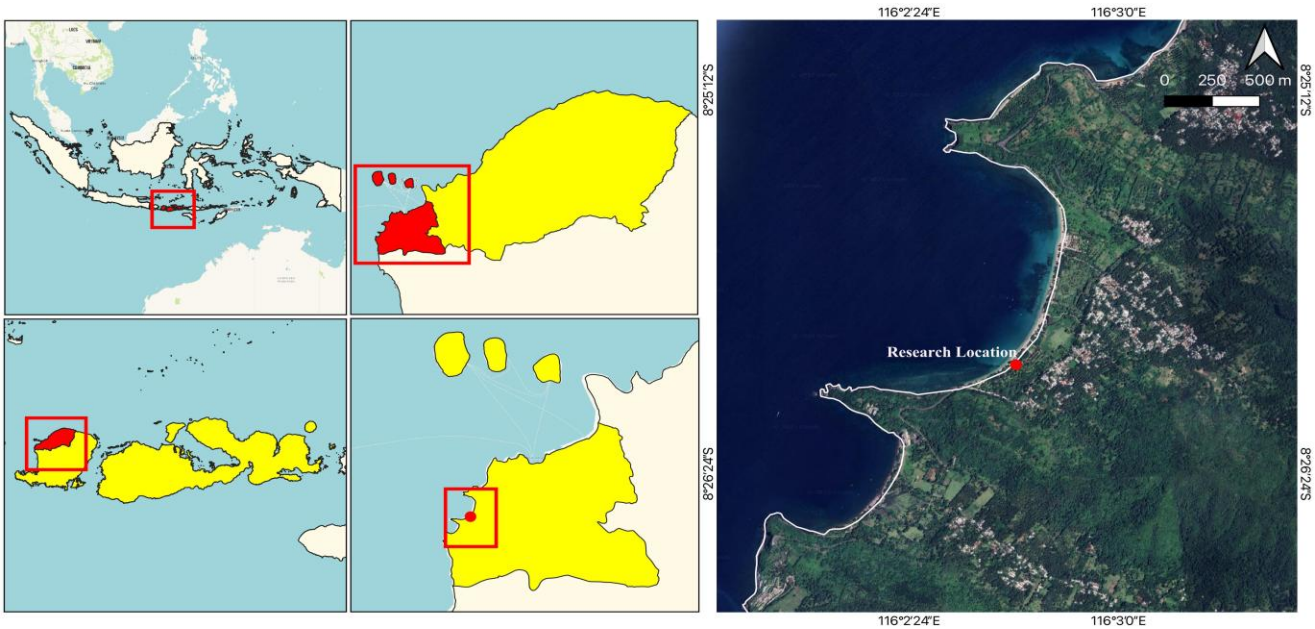

Figure 1. Sea turtle captive facility located in Malaka Village, Pemenang Sub-district, North Lombok District, West Nusa Tenggara Province, Indonesia

Procedures

Research tools and objects

The tools and materials used in this study included a ruler, tape measure, thermo-hygrometer, camera, stopwatch, digital recorder, salt meter EZ-9909 (including TDS, pH, and thermometer functions), plastic sampling bags, sample bottles, and stationery (Joana et al. 2023). The object of this study was the sea turtle captive facility located at Nipah Beach, comprising five rearing ponds and associated facilities, which at the time of the research, housed 566 individual sea turtles representing three species: the olive ridley turtle (*L. olivacea*), the hawksbill turtle (*E. imbricata*), and the green turtle (*C. mydas*) (Syaputra et al. 2023a, b) (Table 1).

Data collection method

The suitability of sea turtle handling in captivity was assessed using a modified version of the 2019 Captive Sea Turtle Standards issued by the USDI Fish and Wildlife Service. These guidelines encompass key aspects such as ponds, water, feed, health, and demonstration activities (USDI-Fish and Wildlife Service 2019) as shown in Table 2. Data were collected through measurements, in-depth interviews, and direct observations. Respondents were selected using a key informant approach, targeting individuals with knowledge of, involvement in, or responsibility for handling activities, including the head of the Turtle Conservation Community (TCC), animal keepers, the feed and nutrition staff, and the health section. One representative was chosen as the most credible key informant for each category. In-depth interviews consisted of face-to-face question-and-answer sessions conducted with or without structured guidelines (Rutledge and Hogg 2020; Knott et al. 2022). These interviews involved extended engagement between interviewers and informants (Schoonenboom 2023). The questions asked included how to treat the water in the pond, how to handle turtles in the pond, how to prevent and handle sick turtles, and how to manage visitors, with the parameters, aspects observed, and asked are summarized in Table 2.

Data analysis

The level of sea turtle handling in captivity is analyzed using the scoring method, where each parameter has a different influence, described through scoring and weighting. The score is worth 1-3 (3: according to standards, 2: there have been efforts but have not met standards, 1: no effort has been made). At the same time, the weight is the level of influence on the survival of sea turtles obtained from expert discussions (1: no influence, 2: less influence (very low or insignificant), 3: sufficient (neither too strong nor too weak), 4: influential (has a significant effect), and 5: very influential). The results of the scoring of the level of sea turtle handling in captivity in each aspect are added up and then expressed as a percentage of the maximum score, which is categorized in Tables 3 and 4.

The level of sea turtle handling in captivity was analyzed using a scoring method, in which each parameter was evaluated based on both a score and a weighting factor. Scores ranged from 1 to 3, where 3: meets the standard, 2: efforts have been made but do not meet the standard, and 1: no effort has been made. Weighting represented the degree of influence on sea turtle survival, as determined through expert discussions: 1: no influence, 2: low influence, 3: moderate influence, 4: influential, and 5: highly influential. The total score for each aspect of sea turtle handling was then summed and expressed as a percentage of the maximum possible score. These percentages were further categorized (Tables 3 and 4).

Subsequently, the key aspects and optimization steps of the captivity were analyzed using the Analytic Hierarchy Process (AHP). AHP is a decision-support tool that facilitates the determination of priorities by evaluating multiple factors (Widjaja 2025). This method was applied because not all factors influencing decision-making are tangible or directly measurable. The AHP model is structured hierarchically, comprising the overall goal, the criteria or factors to be considered, and the decision alternatives.

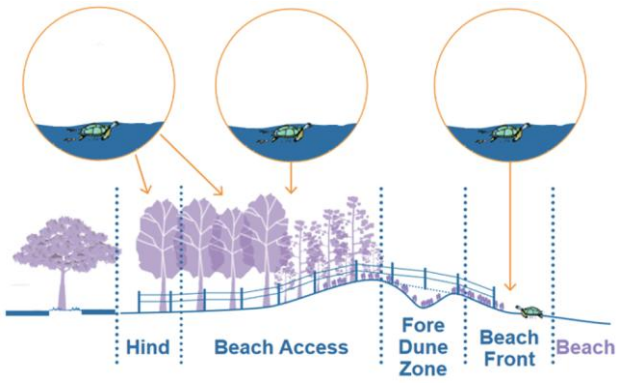

Figure 2. Sea turtle nesting areas (SCS 2021, modified)

Table 1. Number of turtles when this research was conducted

Pond number	Pond size			Number of sea turtles
	Width (cm)	Length (cm)	Water depth (cm)	
1	149.1	188	23.5	94
2	130.4	188	23.4	98
3	149.3	188	20.5	97
4	225	158	18.5	169
5	224.1	158	19.2	108
Total				566

Table 2. Research parameters and aspects

Parameter	Standard	Method
Pond management		
1. Size	The minimum area is five times the length of the shell and twice the width of the carapace, with a minimum water depth of 1 foot	Measurement and observation
2. Material	The pond surface must be non-abrasive, free from protrusions (gaps), and not peeling	
3. Substrate	Ponds should not contain any non-food items that could be swallowed or any items that could hinder the sea turtle's ability to surface, either to breathe or to float	
4. Pond edge	Provide rock ledges or similar structures in the tank for sea turtles to rest	
5. Fence	Ponds must use barriers to prevent people from entering	
6. Piping	Have a safe drainage channel or holding tank inlet	
7. Roof	Have a minimum of 30% shade. If the water is recirculated, the shade should be increased to a minimum of 50%	
8. Light	Following natural lighting, the lights do not stay on for more than 14 hours	
9. Light cover	Lights above the ponds must have a guard to prevent accidental damage	
Water handling		
1. Circulation	Carry out regular water circulation to maintain water quality	Observation and in-depth interview
2. Fulfillment	During the draining and filling of the pond, care must be taken to minimize stress and avoid injury to the sea turtle	
3. Inlet filtration	Pre-filter natural seawater to prevent disease	
Water quality		
1. Purity	The water should be clear enough so that the sea turtles can be easily seen anywhere in the pond to assess their health and activity	Laboratory analysis (Forestry Technology Lab, Universitas Mataram, Indonesia)
2. Salinity	20-35 ppt	
3. pH	7.2-8.5	
4. Temperature	20-30°C	
5. Coliform	<400 Coliform bacteria /100 mL	
Sea turtle treatment		
1. Aggressive behavior	Sea turtles housed together should be carefully observed until it is certain that the sea turtles are not exhibiting aggressive behavior that could result in injury or death	Observation and in-depth interview
2. Separation	Male and female adult sea turtles should be separated (with a divider or separate enclosure) to prevent breeding in captivity	
Feed management		
1. Feed condition	Good quality and fresh	Observation and in-depth interview
2. Feed type	Low-fat fish and commercial feed	
3. Feeding	Spread throughout the pond to prevent competition	
4. leftover feed	Discard uneaten food in a timely manner (except live prey) to minimize water pollution	
Health facilities		
1. Doctor	Each captivity has access to a veterinarian	Observation and in-depth interview
2. Action	Diagnosis of disease, surgical intervention, and prescription of drugs should be carried out only by a veterinarian	
3. Isolation	Sick sea turtles are placed in smaller isolation tanks	
4. Treatment	Rehabilitated sea turtles proposed for public demonstration are supervised by a veterinarian	
5. Inspection	Evaluate the sea turtle's skin and shell daily for any abnormalities or decline in the sea turtle's condition	
Tourism stress		
1. Time	Tours are only conducted during the hours when the sea turtles are exposed to light	Observation and in-depth interview
2. Tour materials	Educational topics should include species identification, protection status, conservation issues	
3. Contact	Contact with sea turtles is not permitted	
4. SOP delivery	Visitors should be given clear instructions to minimize disturbance and stress to the sea turtles	
5. Companion	Each tour must have at least one staff member/volunteer present on the tour for every 15 guests	
6. Shade	Ponds should be semi-enclosed or have hiding places for sea turtles to reduce stress from the tour	

Table 3. Scoring of sea hurtle handling levels

Measurement aspects	Weight	Score			Sources
		3	2	1	
Pond management (Table 2)					
1. Size					USDI-Fish and Wildlife Service (2019)
2. Material					
.					
.					
9. Light cover					
etc					

Table 4. Definition of sea turtle handling levels

Implementation level (%)	Criteria	Definition of management
80-100	Very good	Acceptable
70-79	Good	Monitored
60-69	Enough	Control efforts are needed
<60	Poor	It must be of concern

RESULTS AND DISCUSSION

Effective management of ex-situ conservation programs (Ritonga et al. 2018) must consider animal welfare principles as the fundamental guidelines for maintenance activities (Robledo-Avila et al. 2022). Neglecting animal welfare can result in suffering or even mortality (Lestari et al. 2021). Animal welfare management represents a set of ethical guidelines designed to promote optimal well-being and survival (Buller et al. 2020). These principles encompass physical, psychological, and behavioral dimensions that must be addressed and implemented by managers. Evaluations of animal welfare may refer to various standards issued by both national and international institutions (Diggins et al. 2023). One widely recognized framework for sea turtle management is the International Captive Sea Turtle Standards developed by the USDI Fish and Wildlife Service (2019), which cover aspects such as pond construction, water quality and quantity, feeding, health, and human interaction. Risk reduction in biodiversity management follows a mitigation hierarchy consisting of avoidance, minimization, rehabilitation, and offsetting, with higher levels of mitigation offering fewer available options. Accordingly, risk reduction measures are necessary to prevent or minimize sea turtle mortality resulting from unmet management standards. The Turtle Conservation Community (TCC), as the manager of the Nipah Sea Turtle captive facility, plays a central role in implementing comprehensive sea turtle handling and maintenance. The findings of this study provide important feedback for TCC to improve the effectiveness of its conservation practices. An overview of the Nipah sea turtle captive facility can be seen in the Figure 3.

Pond management

Maintenance ponds in captive sea turtle breeding serve as artificial habitats that support survival by simulating natural sea conditions (Kobolkuti et al. 2016). These ponds are designed with consideration of size, depth, and shape to allow sea turtles to swim and engage in natural behaviors, thereby minimizing stress caused by environmental changes. Observations of pond size and depth revealed that USDI standards were not fully met. In particular, the ponds were found to be overcrowded (Table 1). The absence of adequate pond edges and the continuous use of artificial lighting at night also affected assessment results and likely contributed to stress. Nevertheless, the use of non-abrasive ceramic tiles, a fully shaded roof, and a water exchange piping system positively influenced the evaluation. Overall, pond management scored 71.05%.

Ritonga et al. (2021) reported that environmental stress significantly reduces the quality of life in organisms. Accordingly, ponds must be designed to accommodate the number and size of sea turtles to ensure optimal movement (Nursyam 2017). Pond materials must also be resistant to saltwater and free from toxic substances that could affect sea turtle health. In addition, non-food objects should be absent, as they may hinder the turtles' ability to breathe or float (Kiss et al. 2024).

Pond edges must be designed to ensure that both surface and height are accessible for sea turtles to rest. Fences should also be constructed to provide additional protection by preventing entry of other animals or unauthorized persons. The water channel functions to maintain water quality by enabling efficient circulation and regular discharge. The roof structure regulates direct sunlight exposure, maintaining stable temperatures and reducing the risk of overexposure (Garefino and Milton 2022; Geisler et al. 2023). Light shields are also necessary to prevent direct glare, which may induce stress, as sea turtles are sensitive to bright light sources. Collectively, these structural parameters influence the welfare and behavior of sea turtles in captivity (USDI-Fish and Wildlife Service 2019). The results of pond management assessment in this study are presented in Table 5.

According to several references, the size of rearing ponds varies considerably, including 2×3×0.6 m at the Kebumen sea turtle captive facility (Rahmaningtyas 2024), 2.5×1.5 m at the Rantau Sialang sea turtle captive facility (Syam 2021), and 1×4 m at Taman Kili (Satria 2014). The absence of national standards regulating the appropriate dimensions of ponds has resulted in substantial variation in pond sizes across regions.

Water handling

Proper management of pond water is essential in ex-situ sea turtle conservation to maintain environmental stability and health. This aspect was rated as very good, achieving a score of 88.09% based on USDI standards. Pond water circulation was performed daily, and during water changes, the sea turtles were transferred to a temporary tank to reduce stress. Although no microorganism filter was used, physical filtration of coarse particles and sea sand was implemented. In this process, water circulation and filtration were the main elements (Flint et al. 2015) to prevent the accumulation of debris and hazardous substances such as ammonia and nitrate, which are toxic to sea turtles (Ross et al. 2017). Effective circulation also ensured even distribution of temperature and salinity throughout the ponds, thereby creating conditions resembling the natural marine environment. The filtration system removed particles and pathogenic organisms that could cause disease or reduce water quality, such as harmful bacteria and excessive algae (Filek et al. 2024). These findings suggest that optimal circulation and filtration support the establishment of stable water quality that meets the physiological requirements of sea turtles (Jualaong et al. 2021).

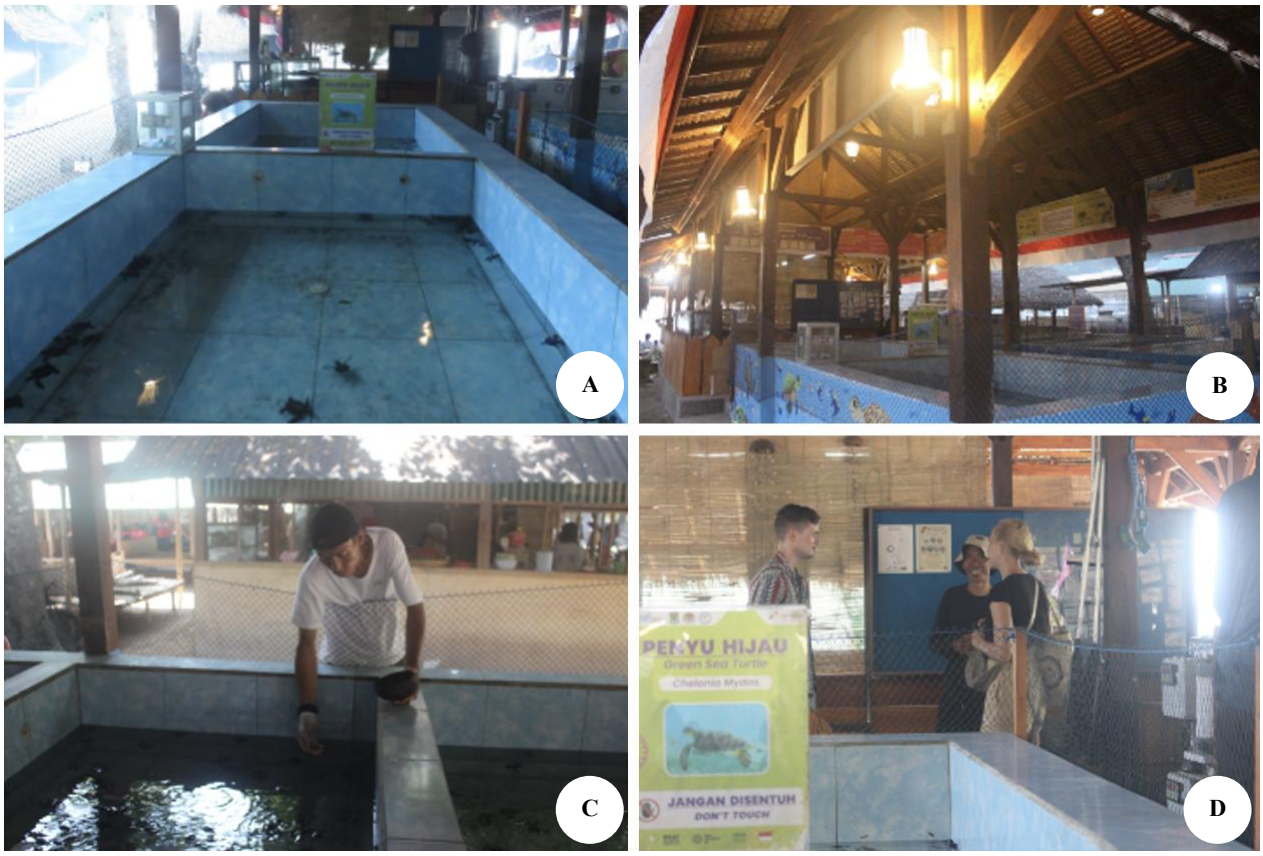

Figure 3. Nipah Sea Turtle Captive Facility in Malaka Village, Pemenang Sub-district, North Lombok District, West Nusa Tenggara Province, Indonesia. A. Pond facilities, B. Roof and light source, C. Feeding activity, D. Tourist activities

In addition to circulation and filtration, the process of water replenishment must also be considered in pond water management. This process should be conducted carefully, as uncontrolled replenishment can lead to significant changes in parameters such as temperature and salinity, which can cause stress in sea turtles (Espinoza et al. 2022). When properly regulated, water replenishment ensures both adequate quality and sufficient volume to support sea turtle activities, thereby promoting comfort and welfare. Filtration of incoming seawater is another essential component of the ex-situ pond system, particularly when natural seawater is used (Francis et al. 2022). This process removes contaminants and microorganisms that may harm sea turtles and minimizes the risk of disease transmission. Initial filtration of seawater prior to entering the pond can be conducted using a physical strainer, ensuring that incoming water meets the quality standards required for sea turtles (Perrault et al. 2019). Overall, pond water management through controlled circulation, filtration, and replenishment contributes to stable environmental conditions, supports animal welfare, and sustains the artificial habitat (Herbst and Klein 1995). The results of the water management assessment are presented in Table 5.

Water quality

Monitoring pond water quality in sea turtle husbandry involves several key parameters, including water clarity, salinity, pH, temperature, and coliform bacteria content. Based on observations and laboratory analyses, water clarity was satisfactory, meeting the USDI requirement that turtles must be clearly visible through direct inspection. The average pond temperature was 24.4°C, and coliform levels remained within acceptable limits (262 CFU/100 mL). However, salinity (37 ppt) and pH (7.1) slightly exceeded the recommended thresholds. Overall, the water quality score was 88.09%. These parameters ensure that pond conditions meet the physiological and health requirements of sea turtles (Ebani 2023). Water clarity indicates pond cleanliness, while turbidity often reflects the presence of food waste, microorganisms, or organic particles that may reduce water quality and hinder visual observations. Salinity must be tightly controlled, as sea turtles are sensitive to fluctuations; imbalances can cause osmoregulatory disorders, dehydration, or osmotic stress, ultimately compromising health. Water pH should be maintained within the optimal range of 7.2-8.5 to prevent extreme acidic or alkaline conditions that may trigger metabolic disturbances (Jualaong et al. 2019). Pond water temperature is another critical factor influencing sea turtle welfare (Staines et al. 2023), since extreme temperatures can suppress activity and immune function, thereby increasing susceptibility to infection. Conversely, stable temperatures support metabolism and overall animal comfort (Shepherd et al. 2020; McKnight et al. 2023;

Kidman et al. 2024). Finally, monitoring coliform content is essential, as its presence indicates biological contamination (Ebani 2023). Elevated coliform levels increase the risk of infection and reduce pond hygienic standards. The results of water quality assessments in this study are presented in Table 5.

Sea turtle treatment

Monitoring maintenance in captive sea turtles involves observing aggressive behavior and separating adult males and females to maintain welfare and prevent uncontrolled breeding (Maggeni and Feeney 2020). Despite appropriate supervision by caretakers, aggressive interactions still occurred, leading to injuries in some individuals, which were likely exacerbated by overcrowding in the ponds. With regard to separation, this measure was implemented effectively, as adult sea turtles although not in large numbers were maintained in separate ponds. The total assessment score for this aspect was 83.33%. Aggressive behavior, often driven by competition for space and food, may result in severe injury or mortality, thereby compromising overall welfare. To address this issue, separating adult males and females is essential to reduce aggression and prevent uncontrolled breeding. Captive ponds frequently present challenges due to confined environments that constrain natural development (Kobolkuti et al. 2016). Furthermore, unplanned breeding can increase population density beyond pond capacity, intensifying competition for resources (Hong et al. 2022). The results of monitoring sea turtle maintenance in this study are presented in Table 5.

Feed management

Within ex-situ management practices, feed management is crucial for maintaining the health and welfare of sea turtles (Lemell et al. 2019; Fitriyah et al. 2021). Monitoring feed quality is a key priority, as poor-quality diets can result in digestive disorders or poisoning. Sea turtle diets vary by life stage; hatchlings up to one year old are primarily carnivorous (Tumanggor 2018), consuming shellfish, shrimp, jellyfish, crabs (Rachman 2021), and fish (Damayanti and Junianto 2023). At the Nipah Beach conservation facility, turtles are fed chopped fresh tuna, with uneaten portions removed during daily water changes. Although uneaten feed was occasionally observed prior to water replacement, the overall score for this aspect was very good at 90.19%. Appropriate feed selection and nutritional content are vital for supporting healthy growth. Tuna, in particular, has a high protein content (Lazaren et al. 2018), consisting of 25.0% protein, 0.03% carbohydrates, 1.50% fat, 2.25% minerals, and 69.40% water per 100 grams. The high protein content in feed such as tuna provides a complete amino acid profile, making it essential for growth (Wardana et al. 2022).

Fresh and well-maintained feed provides optimal nutrition essential for the growth and immunity of sea turtles. Therefore, monitoring feed conditions is a crucial step to prevent the ingestion of harmful substances. Depending on the species, sea turtles are omnivorous or carnivorous and require feed rich in protein, fiber, vitamins, and minerals (Ducotterd et al. 2020). The provision of these nutrients supports growth and health, thereby minimizing the risk of malnutrition and associated health problems. Feeding methods also influence welfare by creating comfortable conditions and reducing stress, highlighting the need for a consistent supply and adequate access. Moreover, a structured feeding regime helps establish regular eating patterns and reduces food-related aggression (Lemell et al. 2019). Feed should also be distributed evenly to minimize competition. Uneaten feed left in the ponds decomposes and produces toxic substances such as ammonia, which can harm sea turtles and deteriorate water quality. Consequently, the management of uneaten feed through regular cleaning is essential to prevent the accumulation of organic matter, maintain water quality, and reduce the risk of infection (Tao et al. 2024). The results of feed management assessment in this study are presented in Table 5.

Table 5. Scoring of sea hurtle handling levels

No	Parameter	Weight	Score			Total	%
			3	2	1		
Pond aspects							
1.	Size	5	-	2	-	10	80/114:
2.	Material	5	3	-	-	15	71.05
3.	Substrate	4	-	2	-	8	
4.	Pond edge	3	-	-	1	3	
5.	Fence	3	-	2	-	6	
6.	Water circulation	5	3	-	-	15	
7.	Roof	5	3	-	-	15	
8.	Light	5	-	-	1	5	
9.	Light cover	3	-	-	1	3	
Water handling aspects							
1.	Circulation	4	3	-	-	12	37/42:
2.	Fulfillment	5	3	-	-	15	88.09
3.	Inlet filtration	5	-	2	-	10	
Water quality aspect							
1.	Purity	5	3	-	-	15	65/75:
2.	Salinity	5	-	2	-	10	86.66
3.	pH	5	-	2	-	10	
4.	Temperature	5	3	-	-	15	
5.	Coliform	5	3	-	-	15	
Maintenance aspect							
1.	Aggressive behavior	4	-	2	-	8	20/24:
2.	Separation	4	3	-	-	12	83.33
Feed aspect							
1.	Feed condition	5	3	-	-	15	46/51:
2.	Feed type	4	3	-	-	12	90.19
3.	Feeding	3	3	-	-	9	
4.	leftover feed	5	-	2	-	10	
Health aspect							
1.	Doctor	5	3	-	-	15	51/69:
2.	Action	5	3	-	-	15	73.91
3.	Isolation	4	-	2	-	8	
4.	Treatment	4	-	2	-	8	
5.	Inspection	5	-	-	1	5	
Tourism stress aspect							
1.	Time	5	3	-	-	15	70/84:
2.	Tour materials	5	3	-	-	15	83.33
3.	Contact	5	3	-	-	15	
4.	SOP delivery	4	-	2	-	8	
5.	Companion	4	3	-	-	12	
6.	Shade	5	-	-	1	5	

Health facilities

Health facilities and infrastructure in sea turtle breeding are essential for ensuring animal health and welfare. The Nipah sea turtle captive facility maintains access to veterinarians through collaboration with a city clinic to address health issues. Veterinarians conduct visits upon receiving reports from keepers. As continuous veterinary supervision is unavailable, isolation and minor treatments are performed directly by keepers with appropriate guidance and training. Moreover, daily evaluations were not routinely conducted, resulting in a score of 73.91% for this aspect. In captivity, access to veterinarians is a top priority to enable medical examinations and the early detection of disorders or injuries, thereby allowing appropriate care when required. With their expertise, veterinarians design health and treatment programs tailored to the specific needs of sea turtles, minimizing the risk of infection or mortality (Page-Karjian and Perrault 2021). In this context, implementing actions based on Standard Operating Procedures (SOPs) is essential to ensure that all handling practices are consistent with medical principles. SOPs include protocols for disease management, animal transfer, nutritional provision, and behavioral monitoring. These procedures ensure that every situation is addressed using established protocols that safeguard safety and welfare. The presence of isolation facilities for sick sea turtles reduces the risk of disease transmission and ensures proper treatment for rapid recovery (Ciccarelli et al. 2020), thereby protecting both the infected individuals and the broader population (Tetzlaff et al. 2019). Specialized care during rehabilitation plays a critical role in recovery, as sea turtles require calm, low-stress environments (Nursyam 2017). Public exposure can disrupt this process and increase stress, limiting the effectiveness of intensive care. Daily health checks, particularly of skin and shell conditions, are also vital for detecting early signs of physical problems. Changes in shell color, texture, or structure may indicate infection or malnutrition (Fraga et al. 2018). Routine monitoring enables caretakers to take proactive measures before problems progress, helping maintain sea turtles in good health and ready for release when possible. The results of the sea turtle health assessments in this study are presented in Table 5.

Tourism stress

Tourism-related stress must be considered, as this factor directly influences the welfare of captive sea turtles. Observations indicated that all assessment criteria established by the USDI were met, except for the absence of written SOPs and insufficient shading around the ponds at the Nipah Sea turtle captive facility, which would allow turtles to hide and avoid visitor-induced stress. Consequently, this aspect received a score of 83.33%. Restricting demonstrations to daytime hours helps minimize stress by reducing prolonged exposure to tourists. During tours, the material presented by guides should be informative and educational, highlighting the critical ecological role of sea turtles and the challenges of conservation (Zerr et al. 2022). Limiting physical contact between visitors and turtles serves as a preventive measure against both disease transmission and stress caused by physical disturbances. The impacts of visitor interactions in captive facilities include elevated stress levels and an increased potential for disease spread (Zerr et al. 2022). Research by Flower et al. (2015) demonstrated that human touch elevated corticosterone levels, a hormone associated with stress regulation in sea turtles. A subsequent study by Hayes et al. (2017) further revealed that the frequency of human contact was directly proportional to reductions in natural behaviors. In this context, the communication of SOPs by tour guides is essential to ensure safe interactions, while guides also act as supervisors to ensure compliance with established rules. Providing shade over ponds helps regulate water temperature, protect turtles from direct sunlight, and create conditions resembling natural habitats (Rathnayake 2016), it also provides a hiding place for sea turtles to reduce tourism stress. The results of the tourism stress assessment in this study are presented in Table 5.

Key aspects and improvements

This study also examined the key aspects of sea turtle management in captivity. The Analytic Hierarchy Process (AHP) was applied to compare seven aspects: pond management, water handling, water quality, sea turtle treatment, feed management, health facilities, and tourism stress. The analysis revealed that pond management constitutes the primary determinant in sea turtle captivity (Figure 4), with a value of 0.3049 (30.49%). Table 6 presents the results of pairwise comparisons among the criteria assessed using the AHP in evaluating sea turtle management. The computational results yielded λ max: 7.42, a Consistency Index (CI) of 0.07, and a Consistency Ratio (CR) of 5.62%. Since the CR value falls below the 10% threshold, the pairwise comparison matrix can be considered consistent, thereby confirming that the derived priority weights are scientifically reliable.

Based on the findings of this study, several evaluation criteria were identified as suboptimal, necessitating further analysis to determine the order of management priorities required by facility managers. A vertical analysis was conducted to obtain the relative importance of each alternative priority in sea turtle husbandry. The weights generated from this analysis represent the average values of each alternative weight derived from the horizontal processing of alternatives against criteria at the same hierarchical level. The final results of the Analytic Hierarchy Process (AHP) revealed the priority order of management actions required to optimize sea turtle captivity practices. From highest to lowest, the priorities are: shading, inspection, lighting, pond edges, and light covers (Figure 5).

Comparative with international best practices and policy implications

Several results from this study show convergence with National Oceanic and Atmospheric Administration (NOAA) Fisheries' handling and resuscitation protocols, which were originally developed for field and fishery contexts. For instance, the practice of transferring sea turtles to temporary tanks during water changes reflects NOAA's principle of minimizing handling stress and

ensuring shading and moisture during interventions (NOAA Fisheries 2020). The International Union for Conservation of Nature (IUCN) Marine Turtle Specialist Group (MTSG) and IUCN Species Survival Commission (SSC) translocation guidelines provide another important benchmark, especially regarding rehabilitation, quarantine, and release readiness. While the collaboration with local veterinarians represents good practice, the lack of routine daily health monitoring and limited on-site clinical presence are inconsistent with IUCN's recommendations for structured health surveillance, isolation capacity, and explicit release criteria. Adopting IUCN guidance would strengthen decision-making by formalizing daily health checklists, quarantine protocols, and evidence-based criteria for release, while also addressing biosecurity and disease-transmission risks in captive environments (IUCN 2013, 2019).

When considered alongside Food and Agriculture Organization (FAO) Guidelines to Reduce Sea Turtle Mortality in Fishing Operations, the scope of the Nipah captive facility is somewhat distinct. FAO guidelines primarily focus on reducing bycatch and promoting safe handling and release at sea through gear modification, resuscitation methods, and rapid triage. Although these recommendations do not directly regulate ex-situ husbandry, their handling protocols remain relevant at the intake stage of hatcheries, where sea turtles are sometimes retrieved from strandings or local fisheries. Incorporating FAO's operational handling checklists into local SOPs would strengthen staff capacity to ensure survival at the point of transfer from capture to captive care (FAO 2009).

Overall, this comparative analysis demonstrates that while the Nipah captive facility's practices already meet many of the operational requirements articulated in the USDI Fish and Wildlife Service standards, several areas require upgrading to achieve full alignment with the broader suite of international best practices. These enhancements would position Indonesian sea turtle conservation programs in closer conformity with established global benchmarks and elevate their contribution to species recovery and welfare outcomes.

From a policy perspective, the absence of nationally endorsed, species-specific standards documented in this study creates several governance challenges. First, facility managers lack a consistent legal benchmark for infrastructure, staffing and veterinary expectations; quasi-voluntary adoption of foreign standards (e.g., USDI Fish and Wildlife Service, IUCN) yields uneven implementation across regions. Second, regulatory gaps complicate oversight: without codified minimum thresholds for stocking density, water quality, veterinary frequency or quarantine procedures, local authorities cannot systematically inspect, accredit or require corrective action. Third, fragmented responsibilities (e.g., fisheries, environment/forestry, local governments, community groups) impede coherent intake pathways for stranded or fishery-caught turtles and create blurred accountability for post-capture care (FAO 2009).

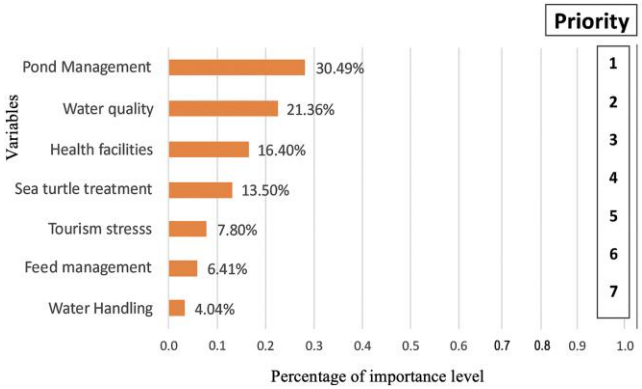

Figure 4. The sequence of key aspects in sea turtle captivity

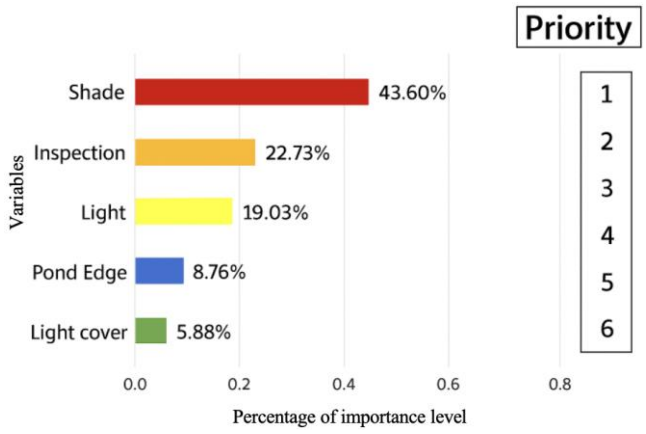

Figure 5. Priority order of management actions required to optimize sea turtle captivity

Table 6. Key aspect of sea turtle management in captivity

Criteria	Pond management	Water handling	Water quality	Sea turtle treatment	Feed management	Health facilities	Tourism stress
Pond management	1.0	4.9	1.4	1.7	4.0	4.9	4.0
Water handling	0.2	1.0	0.3	0.4	0.5	0.2	0.3
Water quality	0.7	4.0	1.0	1.0	4.0	1.6	4.9
Sea turtle treatment	0.6	2.8	0.7	1.0	1.6	0.6	2.8
Feed management	0.3	2.0	0.3	0.6	1.0	0.4	0.6
Health facilities	0.2	5.2	0.6	1.7	2.8	1.0	3.0
Tourism stress	0.3	4.0	0.2	0.4	1.6	0.3	1.0

To address these deficits, policymakers should prioritize the development of a national framework that: (i) defines minimum, evidence-based welfare standards for captive sea turtles (covering infrastructure, water quality, feeding, veterinary care, quarantine and visitor interaction); (ii) establishes accreditation and periodic audit mechanisms; and (iii) integrates intake/transfer SOPs that connect fishery interaction responses (FAO/NOAA) with facility reception and rehabilitation (USDI Fish and Wildlife Service/IUCN). Such hybridized frameworks combine operational specificity (USDI Fish and Wildlife Service) with rehabilitation ethics (IUCN) and intake/handling procedures (FAO/NOAA), creating a comprehensive policy instrument appropriate to Indonesia's conservation context.

In conclusion, the management of captive sea turtles achieved an overall score of 369 out of 459 (80.39%), indicating very good conditions. The analysis revealed that pond management constitutes the primary determinant in sea turtle captivity, with a value of 0.3049 (30.49%). The final results of the AHP revealed the priority order of management actions required to optimize sea turtle captivity practices. From highest to lowest the priorities are: providing pond shading, conducting daily health inspections, regulating pond lighting in accordance with natural daylight cycles, constructing pond edges, and equipping pond lights with covers. The absence of nationally recognized welfare standards in Indonesia highlights the need for policymakers to establish comprehensive guidelines for sea turtle captivity to ensure consistent and sustainable management practices.

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