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Spatial and temporal nesting pattern of Sea Turtles in Alas Purwo National Park, and its implications for conservation management practices

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Abstract: As a sea turtle conservation area, Alas Purwo National Park (APNP) shows different patterns in the four species of turtles that have nesting records, such as an increase in Olive Ridley Turtle (*Lepidochelys olivacea*), stability in Green Turtle (*Chelonia mydas*), and a decline in Hawksbill Turtle (*Eretmochelys imbricata*) and Leatherback Turtle (*Dermochelys coriacea*). During the survey, which lasted from January to July 2023, we discovered that each type of sea turtle preferred nesting sites at specific hypothetical stations, except for the *L. olivacea*, which nested at all hypothetical stations along Pancur-Cungur Coast. We also discovered that it is highly encouraged to continue relocations that have already been carried out, given the variety of predators encountered during the survey period. This discovery supports the need for in situ conservation at preferred sites for sea turtle species.

Key words: Conservation practice, sea turtle, nesting, Alas Purwo National Park

1. Introduction

Sea turtles play a crucial role in upholding the equilibrium and well-being of diverse aquatic ecosystems, particularly those found in the ocean. These species possess significant value due to their frequent utilization as sentinel species, keystone species, and even flagship species, thereby instigating diverse conservation initiatives for marine ecosystems worldwide (Aguirre and Lutz, 2004; Frazier, 2005; Sterling et al., 2013; Abreu-Grobois, 2016). According to IUCN (2023)[1] classification, four species of sea turtles (*L. olivacea, C. mydas, C. caretta,* and *D. coriacea)* are categorized as Vulnerable (VU), two species (*L. kempii* and *E. imbricata*) are classified as Critically Endangered (CR), while *N. depressus* is categorized as Data Deficient (DD). The decline in sea turtle populations can be attributed to various factors, including damage to their food habitat, disturbance caused by predators, climate change and global warming, and the adverse effects of disease and mortality resulting from interactions with fishing activities. Conservation is regarded as a crucial endeavor aimed at mitigating the decline in sea turtle populations. Sea turtle conservation initiatives encompass activities such as the rearing and releasing of juvenile sea turtles. According to Winata et al. (2010), these efforts have the potential to significantly enhance the efficacy of egg incubation, resulting in a success rate ranging from 74% to 98%. The education program incorporating hatchling release activities is anticipated to contribute to the ecological sustainability of the sea turtle population within the community. In contrast, the implementation of captive breeding techniques and the process of rearing hatchlings prior to their release have the potential to impact hatchling orientation and the development of survival instincts (Whitten et al., 1996). Additionally, it should be noted by Bjorndal (1997) that the sea current patterns in Indonesia exhibit seasonal variations, which can potentially impact the spatial distribution pattern of hatchlings after their rearing process.

Conservation management practices have been implemented by stakeholders in Alas Purwo National Park (APNP), located in Banyuwangi, East Java, Indonesia. Given the significance of this national park region as

[1]IUCN (2023). The IUCN Red list of Threatened Species [online]. Website https://www.iucnredlist.org [accessed 19 November 2023]

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a nesting destination for four out of the seven existing turtle species globally (e.g., *Lepidochelys olivacea*, *Chelonia mydas*, *Eretmochelys imbricata*, *Dermochelys coriacea*), it is crucial to acknowledge its importance. Implementation of sea turtle conservation management practices in APNP commenced in 1983, during the period when the region was designated as the Blambangan Wildlife Reserve. The driving force behind sea turtle management during that period stemmed from the lack of any discernible response to the substantial influx of sea turtles arriving at APNP. In accordance with the advancements that have transpired over a span of four decades in the realm of conservation practices, the management implemented at PPSA Ngagelan presently encompasses several primary conservation practices (e.g., monitoring patrols, tagging, relocation, and hatchling rearing).

APNP has been involved in implementing science-based conservation practices since 1994 (Anggraeni et al., 2017). Several studies have even been published, including investigations into the potential and management of sea turtles (Suharso and Kusrini, 1997), the effect of temperature in sea turtle nests within seminatural hatcheries (Maulany et al., 2012), surveys of parasites and microbes (A'yunin, 2017), as well as examinations of trends in sea turtle nesting populations (Sulaiman and Wiadnyana, 2009; Maulany et al., 2017; Kurniawan and Gitayana, 2020). Nevertheless, there has been a lack of discourse surrounding the potential implications of spatial and temporal nesting patterns knowledge on conservation management strategies in APNP, which this article explains in context to enhance.

2. Materials and methods

2.1 Study area

Our study was conducted between January and July of 2023 in Alas Purwo National Park (APNP), situated at the southeastern edge of Java Island, Indonesia. On the western side of APNP is an 18.5-km-long coast Pancur-Cungur that serves as a rookery for four species of sea turtles: Green turtle (*Chelonia mydas*), Hawksbill turtle (*Eretmochelys imbricata*), Leatherback turtle (*Dermochelys coriacea*), and Olive Ridley turtle (*Lepidochelys olivacea*). Every 100 m of coast is marked with a sector benchmark point, resulting in less difficulty for officers to record nest locations. Along this coast, there are a total of 186 sector benchmark points (HM 000-HM 185), which stretch in a direction from east to west.

2.2. Field survey and data collection

Survey of the spatial nesting pattern of sea turtles were made by daily monitoring that were carried out in line with the activities of officers at the Ngagelan Semi-Natural Hatching Unit. Activities involve dirt biking on two routes simultaneously. Low tides were used to determine survey times to prevent tidal interference. Identification of nests or landings of individual female sea turtles is carried out by identifying traces that are identified based on the knowledge of the experienced officers and validated using identification guides (Sulaiman and Wiadnyana, 2009; Witherington and Witherington, 2015; Anggraeni et al., 2017).

The data collected during the survey from each sector benchmark point was recorded and then classified into six hypothetical stations using the equal interval classification method (Figure 1). Each station consisted of 31 sector benchmark points (Station 1: HM 000-HM 030; Station 2: HM 031-HM 061; Station 3: HM 062- HM 092; Station 4: HM 093-HM 123; Station 5: HM 124-HM 154; Station 6: HM 155-185). In addition, we also present time series data spanning from 1983 to 2023, which has been authorized and kindly provided by APNP for research purposes.

2.3. Data analysis and visualization

We categorize all data collected for species of sea turtles that nest, whether obtained during the survey period or provided by APNP. Linear regression analysis was conducted on the nesting time series data lasting the past four decades, as provided by APNP. This analysis is utilized to illustrate the trends observed for each species of sea turtle. Furthermore, we conducted an equal interval classification analysis for each observed sea turtle nesting frequency during the survey period, allowing for spatial and temporal comparisons.

3. Results and discussion

3.1. Sea turtle nesting trend

The temporal pattern of nesting behavior exhibited by the four sea turtle species in APNP from 1983 to 2023 demonstrates discernible fluctuations for each respective species (Figure 2). The population of *L. olivacea* exhibited a notable increase, while the population of *C. mydas* remained relatively stable. Conversely, there was a decline observed in the populations of *E. imbricata* and *D. coriacea*. *L. olivacea* exhibited a significantly higher nesting rate in comparison to other species, as evidenced by the recording of over 1500 nests by these sea turtles in the year 2023. In the identical year, a total of eight *C. mydas* nests were documented, whereas the *E. imbricata* and *D. coriacea* were observed nesting only once each. The presented figure illustrates the variation in nesting patterns observed among the four sea turtle species within Pancur-Cungur coast, APNP.

The number of *L. olivacea* nesting which continues to increase has become an interesting discussion in several previous studies, whether this increase occurred as an outcome of conservation efforts carried out by APNP or whether other reasons were found to be a factor in the increasing number of *L. olivacea* nesting (Sulaiman and

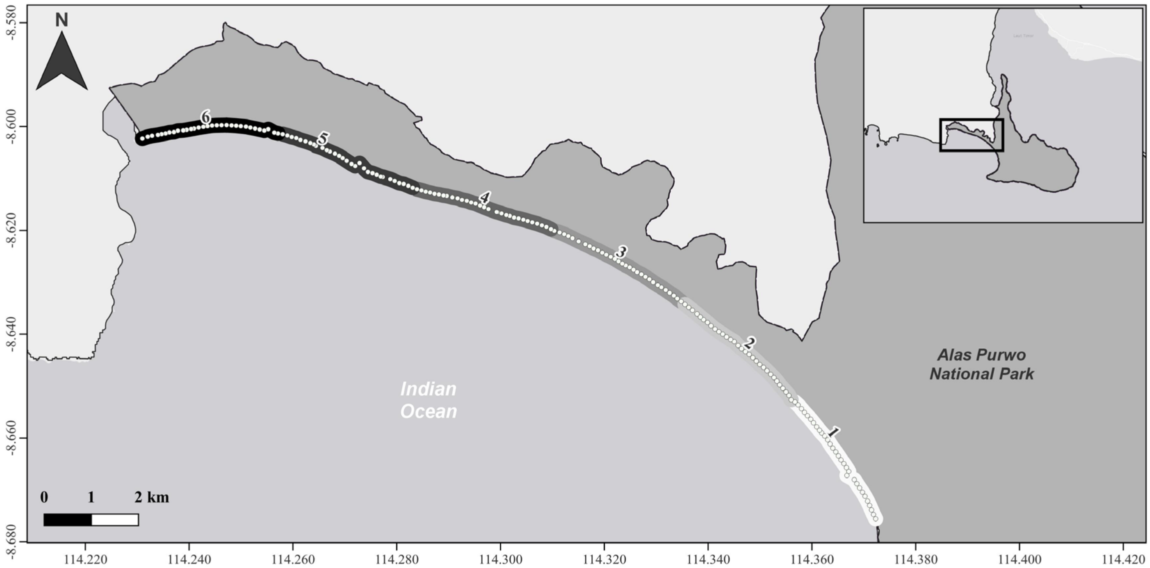

Figure 1. Study location in Alas Purwo National Park's Pancur-Cungur Coast with six hypothetical stations (dot: sector benchmark point).

Wiadnyana, 2009; Kurniawan and Gitayana, 2020). If this increase is due to the success of conservation efforts, then "natal beach homing" conceived by Carr (1967) may be a hypothesis that explains this success.

Baglione et al. (2006) and Lohmann et al. (2013) found that natal philopatry potentially enhances the likelihood of reproductive success in contrast to the alternative strategy of seeking out a new nesting site. Nevertheless, if the hatching locations of sea turtles have undergone alterations in environmental conditions, natal philopatry may not be advantageous for sea turtle populations. Consequently, it is plausible to consider that the APNP region holds significance in terms of sea turtle migration (Carr and Carr, 1972; Carreras et al., 2018). The existing collection of empirical evidence pertaining to natal philopatry remains constrained, necessitating further genetic analysis to establish the significance of this hypothesis in the context of animal population and natural selection. Furthermore, the observed increase in nesting behavior exclusively observed in *L. olivacea* presents a incongruity to this hypothesis, as natal philopatry is not limited to a single species. However, caution must be carried out when interpreting the causal relationship between conservation efforts and the observed rise in nesting numbers of *L. olivacea*, as it has been determined that various other factors contribute to the increase in nesting numbers in APNP (Dermawan et al., 2009; Kurniawan and Gitayana, 2020).

Kurniawan and Gitayana (2020) hypothesize several factors other than natal philopatry which may be the cause of the increase in nesting of *L. olivacea* in APNP, including: (1) age of maturity, (2) ocean currents, (3) reproductive patterns, (4) genetic variations, and (5) hunting. *L. olivacea* exhibits a comparatively accelerated maturation process (around 13 years with the possibility to achieve earlier between 10 and 12 years) in comparison to other sea turtle species (Ewing, 1943; Zug, 2006), thereby presumably contributing to its relatively rapid growth. Furthermore, ocean currents facilitate the opportunity for individuals to engage in reproductive activities with members of different populations (Moran and Garcia-Vazquez, 1998; Pearse et al., 2002; Hamann et al., 2003). This species exhibits a capacity for engaging in multiple paternity (Fitz, 1998; Pearse and Avise, 2001; Lee and Hays, 2004). The observed behavior is hypothesized to be a consequence of their pronounced genetic diversity, which confers a heightened capacity for adapting to fluctuations in the environment. The last reason for suspicion is the low amount of poaching they experienced.

An alternative hypothesis for the observed increase could be explained by the potential adverse effects of extensive tourism infrastructure development initiatives along the southern coast of Java, which may disrupt turtle habitats and compromise the viability of egg hatcheries (Septiana et al., 2019; Pattiwael, 2022). The presence of artificial lighting resulting from human activities can have a negative effect on the innate navigation abilities of recently hatched sea turtle offspring, as observed by Truscott et al. (2017). Upon reflection of these hypotheses, it is reasonable to expect a corresponding rise in the population of various sea turtle species in APNP. However, empirical evidence contradicts this presumption.

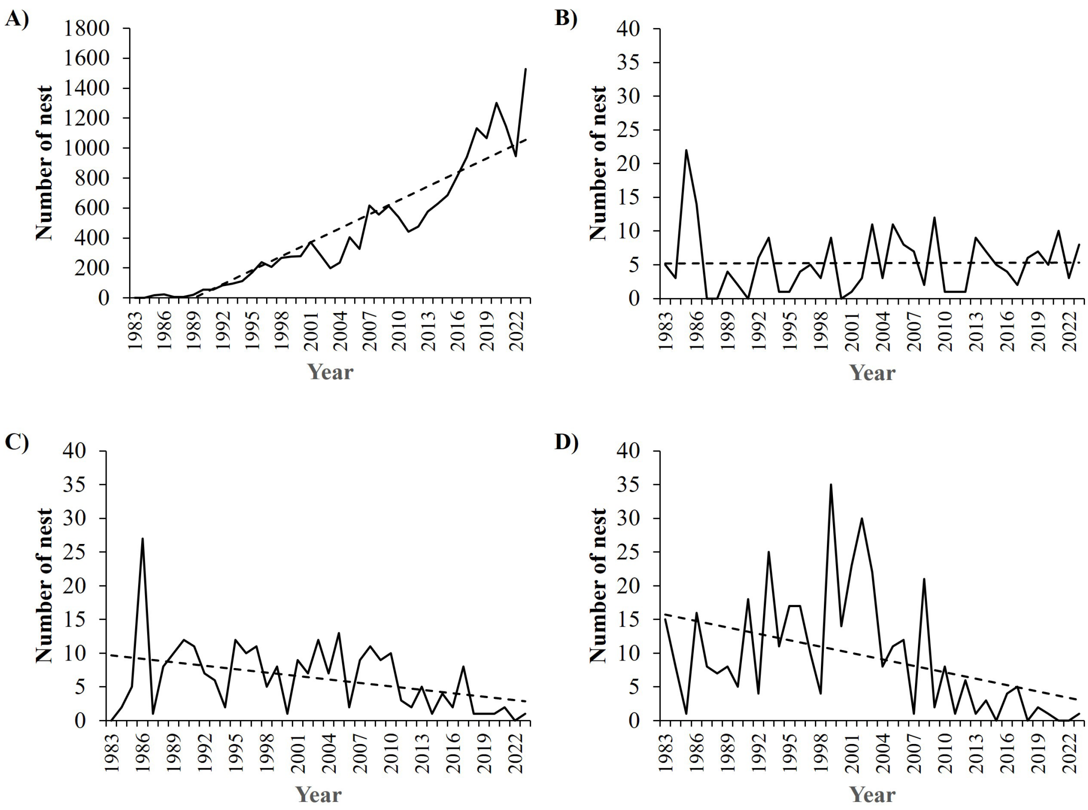

Figure 2. Trend of sea turtle nesting in the past 40 years at APNP: (A) *L.olivacea*, (B) *C. mydas,* (C) *E. imbricata*, and (D) *D. coriacea*.

Although some tribes have been observed hunting *C. mydas* for meat in traditional rituals (Whitten et al., 1996), we argue that the stable nesting population of *C. mydas* is maintained due to recent prohibitions imposed by APNP stakeholders and local fisheries communities. These communities believe that hunting sea turtles brings negative consequences. Moreover, the reproductive conditions that result in a relatively similar age of maturation possibly involve preserving the stability of the *C. mydas* population (Limpus and Chaloupka, 1997). For instance, Pacific Ocean *C. mydas* populations exhibit a range of maturity ages, with the earliest observed at 25 years and the slowest observed at 50 years (Limpus and Chaloupka, 1997; Zug et al., 2002; Balazs and Chaloupka, 2004; Chaloupka, 2004). *C. mydas* exhibits a considerably longer duration for reaching sexual maturity, necessitating a minimum of twice the time compared to *L. olivacea*. Despite the fact that male *C, mydas* exhibits a lengthier reproductive period in comparison to their female, they possess the ability to migrate concurrently between mating habitats and foraging habitats (Ulrich and Parkes, 1978; Comuzzie and Owens, 1990; Limpus, 1993; Owens, 1997). This enables the occurrence of opportunistic mating, thereby ensuring the continuity of the population generation cycle.

The populations of *E. imbricata* and *D. coriacea* in Alas Purwo National Park have undergone declines in recent years. *E. imbricata* and *D. coriacea* necessitate nesting habitats characterized by abundant vegetation cover, encompassing sea turtles, mangroves, and other plant species. This vegetation serves the dual purpose of safeguarding hatchlings upon emergence and regulating the temperature of the eggs (Kamel and Mrosovsky, 2004; Hernández-Cortés et al., 2018). The practice of turtle hunting has been carried out with the purpose of acquiring eggs and meat for human consumption, as it is widely believed to be a valuable source of protein and is thought to have the potential to enhance overall vitality (Retawimbi, 2011; Pertiwi et al., 2020). Furthermore, the demand for *E. imbricata* skin and shells is driven by their value in the production of crafts and accessories, as highlighted by Mortimer and Donelly (2008)[2] and

[2*]Mortimer JA, Donelly M (IUCN SSC Marine Turtle Specialist Group) (2008). Eretmochelys imbricata. The IUCN Red List of Threatened Species [online]. Version 2014.2. Website https://dx.doi.org/10.2305/IUCN.UK.2008.RLTS.T8005A12881238.en [accessed 19 November 2023]

Wallace et al. (2013)[3]. This activity results in the significant depletion of a substantial quantity of eggs that would otherwise develop into progeny, thereby posing a threat to the reproductive cycle of the turtle. In the Indo-Pacific region, *E. imbricata* attain sexual maturity between the ages of 23 and 24, as recorded by Snover et al. (2012). In contrast, *D. coriacea* attain sexual maturity at a longer period, typically between 26 and 32 years, as reported by Wallace et al. (2013). The protracted period of reproductive maturation observed in turtles can potentially contribute to declines in population numbers. The reduction in the population of prereproductive individuals will lead to a decline in reproductive capacity and the number of individuals capable of producing offspring, consequently resulting in a decrease in the survival rate of juvenile turtles (Adnyana, 2016). The diminished survival rate of hatchlings in *E. imbricata*, which accounts for a mere 2% of the total number of eggs, can be attributed to the presence of natural predators in both terrestrial and marine environments (Sumarmin et al., 2012). In contrast, it is observed that leatherback turtles exhibit a diminished capacity for reproduction as a result of a substantial incidence of embryonic mortality and a comparatively limited quantity of successfully hatched eggs (Bell et al., 2003; Tomillo et al., 2012). The vulnerability of leatherback and hawksbill turtles to population pressures is increased by this phenomenon. Nevertheless, the determinants contributing to the population decrease can be complex and interconnected.

3.2. Spatial and temporal sea turtle nesting pattern

The spatial nesting patterns exhibited by the four species of sea turtles demonstrate variability across species (Figure 3). The phenomenon of *L. olivacea* exhibiting nesting behavior on Pancur-Cungur Coast has been documented. Nevertheless, it has been observed that these sea turtles reveal a preference for nesting in specific areas, particularly Stations 2, 3, and 5. *C. mydas* exhibit a strong preference for selecting station 1 as their primary nesting site, although a single nest was found at station 6. In contrast to the other two species of sea turtles, namely *E. imbricata* and *D. coriacea*, it is noteworthy that these species exclusively made a single nesting at stations 1 and 3, respectively. According to previous study regarding habitat condition in the same study site (Sulaiman and

3 *Wallace BP, Tiwari M, Girondot M (2013). Dermochelys coriacea. The IUCN Red List of Threatened Species 2013 [online]. Website https://dx.doi.org/10.2305/IUCN.UK.2013-2.RLTS.T6494A43526147.en [accessed 19 November 2023].

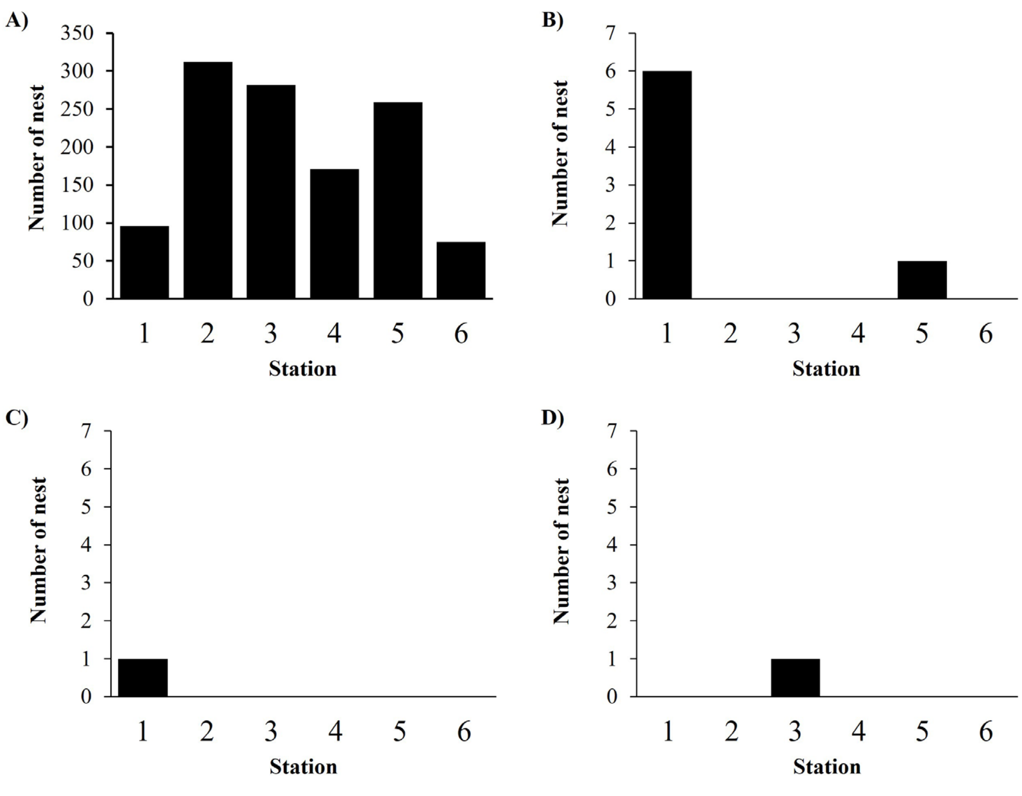

Figure 3. Number of four sea turtles nesting in each hypothetical station during survey period: (A) *L.olivacea*, (B) *C. mydas,* (C) *E. imbricata*, and (D) *D. coriacea*.

Wiadnyana, 2013), nesting preferences of *C. mydas* and *E. imbricata* might be influenced by the high sand substrate and low water content percentage in station 1, while *D. coriacea* preference is possibly due to station 3 has the widest coastal along Pancur-Cungur Coast. Additionally, we observed that station 1, preferred by *C. mydas* and *E. imbricata*, has a lighter sand color compared to other stations, possibly due to an accumulation of residual shells. However, given how rarely *E. imbricata* and *D. coriacea* nest, it can be difficult to determine possible patterns of spatial distribution.

One of the sea turtle species found in the APNP, *L. olivacea* exhibit a distinct reproductive strategy. According to Bernardo and Plotkin (2007), this species exhibits three distinct reproductive modes. The first mode, known as "arribada" involves the simultaneous and mass nesting behavior of hundreds or even thousands of individuals in various locations worldwide, spanning multiple days. The second mode, referred to as "dispersed nesting" is characterized by isolated nesting behavior. Lastly, there are combination of reproductive modes, where both arribada and dispersed nesting occur within a specific region.

The APNP region is one such location where variations in these reproductive modes have been observed. The occurrence of nesting season throughout the year is a defining characteristic of this event. According to our data, it is indicated that the onset of the arribada phenomenon in *L. olivacea* occurs between the months of April and June. When the arribada phenomenon reaches its maximum intensity, typically occurring in the month of June, the total number of nests recorded can reach as high as 567 nests. During periods outside of the arribada season, specifically in the months of January-March and July, it appears that they take on a dispersal reproduction mode. As depicted in Figure 4, *C. mydas* exhibits an interesting pattern. Despite the significantly lower quantity of nests, the temporal progression of nesting numbers during the months of April to June exhibits a similar pattern with arribada phenomenon in *L. olivacea*. On another occasion, the determination of the nesting season for *E. imbricata* or *D. coriacea* remains challenging based on the findings of this study. It is highly advisable to prolong the duration of the survey until the completion of the entire year to acquire an in-depth understanding that would enable the recognition of the nesting season for *E. imbricata* and *D. coriacea* within the APNP.

3.3 Implication for conservation management practices

Semi-Natural Hatching Facility development at APNP represents a significant improvement in the context of sea turtle conservation management practices. Nevertheless,

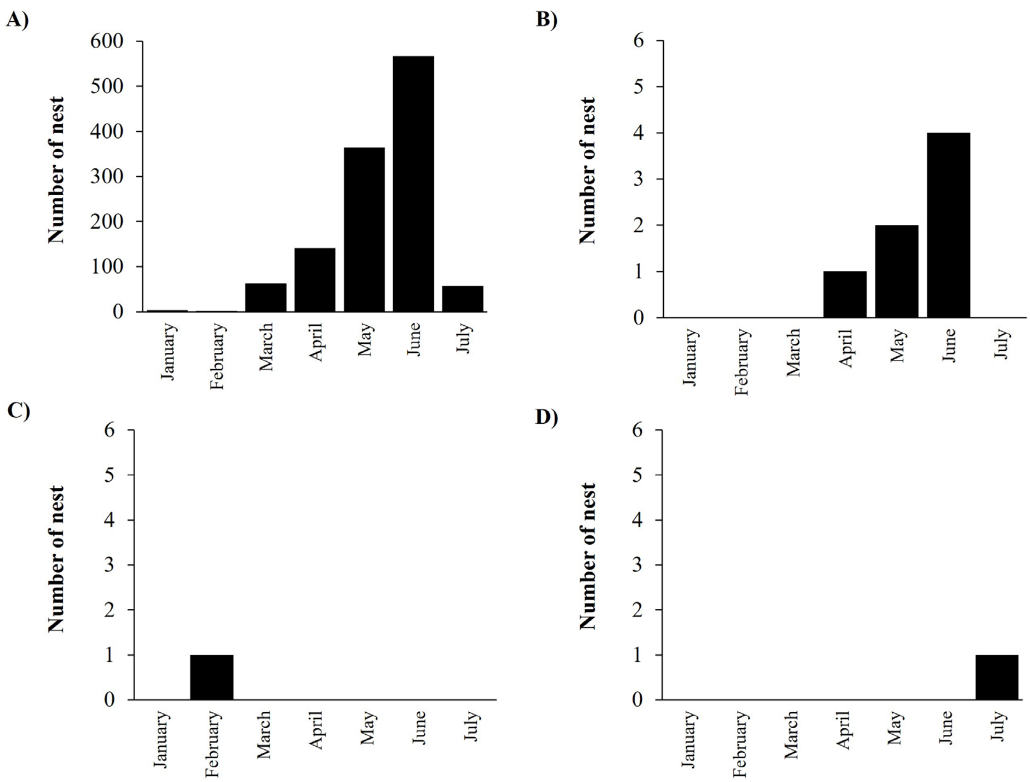

Figure 4. Number of four sea turtles nesting in each month during survey period: (A) *L.olivacea*, (B) *C. mydas,* (C) *E. imbricata*, and (D) *D. coriacea*.

it is important to highlight that the performance of this practice is not devoid of its consequences. According to Kurniawan and Gitayana (2020), the reported increase in the population of *L. olivacea* can be considered as a positive outcome of the conservation initiatives implemented in APNP. However, an uncertainty arises when considering that this increase is exclusive to *L. olivacea* and does not occur to other sea turtle species. The nesting rate of the other sea turtle species is obviously lower in comparison to that of the *L. olivacea*. The current scenario reinforces the perspective stated by Frazer (1992) that several efforts to conserve sea turtles have been implemented globally, including APNP, as a halfway method.

Although sea turtle conservation practice in APNP can be considered as a halfway method, relocation of eggs to seminatural hatcheries is an important practice to implement in this region, given the existence of predators that can threaten their survival. Predators exhibit diverse and distinct prey preferences and behavioral patterns. During our survey, we noticed evidence of the presence of Water Monitor Lizard (*Varanus salvator*) as well as the remnants of sea turtle eggshells that had been consumed by this species. In addition to this, it has been discovered that sea turtle eggs are preyed upon by wild boars (*Sus scrofa*). Aside from predators of eggs, there are other animals that feed on hatchlings. These include the Civet (*Paradoxurus hermaphroditus*), the Long-tailed Monkey (*Macaca fascicularis*) and two possible predators that seem to be lurking in the coastal area: the White-bellied Sea Eagle (*Haliaeetus leucogaster*) and the Forest Crow (*Corvus enca*). Nevertheless, certain observations made during the survey lacked comprehensive analysis regarding the specific patterns of prey behavior exhibited by individual predators. Therefore, additional research should be conducted to investigate further the subject.

Typically, the solitaire reproductive mode exhibits higher hatching rates in comparison to the arribada mode (Cornelius et al., 1991; Gaos et al., 2006). The previously mentioned condition corresponds with the theory of density-dependent mortality as proposed by Cornelius et al. (1991). Furthermore, their periodicity of return spans a duration of three to six months, coinciding with the nesting season. Nevertheless, it is important to recognize that nests that were previously undisturbed may encounter potential risks due to a subsequent increase in nesting activities. Given the ongoing upward trend in nesting activity within the *L. olivacea* species, it is important to determine the concurrent existence of predators and the potential risk of diminished hatchling quality upon their emergence.

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