Spatiotemporal Predation Pattern of The Loggerhead Nests on Dalyan Iztuzu Beach Turkey

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Abstract

Sea turtle acts as an important integral part of the marine ecosystem as it maintains healthy seagrass beds and coral reefs, keeps the balance of marine food chains, and transports the nutrients within water and land. The loggerhead (Caretta caretta), a sea turtle species with strong resistance and adaptability has been nesting for a long time in Turkey’s coastline. During its lifetime, however, harmed by various factors, ranging from natural to human-induced factors. Specifically, the nest that is considered as a vulnerable initial stage is threatened by mammal predators. Therefore, it is important to understand the nest predation dynamics on Dalyan beach due to its significance as the main nesting ground in Turkey. It is also critical to conservation and management efforts of the loggerheads to force the nest recruitment success. This study aimed to explore the spatial and temporal nest predation pattern to find in which part of the beach and in what time the nests are more vulnerable to being predated. A field observational study has been set on the beach during the nesting season from April to August 2017. The beach was categorized into several zones regarding its characteristics which expected affecting the nest predation, namely anthropogenic structure (building), grass-shrubs vegetation, woody forest, and distance to the seawater edge. A standardized wood sticks method was used as a point marker for the nest location as well as indicating the beach zones. The Anova test using IBM SPSS has been performed to analyze the data. Spatially, it is indicated that the middle part of the beach where grass-shrub vegetation and woody forest occur and far from the anthropogenic structure is more susceptible to predation. Moreover, the nest distance to the seawater edge does not influence the nest predation. Temporally, the nest predation occurs more frequently in May, June, and July following the nest density when the nesting reaches its peak. It is, therefore, necessary to put more concern in the middle part of the beach during the peak nesting months to be monitored more intensely to compete for a high predation risk.

Keywords: loggerheads, spatiotemporal, nest predation, anthropogenic structure, grass-shrub vegetation, woody forest, seawater edge.
1. Introduction

Sea turtles, the ancient reptile from the early Mesozoic age [3, 5, 10, 18, 26], play vital ecological roles in the marine ecosystem as it supports healthy seagrass beds and coral reefs [13], provides key habitat for other marine life, helps to balance the marine food webs [1], and transports the nutrients between water and land [2, 5, 36, 37]. It also acts as a host for epibionts and as a landscape modifier [1]. Without its existence, the health and sustainability of marine and coastal ecosystems would be extensively affected [14]. It inhabits oceanic and neritic environments in tropical and subarctic waters and ventures onto terrestrial habitats for nesting or basking [1, 3, 5, 12, 16, 34]. Possessing a long and complex life span [2, 16], its life is started from the egg, followed by hatchling, young, sub-adult, and reaching the adult stage eventually [10]. The sexual maturity is reached between 20 to 50 years old, varying among the different species [8]. Mating occurs in the front of the nesting site in April [10], and the sea turtles subsequently return to the beaches on landside for nesting from May to August [12, 19]. In one oviposition attempt, about 50-130 eggs per nest chamber are produced [16].

The loggerheads, a sea turtle species can be found in the Pacific, Indian, and Atlantic Oceans [28, 34]. It also occurs in the Mediterranean Sea, including the sea of Turkey, Cyprus, and Greece [28, 20]. Turkey’s coastline itself produces a significant number of loggerhead nests as a nesting ground [7, 19] together with the green sea turtle (C. mydas) [16]. One of the most important nesting grounds for the loggerheads in Turkey’s coastline is located on the coast of Dalyan [7, 19].

Nesting has a crucial meaning as it initiates sea turtle life [37], yet certain factors decline the nesting success, naturally or through human-induced disturbances [16]. Since Dalyan coast has been established as Specially Protected Area (SPA) in 1998 [33, 35], people are disallowed to commit sea turtle exploitation and beach alteration which may change and disturb the nesting site [7]. Nevertheless, (red) foxes (Vulpes vulpes) and badgers (Meles meles) as the natural threat predate the nests [7, 11, 19]. This nest predation can heavily affect sea turtles nesting success [37], resulting in long-term demographic impacts [17]. Nest predation is also deemed as an important determinant factor which likely lowering the sea turtle emergence, besides a high nest temperature, salinity, humidity, and water inundation [15].

Regardless of beach establishment as a protected area, it still requires intense protection to mitigate the nest predation by mammals. It is indicated that fox predation on the loggerhead’s nests on Dalyan was extremely high [11]. Reported that (red) foxes raid about almost 90% of the loggerhead’s nests [27]. Dekam Turkey, therefore, initiated the nest protection and monitoring program to force the emergence success during the nesting season [19]. Further, the nest protection requires a sustainable assessment on the effectiveness of the monitoring program regarding the dynamics of the sea turtle and predators as well as the coastal ecosystem because spatially and temporally, the nest predation pattern may change. A comprehensive understanding of the nest predation dynamics is critical to the
conservation and predation mitigation of the loggerheads nest due to the potential for decreasing hatchling recruitment success and inhibiting the recovery of this vulnerable population. Hence, this study aimed to explore the spatial and temporal nest predation pattern of the loggerheads (*Caretta caretta*) to seeking which part of the beach and in what time the nests are more vulnerable for being predated.

![Diagram](image)

*Fig 1.* Depicting a conceptual model of the study of how human-induced factors and natural factors affect nest predation (1)[16]. Human-induced factors i.e. anthropogenic structure, such as buildings (2)[31] and natural factors (1)[21, 23], i.e. nest density (3)[4, 23], grass-shrub vegetation (4)[23], and edge effects (5)[21, 32].

A conceptual model of the study has been created based on the previous studies upon the nest predation pattern as illustrated in *Fig 1*. The nest predation is associated with anthropogenic factors [31] and natural factors [21, 23]. Certain natural factors may also affect the nest predation pattern, including firstly, the nest predation may depend on the nest density – denser the nests, the more nest predation [4, 23]. Secondly, found that surrounding vegetation decreases the predation intensity as the nest is more susceptible to the open area [23]. Lastly, another possible natural factor which can affect the nest predation is edge effect – the nests closed by water environment and wooded (forest) edges possess a higher probability for being predated [21, 32].
2. Material & Methods

2.1 Site

The study was conducted on Iztuzu Dalyan coast of Turkey (Coordinate: 36.788505°/28.618175°). The site is located in Dalyan Mugla province, south-west coast of Turkey. Dalyan beach is about 4.5 km long, curved sand dune, wide, and open, connected to the mainland to the eastern direction [11]. Next to the beach, a river delta/lagoon on the northern direction and two lakes separated by the hill on the southern direction are laid (Fig 2).

![Fig 2. A map of study site of Iztuzu Dalyan beach, south-west coast of Turkey. Grey area with lines indicates pinewood forest in high altitude, from 200m to 400m and fully blue and gray color and strips indicate the water areas. Coordinate: Lat/Long: 36.788505°N/28.618175°E (Adopted from Global Forest Watch).](image)

2.2 Design

We carried out field observational study using the transect method. The transect was established along the beach from the north to the south direction as illustrated in Fig 3. The transect is parallel with sea water edge, grass vegetation edges, and wooded edges. Along the transect, we placed the standardized wood sticks as a point marker every 5m to 10m. The nesting ground was divided into 9 zones, i.e. zone 1, zone 2, zone 3, until zone 9 with different length depending on the stick number (Table 1).
Table 1. Detail characteristics of the classified nesting zones.

<table>
<thead>
<tr>
<th>Zones</th>
<th>Zones based on stick number</th>
<th>Width (m)</th>
<th>Physical surrounding characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beginning zone</td>
<td>Zone 1 (0-50)</td>
<td>161.0</td>
<td>A presence of anthropogenic structure surrounded by grassy vegetation.</td>
</tr>
<tr>
<td></td>
<td>Zone 2 (51-100)</td>
<td>161.0</td>
<td>A presence of anthropogenic structure surrounded by grassy vegetation.</td>
</tr>
<tr>
<td>Middle zone</td>
<td>Zone 3 (101-150)</td>
<td>161.0</td>
<td>A dense grass-shrubs vegetation with few trees grow on the lake side.</td>
</tr>
<tr>
<td></td>
<td>Zone 4 (151-200)</td>
<td>175.0</td>
<td>A dense grass-shrubs vegetation with few trees grow on the lake side.</td>
</tr>
<tr>
<td></td>
<td>Zone 5 (201-250)</td>
<td>175.0</td>
<td>A dense grass-shrubs vegetation with few trees grow on the lake side.</td>
</tr>
<tr>
<td></td>
<td>Zone 6 (251-300)</td>
<td>80.7</td>
<td>A presence of a hill behind the beach separate two lakes. Grass and shrubs vegetation with dense pine trees grow on the lake side.</td>
</tr>
<tr>
<td></td>
<td>Zone 7 (301-350)</td>
<td>80.7</td>
<td>A presence of a hill behind the beach separate two lakes. Grass and shrubs vegetation with dense pine trees grow on the lake side.</td>
</tr>
<tr>
<td>End zone</td>
<td>Zone 8 (351-400)</td>
<td>147.0</td>
<td>A presence of anthropogenic structure backed by grass and shrubs vegetation. Far from the end of the beach there is road and pine forest.</td>
</tr>
<tr>
<td></td>
<td>Zone 9 (&gt;400)</td>
<td>147.0</td>
<td>A presence of anthropogenic structure backed by grass and shrubs vegetation. Far from the end of the beach there is road and pine forest.</td>
</tr>
</tbody>
</table>

Fig 3. Depicting the transect design of the study. A transect lays from east to west direction of the beach (blue line). The standardized wood sticks are occurring along the blue line. The nests along the transect were recorded based on the standardized stick method for marking the nests.

We collected the data of the nest predation in the 2017 nesting season started from April to August. Data collection have been done during the nighttime, which is the nesting time for the loggerheads. Found nests were protected using a special cage. The GPS point of the nests were recorded and its distance to the seawater edge was also measured. In the morning time, we returned to re-observe the nest whether it is predated or not. We categorized the
predation into certain level: non-predated fully predated and partly predated with some eggs left. The mammal predator tracks are identified based on field guide to animal tracks [29].

2.3 Analysis

Collected data were statistically analyzed by IBM SPSS based on the given hypothesis. To begin, Generalized Linear Model (GLM) has been performed to find the temporal nest predation pattern through analyzing whether the nest and eggs predation is related to the nest density or not. Subsequently, a similar test has been performed to find the spatial nest predation pattern through analyzing the effect of grass-shrub and woody vegetation on the nest predation. Grass-shrub and woody vegetation are represented in several zones. Moreover, a similar test has also been performed to test the effect of nest distance to the seawater edge on the nest predation. Ultimately, to better understand the spatial nest predation pattern, a GLM with regression backwards selection method has been performed to seek for the parameter that affect the nest predation the most.

3. Results

3.1 The Changes of Nest Predation Overtime

Nesting started on April and finished at the end of August. The nest predation pattern is high in the middle of the nesting season in May, June, and July. Nest predation is slightly higher in May compared to June and it starts decreasing in July until the end of the nesting season (Fig 4a). The proportion of predated eggs show a similar pattern to predated nests in which the highest proportion of predated eggs occurs on May, starting to decrease in June to July until no predated eggs at the end of the season (Fig 4b). It is also seen in Fig 4a that nest predation follows the nest density on those peak nesting months.

![Fig 4](image-url)

*Fig 4. Depicting nest predation pattern overtime during the nesting season of 2017. a) The nest predation reaches a high proportion during the peak nesting month of May-July following the nest density (F=7.913 df=2 p<.05). b) The proportion of predated eggs corresponds a similar pattern – predated eggs in monthly basis is significantly different among all months are high on May-June and decreasing significantly in August (F=4.401, df=3, p<.005).*
3.2 The Effect of Anthropogenic Structure, Grass-shrubs and Woody Vegetation on the Nest Predation

The effect of anthropogenic structure, grass-shrubs and woody vegetation on the nest predation is represented by different nest predation proportion as classified in different zones. In one hand, nest predation is high in the middle part of the beach where grass-shrubs and woody vegetation occur. This is indicated by the highest proportion of predated nest within sticks zone 101st-350th (Fig 5a). On the other hand, the nest predation is low at the beginning and the end of the beach where anthropogenic structures occur. Within zone 0-100th and zone 350-400th at the end of the beach the nest predation is almost zero. The pattern shown in Fig 5b corresponds the proportion of predated eggs. The highest proportion of predated eggs is shown in the middle part of the beach while at the beginning and at the end of the beach the proportion of predated eggs is zero.

Fig 5. Depicting the nest predation pattern within different zones on the beach. a) Middle part of the beach has higher proportion of predated nests (F=30.962, df=2, p<.001) and b) predated eggs (F=9.679, df=8, p<.001).

3.3 The Effect of Seawater Edge on the Nest Predation

Fig 6 reveals no significant effect of distance from the nests to the seawater edge on the nest predation, both on predated nests and eggs. As no significant effect of distance found, the interaction effect between distance, zones, and nest density has been test revealing that the nest predation is not affected by the interaction of nest distance to seawater edge and zones, while it remains following the nest density (Fig 7).
Fig 6. Depicting the effect of nest distance from sea water edge on the nest predation. Distance to the seawater edge does not affect nest predation ($F=.799$, $df=2$, $p>.05$).

4. Discussion

The predation on the sea turtle nests by big mammals, (red) foxes and badgers on Dalyan beach has been previously studied revealing a high predation rate [11, 27, 38]. Red foxes are opportunists’ predators with hearing, vision, and sense of smell in detecting prey, even it often stalks on the prey [30]. The hunting range of this predator is estimated approximately...
between 10 to 5000 ha [27], covering coastal ecotone to high altitude of pinewood forest [25]. Badgers (Meles meles), a generalist predator [9] competes the (red) foxes for food resources in Dalyan. Both predators are diurnal yet switching into the nocturnal activity when disturbed by trophic factors [6].

Overall, the spatial and temporal nest predation pattern of the loggerhead nest on Dalyan nesting ground is significantly affected by certain expected factors. Temporally, the nest predation follows the nest density in which the proportion of predated nest is higher in the peak nesting months compared with the beginning and the end of the nesting season, indicating that the more the nest, the more vulnerable it is. Spatially, the nest predation on Dalyan nesting ground is driven by the anthropogenic structures situated at the beginning and the end of the beach, while the nest distance to seawater edge does not affect it. The nest predation is also significantly affected by dense grass-shrubs and woody vegetation occurring in the middle of the beach – proven by a significant effect of zones on the nest predation. Hence, the nests are more vulnerable in the middle zone of the beach (Fig 8, red circle), while the beginning and the end of the beach are less vulnerable (Fig 8, yellow circles).

Fig 8. Depicting the spatial nest predation pattern on Dalyan Iztuzu beach. Yellow circles indicate the beginning and end zone where the nest predation proportion is almost zero - an anthropogenic structure occur in the zones, while the red circle indicate the middle zone as the most threatened zone with the most predated nests - the middle zone is backed by dense grass-shrub vegetation and woody vegetation next to the lake an creek. The black dots indicate the nests (Modified from Google Earth Pro).
As hypothesized on the conceptual model of the study (Fig 1), the nest predation on Dalyan nesting ground is affected by various factors, ranging from anthropogenic factors to natural factors [21, 23, 31]. Firstly, from May to July, the nest density is higher than the early and late months. It is hypothesized that the nest predation will follow the nest density [4, 23]. We expected that nest predation will reach the highest proportion in the peak nesting month of June. The result reveals, however, even though those peak nesting months possess higher nest predation proportion, there is a little variation during those three months. It is suggested that the evidence for density-dependent predation in sea turtle nests is mixed [23]. This might also be related to the monitoring intensity which also increased in June. A similar pattern is also shown in the proportion of predated eggs in that is higher in May. This might be attributed to a higher vulnerability of the nests for being predated in an early period following oviposition and at the end of incubation time [19, 23]. The nest predation is likely triggered by the cues left by the female turtle (i.e. visual, tactile, and olfactory), and many predators have the ability to detect those cues [24], including (red) foxes and badgers as opportunist and generalist predator with the ability to detect the nests towards the cues [6]. This, therefore, causes predators to attack sea turtle nests more frequently immediately after the nest construction [22], which mostly occurs in May, or after hatching at the end of the incubation period [22].

The results also reveal that the anthropogenic structure situated at the beginning and at the end of the beach decreases the nest predation. Theoretically, habitat changes caused by anthropogenic structure can negatively affect the wildlife [31], probably including sea turtles. This, however, sometimes may cause adverse effects on the predators and then favor the sea turtle as the spatial proximity of the anthropogenic structure – the waste produced by anthropogenic structure can be used as another food resource by predators [31]. The occurrence of human activities around the anthropogenic structure also causes predators switching the predation area because it tends to avoid humans [6]. Consequently, the closer the nests from the anthropogenic structure, the less risk of being predated by mammal predators (Fig 5). A similar pattern is also shown on the proportion of predated eggs with the highest proportion of predated eggs occurs in the middle of the beach away from the anthropogenic structure. The nest predation decreases gradually following the distance to the anthropogenic structure. In addition, natural factors such as vegetation [21, 23] both woody forests [23] and grass-shrubs vegetation [21, 32] are expected to provide another food resource for predators. However, in fact, this conversely attract more predators to feed on that area. That vegetation is dense in the middle of the beach where possibly predator’s population is also denser.

Other results indicate that the nest distance to the seawater edge does not affect the nest predation as well as the proportion of predated eggs. The nests closed by the seawater edge seem to be more vulnerable, but it is actually related to the nest density closed by the seawater edge. Some variation occurs regarding the effect of distance on the nest predation. This might be due to the width of the beach which is approximately less than 300m in which the predators can still randomly search for the nests.
5. Conclusion

Based on the whole results, it is necessary to conduct sound predation mitigation efforts to optimize the nest predation monitoring in the middle of the beach. For instance, increasing the nest monitoring intensity in the middle part as well as trying to find the nests as quickly as possible because it minimizes the risk for the nests to be predated by predators. Further, this assessment should also be continuously conducted in the future years for better monitoring practices by adding the parameters of distance from the nest to grass-shrubs and woody vegetation. This will provide a better understanding of the spatial nest predation pattern because it is suggested that the distances from those two parameters play roles in determining the nest predation.

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References


