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MORALITY BEFORE KNOWLEDGE

Hatching success rate of sea turtle in the north coast of Pinrang Regency, South Sulawesi

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ABSTRACT

Background: Turtles are endangered marine reptile species due to various factors, including hunting, habitat loss, and predation. Therefore, practical conservation efforts are essential to protect turtle populations. One effective conservation strategy is to transfer turtle eggs to safe semi-natural nests. **Method:** This study was conducted in Turtle Village, Pinrang Regency. Leatherback and Green Turtle eggs were collected from natural nests along the coast and transferred to semi-natural nests. Observations were made to measure the hatching success rate of the eggs, and factors such as temperature, incubation period, predators, microorganism development, and changes in egg position were also recorded and analyzed. **Findings:** The results showed that the hatching success rate of eggs in semi-natural nests reached 80.23%. The highest hatching percentage was 86.36%, and the lowest was 68.33%. Factors that influenced hatching success included temperature and incubation period while hatching failure was caused by predators, microorganism development, and changes in egg position. **Conclusion:** This study shows that semi-natural nests in Turtle Village have a high hatching success rate with supportive environmental conditions and proper egg transmission. This indicates that conservation efforts through egg transfer to semi-natural nests can effectively increase turtle populations. **Novelty/Originality of this study:** It contributes to turtle conservation by demonstrating the effectiveness of semi-natural nests in increasing the hatching success rate of Leatherback and Green Turtle eggs. This approach can serve as a model for turtle conservation programs in other areas facing similar challenges.

KEYWORDS: eggs hatching; kampong penyu; sea turtle

1. Introduction

Sea turtles, with a lineage spanning over 100 million years, are among the most ancient and fascinating creatures inhabiting our oceans. Their evolutionary history has endowed them with remarkable adaptations for marine life, yet they now face unprecedented challenges that threaten their survival. Globally, sea turtles are classified under varying levels of threat, as indicated by their inclusion in the International Union for Conservation of Nature (IUCN) Red List and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). These classifications, ranging from Critically Endangered (CR) to Vulnerable (VU), reflect the serious risks posed by a combination of natural and

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human-induced factors (Seminoff, 2004; Abreu-Grobois & Plotkin, 2008; Mortimer & Donnelly, 2008; Wallace, Tiwari & Gorondot, 2013; Casale & Tucker, 2017; Wibbels & Bevan, 2019).

The plight of sea turtles is a consequence of multiple interrelated threats that collectively threaten their survival. One of the most significant factors is habitat loss, driven primarily by coastal development, which has had a significant impact on sea turtle populations. Coastal areas serve as important nesting and feeding areas for these marine reptiles, but they are increasingly being altered to accommodate human activities such as tourism, urban sprawl, and industrialization. This relentless development not only reduces the availability of suitable nesting sites but also increases their vulnerability to disturbance and degradation, making it increasingly challenging for sea turtles to thrive.

The impacts of habitat loss are not limited to numbers; loss of nesting beaches and alteration of feeding habitat have been shown to contribute significantly to sea turtle population declines (Bjorndal et al., 1994). Furthermore, these challenges are exacerbated by the impacts of climate change, which introduces additional stressors such as rising sea levels, increasing temperatures, and more frequent and severe weather events. As climate change continues to alter coastal environments, remaining nesting sites may become increasingly unsuitable, further threatening the reproductive success of sea turtles. Additionally, changes in ocean temperature and acidification can impact the availability of food sources, further burdening already vulnerable populations. Therefore, addressing the threats posed by habitat loss and climate change is critical to the conservation of sea turtles and the ecosystems they inhabit.

Climate change represents another significant threat to sea turtles. The warming of global temperatures has far-reaching implications for sea turtle biology and ecology. One of the most direct effects of climate change is the alteration of nesting beach conditions. The temperature of the sand where sea turtles lay their eggs determines the sex of the hatchlings, with warmer temperatures generally producing more females. As global temperatures rise, there is a growing concern that this could lead to skewed sex ratios, with potentially severe consequences for future breeding populations. Additionally, climate change can impact the availability and health of marine ecosystems that sea turtles rely on for feeding and growth. Changes in sea surface temperatures, ocean currents, and prey availability can affect the distribution and abundance of food resources, further exacerbating the challenges faced by sea turtles (Hawkes et al., 2009).

Pollution, particularly in the form of marine debris, is a pervasive and escalating threat to sea turtles. Sea turtles are known to ingest plastic and other forms of debris, often mistaking them for food. This ingestion can lead to a range of adverse health effects, including gastrointestinal blockages, internal injuries, and even death. Additionally, sea turtles can become entangled in discarded fishing gear and other marine litter, which can impair their ability to forage, navigate, and reproduce. The proliferation of marine debris in the world's oceans is a growing concern that requires coordinated global efforts to address (Bjorndal et al., 1994).

Illegal poaching and the trade of sea turtles and their products pose a serious threat to their survival. In many regions, sea turtle eggs are collected for consumption or sale, and adult turtles are hunted for their shells, meat, and other body parts. These activities not only reduce the number of individuals in the population but also disrupt the reproductive processes of sea turtles. The illegal trade of sea turtles and their eggs is a significant problem that undermines conservation efforts and contributes to the ongoing decline of sea turtle populations (Fuentes et al., 2013).

Given the complex and diverse threats, a variety of conservation strategies have been developed to address the challenges facing marine turtles. One of the most effective approaches is the establishment of marine protected areas (MPAs) and the protection of critical nesting sites. MPAs are designated areas of the ocean where human activities are regulated to protect the natural environment and its inhabitants. By creating safe havens for sea turtles, MPAs help protect important nesting and feeding habitats from human disturbance.

Protecting nesting sites is also critical to ensuring the survival of sea turtle populations, and often involves legal action and community involvement. Local communities act as guardians of turtle habitat, so their understanding and awareness of the importance of conservation is vital. By involving communities in these protection efforts, not only sea turtles are protected, but also marine biodiversity as a whole, providing long-term benefits to ecosystems and human well-being (Broderick et al., 2007).

In addition to habitat protection, conservation efforts also include measures to address the specific threats faced by sea turtles. One such measure is the relocation of sea turtle eggs from natural nests to semi-natural or controlled environments. This practice aims to protect eggs from predators and illegal harvesting while allowing for better management and monitoring of the hatching process. Research has demonstrated that relocating eggs to semi-natural nests, which replicate natural conditions while providing added protection, can significantly improve hatching success rates (Karnan, 2008; Maulany et al., 2012). By enhancing the survival rates of hatchlings, this approach contributes to the overall recovery of sea turtle populations.

Monitoring and research play a vital role in the success of sea turtle conservation efforts. Tracking nesting activities, hatching success rates, and the health of hatchlings provides valuable data for evaluating the effectiveness of conservation strategies and making informed decisions. Understanding the impact of environmental variables, such as temperature and incubation conditions, on hatching success is essential for optimizing conservation practices and improving outcomes for sea turtles (Ario et al., 2016). This data also helps identify trends and patterns that can inform future conservation efforts and address emerging challenges.

The study conducted at Kampong Penyu on the Pinrang coast is a significant contribution to the field of sea turtle conservation. More than 3,000 sea turtles have been released into the sea after months of captive breeding in that area. This research focuses on assessing the hatching success rates of Olive Ridley sea turtles (*Lepidochelys olivacea*) and Green sea turtles (*Chelonia mydas*) at a semi-natural nesting site. By analyzing data from the 2021 and 2022 nesting periods, including the number of eggs laid, hatched, and failed to hatch, the study provides important insights into the effectiveness of semi-natural nesting practices. Monitoring environmental factors, such as temperature and incubation periods, further enhances the understanding of the conditions affecting hatching success.

The findings from this research are expected to offer practical recommendations for improving conservation strategies. By identifying factors that positively or negatively impact hatching success, the study can help refine conservation practices and enhance the overall effectiveness of sea turtle protection efforts. Additionally, the data will serve as a benchmark for future comparisons, aiding in the identification of trends and the development of targeted conservation measures.

Therefore, marine turtle conservation is a complex and ongoing challenge that requires a multifaceted approach. Addressing multiple threats such as habitat loss, climate change, pollution, and illegal trade is essential to ensure the survival of these ancient reptiles. Conservation strategies, including relocation of eggs to semi-natural nests and detailed monitoring of hatching success, play a critical role in protecting sea turtles and supporting their recovery.

The research conducted at Turtle Village provides valuable data for the field of marine turtle conservation, supporting ongoing efforts to protect these magnificent creatures and maintain healthy marine ecosystems. The study also highlights the importance of community involvement in conservation efforts, as local stakeholders can provide critical insights and support for protection measures. By encouraging a collaborative approach, the effectiveness of conservation initiatives can be significantly improved. Based on this, this study aims to determine the percentage of successful hatching of Olive Ridley Turtle (Lepidochelys olivacea) and Green Turtle (Chelonia mydas) eggs in semi-natural nests at Turtle Village, so that it can be used as a source of scientific data and comparative data on the success of egg hatching in the following year to minimize the risk of hatching. The aspects observed were the number of eggs during the 2021 and 2022 laying periods, the

number of eggs that hatched, the number of eggs that failed to hatch, and supporting data such as nest temperature and incubation period.

2. Methods

The natural hatching process in the nest is the best condition for hatching sea turtle eggs. However, due to the difficulty of supervision, the threat of predators, and the influence of seawater, it is necessary to move sea turtle eggs to semi-natural nests to maximize the potential number of eggs to hatch. Conservation efforts and the growth of the turtle population need to be carried out through protection activities in the form of monitoring and management of semi-natural hatching nests. Semi-natural sea turtle hatching is used to hatch sea turtle eggs to maintain the sustainability of the population. This method is carried out by moving sea turtle eggs found in natural nests to semi-natural nests that have been provided, with the same treatment and conditions (nest depth and egg position) when the eggs are found in their natural habitat. When transferred to a semi-natural nest, the position of the excavation depth and the layout and order of the sea turtle eggs must follow the position when found in their habitat. This is done to maintain the natural nature of the sea turtle nest.

This study was conducted during the Olive Ridley sea turtle (*Lepidochelys olivacea*) and Green sea turtle (*Chelonia mydas*) nesting period in 2021 and 2022 in the semi-natural nests owned by Kampong Penyu on the coast of Pinrang. Kampong Penyu, a turtle conservation initiative, is situated along the coastal region of Pinrang, known for its efforts in protecting endangered turtle species. The center provides a safe environment for turtles to nest and helps to ensure the survival of these species through various conservation activities, including the establishment of semi-natural nesting sites.

The aspects observed were the total number of eggs, the number of hatched eggs, and the number of unhatched eggs. The samples used in this study consisted of a total of 1889 Olive Ridley sea turtle and Green sea turtle eggs. These sea turtle eggs were collected from natural nests along the coast of Pinrang. The methodology employed an experimental approach with direct field observations, as outlined by Kushartono et al. (2016).

The research procedures began with an observation of the sea turtle broodstock to determine the broodstock species, monitoring the laying process of the female sea turtles, followed by the excavation of natural nests after the females had returned to the sea. After that, the number of eggs in each nest was counted and then relocated to semi-natural nests. The semi-natural nest is made to hatch sea turtle eggs so that they can have a high hatching success rate and are safe from natural disturbances. The location of the semi-natural nests to be made or used has some criteria that need to be met, such as the location must have a substrate that is appropriate for the type of sea turtle that will lay eggs (fine sand and not rocky), safe and far from predator attacks, not affected by tides (15-18 m from the highest tide), and easy to monitor by enumerators (Sinaga et al., 2024). The semi-natural nests in this research were constructed with dimensions of 50 cm in depth and 50 cm in width. The sea turtle eggs that had been collected were incubated in the semi-natural nests, and regular monitoring was conducted to track their development.

Environmental conditions, such as temperature and humidity, were monitored daily to ensure that they remained within the optimal range for egg development, mirroring natural conditions as closely as possible. The temperature and humidity of the nesting sites were critical factors monitored, as these can significantly impact the embryonic development and hatching success of sea turtles. Data loggers and thermometers were used to measure these parameters, ensuring accurate and consistent data collection. Once the turtle eggs hatched, the hatching success rate (HSR) of sea turtle eggs was calculated using the following Equation 1 (Listiani et al., 2015).

$$\text{HSR } (\%) = \frac{\Sigma\ hatched\ eggs}{\Sigma\ eggs\ total} \times 100 \qquad \text{(Eq. 1)}$$

The data obtained were analyzed descriptively, comparing the results with related references to assess the findings. This analysis included a comparison of hatching success rates between semi-natural and natural nests, as well as examining the impact of environmental conditions on hatching success rates. In addition, a detailed examination of the semi-natural nests was carried out. The design and construction of these nests aimed to mimic natural conditions as closely as possible. The nests were built using sand sourced from local beaches to ensure that the substrate composition was similar to that of natural nesting sites. The depth and width of the nests were standardized to provide a consistent environment for all eggs.

Regular nest inspections were carried out to check for signs of disturbance or predation. Measures were implemented to protect the nests from predators and other environmental threats. For example, nets and barriers were placed around the nesting area to prevent access by potential predators. The nests were also monitored for fungal growth or other factors that could negatively impact the eggs.

During the incubation period, the eggs were not disturbed to avoid affecting the hatching process. This non-invasive approach is essential to maintain the natural development of the embryos. The monitoring process included recording the incubation period periodically, from the time the eggs were laid until they hatched. These data provide insight into the duration of the incubation period and any variations that may occur due to environmental factors.

The study also included a survey of local environmental conditions, such as climate patterns and potential threats to turtle nests, including coastal development and human activities. The survey involved working with local communities and authorities to collect comprehensive data on environmental factors that may impact turtle nesting and hatching success. The study's methodological approach emphasized the importance of creating a controlled yet natural environment for turtle egg incubation. By closely monitoring environmental conditions and implementing protective measures, the study aimed to maximize hatching success rates while providing a deeper understanding of the factors that influence sea turtle reproduction. The findings are intended to contribute to broader conservation efforts for this endangered species, offering valuable insights for developing effective conservation strategies. Through this rigorous approach, the study seeks to lay the foundation for future research and conservation initiatives, leading to a more sustainable environment for sea turtles.

3. Results and Discussion

Based on the results of monitoring the hatching of sea turtle eggs in Kampong Penyu, the total number of sea turtle eggs successfully collected in semi-natural nests was 1889 eggs during the laying period in May-June 2021 and March-April 2022 (Table 1). The number of eggs that successfully hatched into hatchlings, both alive and dead, was 1563, where the highest number of eggs and hatching occurred in April with a total of 726 eggs and 627 eggs that successfully hatched. 326 eggs failed to hatch during the study period. Failure of sea turtle eggs to hatch is usually caused by predators and microbial contamination of the nest, nest substrate, and temperature and humidity (Nugroho et al., 2018; Umama et al., 2020). Kushartono et al. (2016) added that the failure of sea turtle eggs to hatch can also be caused by nest depth, rainfall, treatment when moving the nest, and the condition of eggs that were defective from the start (infertile). Eggs that fail to hatch are usually shrunken, irregular in shape, and yellowish in color (Sinaga et al., 2024).

The hatching success is a percentage form of the comparison of the number of surviving hatchlings to the number of eggs in the nests (Sinaga et al., 2016). Based on Figure 1, the relocation of sea turtle eggs to semi-natural nests in Kampong Penyu resulted in the average of 80.23% of eggs successfully hatched during the nesting period of May-June 2021 and March-April 2022 (Table 1). The highest hatching percentage was in April 2022, which was

86.36% with a total of 627 out of 722 eggs, followed by May 2021 at 83.52% with 603 out of 726 eggs, June 2021 at 82.73% with 182 out of 220 eggs, and the lowest was on March 2022 at 68.33% with 151 out of 221 eggs.

Table 1. Data on sea turtle hatching in Kampong Penyu's semi-natural nests in 2021-2022

Egg laying time	Egg hatching time	Eggs total	Hatched eggs	Failed to hatch eggs
May 2021	Juni-August 2021	722	603	119
June 2021	Juli 2021	220	182	38
March 2022	Mei 2022	221	151	70
April 2022	Juni 2022	726	627	99
Total		1889	1563	326

(Kampong Penyu Salopi, 2021-2022)

The hatching success of sea turtle eggs is greatly influenced by environmental factors. One of these factors is temperature. Sea turtles are cold-blooded animals (poikilothermic) whose body temperature follows the temperature of the surrounding environment. According to Nuitja (1982), the ideal temperature for the growth of baby turtles is between 25-32°C. Meanwhile, Laloe et al. (2017) obtained the lowest and highest temperatures, respectively 28.5°C and 32°C, which indicate a good level of hatching success of sea turtle eggs, while the results of research by Salleh et al. (2019) showed that sea turtle eggs hatched well at a temperature of 27.68-29.28°C.

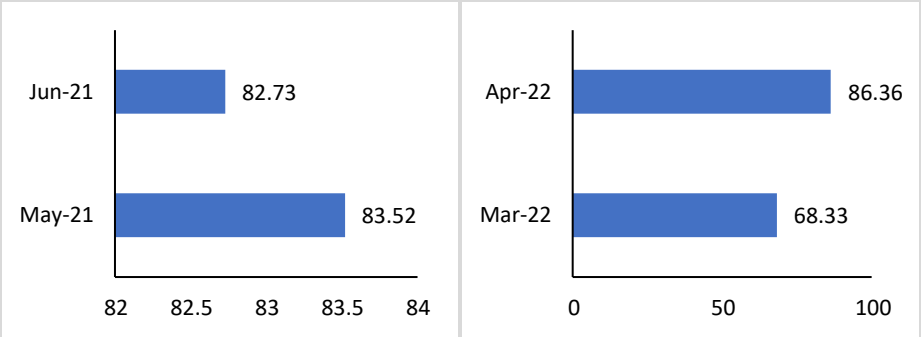

Fig. 1. Hatching success rate of sea turtle eggs in the semi-natural nests of Kampong Penyu in 2021-2022
(Kampong Penyu Salopi, 2021-2022)

Temperature plays an important role in the fitness of hatchlings, both the speed of egg hatching and the ability (based on morphology and swimming speed) to face predators (Booth et al., 2004). Sea turtle eggs at extreme temperatures or above the optimal limit could result in rapid development and the possibility of abnormal development is higher (Miller et al., 2003). This was added by Alfath (2017) who stated that temperatures that are too low can slow down the development and threaten the life of the embryo, and temperatures <24°C can result in a long incubation period, while temperatures >33°C can cause the hatchlings to die. Moreover, according to the research of Yao et al. (2022), hatching success was lowest at 34°C and none of hatchlings hatched with normal condition and survived over one week. This is supported by Bladow & Milton (2019) who stated that sea turtle embryonic mortality increased as the percentage of time above 34°C increased. Based on the observation results, the average temperature during the hatching period in the Kampong Penyu area ranges from 27.5-28.9°C (Figure 2). This follows the reference range, so the temperature during the sea turtle egg-hatching period is classified as normal for embryo formation and turtle egg-hatching.

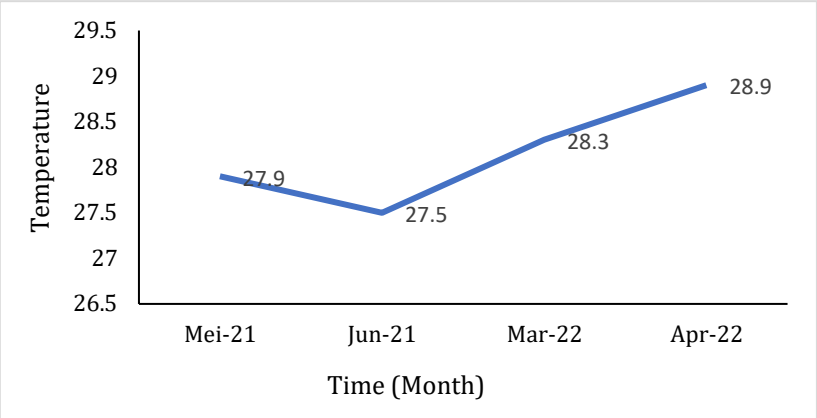

Fig 2. The temperatures of the turtle hatching area in the egg-laying period of 2021 and 2022 (BPS, 2021-2022; BMKG, 2021-2022)

Incubation temperature during one-third of embryonic development is known to determine the sex of the hatchlings, where high temperatures produce female turtles, while low temperatures produce male turtles (Davenport, 1997). Similar to the opinion of Manurung et al. (2015) who stated that the sex of the sea turtle is determined by the incubation temperature. This is supported by Sheavtyan et al. (2014) who stated that if the incubation temperature is > 30ºC, the hatchlings will tend to be female, while incubation temperatures <28°C tend to produce male hatchlings. Yusuf (2000) also stated that temperatures <29°C during the incubation period will result in most of the eggs that hatch being male hatchlings, and vice versa will produce female hatchlings.

Another factor that can affect the success rate of sea turtle egg hatching is the incubation period. The incubation period is the time interval between oviposition and the emergence of some of the hatchlings on the surface of the nest (Alfath, 2017). According to Yusuf (2000), the incubation period can determine the sex ratio of hatchlings, where if the incubation period is more than 50 days, then most of the eggs that hatch are male hatchlings, conversely, an incubation period of less than 50 days produces mostly female hatchlings. According to Samosir et al. (2018), the incubation period can affect the hatching success of sea turtle eggs. Based on Table 2, the range of incubation period of sea turtle eggs per year lasts for 44-65 days in 2021 and 43-52 days in 2022. This is supported by Pratama & Ramadhon (2020), who claimed that the incubation period of sea turtle eggs is 40-66 days. Another opinion is by Sukamto et al. (2016) who stated that the hatching of sea turtle eggs takes 45-60 days. Nooren and Claridge (2002) stated that warmer weather will result in a shorter incubation period, while the average time to hatch will be longer during the rainy season. Manurung et al. (2023) added that the higher the air temperature, the shorter the egg-hatching time. This follows the results obtained, where a higher average temperature resulted in a shorter incubation period. However, according to Steenacker et al. (2023), shorter incubation duration and warmer temperatures were the main factorss affecting scute pattern abnormalities and hatching success, therefore, sea turtle eggs that hatched after a short incubation period have a probability in having a lower hatching success. This is supported by Tello-Sahagun et al. (2023) who stated that sea turtle clutches incubated during dry-low season and exposed to lower temperatures, yielded higher hatching success, and mainly produced male offspring and larger, heavier hatchlings with better locomotor abilities.

Table 2. Data on the incubation period of sea turtle eggs in 2021-2022

Time (year)	Incubation Period (days)
2021	44-65
2022	43-52

(Kampong Penyu Salopi, 2021-2022)

However, some hatchlings may successfully emerge but then die in the nest, a phenomenon believed to be related to the density of hatchlings within the nest. When hatchlings successfully emerge, they often rely on each other to escape the nest. Consequently, the more hatchlings that emerge, the easier it is for each individual to reach the surface. Conversely, a lower number of hatchlings may result in increased difficulty in reaching the surface, as hatchlings that have already hatched may struggle to find their way out. The journey to the surface requires a large amount of energy, and in cases where hatchlings do not have sufficient energy reserves, they may succumb to exhaustion before reaching the surface (Sheavtyan et al., 2014). Furthermore, Miller et al. (2003) noted that the total number of hatchlings that successfully emerged from their eggs was often slightly lower than those that hatched, primarily due to the presence of deformed hatchlings. These deformed individuals may have been unable to climb out of the nest, ultimately leading to their death before they could begin their journey to the sea.

Although most eggs successfully hatched, a significant number—specifically 326—failed to hatch. The factors that cause turtle eggs to fail to hatch are largely related to the conditions surrounding the eggs containing the undeveloped embryos. This undeveloped state can be caused by a variety of factors, including predation and the presence of microorganisms such as bacteria and fungi, which can inhibit proper development. The condition of the eggs can also deteriorate if they are moved from their original location, especially if the move disrupts the special conditions necessary for development. According to Bustard (1972), turtle embryos begin to attach to the inner shell of the egg during their early development, and any disturbance during this critical period can significantly affect their chances of survival.

Kushartono et al. (2016) further explained that undeveloped states can arise from movements such as rotation and shaking during the early stages of development. These movements can disrupt the normal cleavage process of the embryo, leading to delayed formation and, ultimately, failure to hatch. Therefore, improper handling or removal of eggs can be detrimental, making the eggs highly susceptible to death if not managed properly. In addition to human-related factors, there are also a variety of natural influences that can result in eggs not hatching. These include maternal issues, such as infertility or failure to undergo proper embryonic development during the post-egg diapause stage.

In addition, external factors such as environmental barriers—such as roots or other objects—can prevent eggs from hatching. External biological factors, including predation and microbial invasion, also pose significant risks to eggs and hatchlings (Limpus, 2008). The interplay of these factors highlights the complexity of hatchling survival and the challenges faced by turtle populations. Understanding these dynamics is essential to effective conservation strategies. By addressing the causes of hatching mortality and egg failure, conservationists can implement measures that increase the chances of successful hatching and emergence. This can include protecting habitat, minimizing human disturbance during critical developmental periods, and ensuring that nesting areas remain free from predators and other environmental hazards. Ultimately, maintaining healthy turtle populations requires a thorough understanding of the factors that influence hatching success and survival.

4. Conclusions

The success rate of turtle egg hatching in Pinrang Regency, South Sulawesi, especially in Kampong Penyu, is relatively high, with an average percentage of eggs that successfully hatch reaching 80.23%. The highest value was achieved in the April 2022 hatching period, which was 86.36%. The success of turtle egg hatching is influenced by several factors, including temperature (27.5-28.9°C) and incubation period (47-48 days). The optimal temperature during the incubation process is very important because it can affect the development of the embryo in the egg. If the temperature is too high or too low, it can interfere with the development process and reduce the hatching success rate.

However, the failure of turtle eggs to hatch is also caused by several other factors, including the presence of predators that threaten eggs and baby turtles, as well as the development of harmful microorganisms such as bacteria and fungi. These microorganisms can infect eggs, interfere with embryo development, and cause death before hatching. In addition, changing the position of turtle eggs from natural nests to semi-natural nests can disrupt the conditions needed for optimal development. Improper handling and transfer of eggs can cause stress to the embryos and potentially reduce hatching success rates.

Based on the results of this study, it is recommended that further research analyze the effects of several other environmental factors and nest conditions on hatching success rates of sea turtle eggs. Further research could include evaluating the impact of factors such as humidity, interactions with other species, and nest substrate quality. By better understanding the factors that influence hatching success, more effective conservation measures can be implemented to protect and enhance sea turtle populations in the area. This will contribute to overall sea turtle conservation efforts, helping to ensure the future survival of this endangered species.

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