

Using an in-situ infra-red camera system for sea turtle hatchling emergence monitoring

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Abstract. We tested for the first time the efficiency of the use of infra-red (IR) cameras for sea turtle hatchling monitoring. The cameras were installed on one green turtle (*Chelonia mydas*) and four loggerhead turtle (*Caretta caretta*) nests during 2014 and 2015 nesting season in the south-east Mediterranean, Turkey. The camera monitoring, even with the limited sample size, have successfully corroborated the previous observations and provided further insights on hatchling emergence behavior. The analysis of the camera recordings revealed that hatchlings emerged from the nests asynchronously in varying numbers of groups and different group sizes, while c. 60% hatchlings emerged during the first 5 days of emergence activity. 98.6% of hatchlings emerged at night with a peak activity between 21:00 and 00:00. The day of first emergence varied between 38 and 64 days since egg deposition, while the day of last emergence varied only between 60 and 65 days. Total emergence activity continued up to maximum of 22 days, which is longer than that of previous records. Overall, the present study showed that IR camera monitoring is a promising tool for sea turtle monitoring and can provide detailed insights on sea turtle hatchling behavior.

Keywords. Loggerhead turtle, green turtle, hatchling emergence duration, infra-red camera, continuous camera monitoring, sea turtle nest monitoring, sea turtle conservation.

INTRODUCTION

Breeding success has been an essential component of sea turtle conservation (Musick and Limpus, 1997; Hamann et al., 2010; Rees et al., 2016). Therefore, extensive monitoring of sea turtle breeding beaches has become an integral part of sea turtle breeding habitat management (Fowler, 1979, Hays et al., 2001; Taskin and Baran, 2001). These monitoring efforts have focused on various aspects of sea turtle breeding, such as, habitat quality, nest predation, anthropogenic effects and hatch-

ling emergence patterns; leading to the identification of important pressures on the breeding habitats of these endangered species (Kasperek et al., 2001; Tomás et al., 2002), which has led to implementation of better conservation measures.

Sea turtle breeding beach monitoring have been almost exclusively based on regular beach patrols during the breeding period that may last for five months (Henson and Boettcher, 2006; MEDASSET, 2017). These direct visual observations have important limitations in temporal resolution, feasibility and man power (García

et al., 2003). Therefore, sea turtle conservation management may be benefitted from more efficient monitoring alternatives providing standardized survey data. Continuous camera recordings have been used in several organism groups, such as, wild boars (Huckschlag, 2008), deers (Scheibe et al., 2008) and birds (Pierce and Pobprasert, 2013); however, they have not previously been used for sea turtle hatchling monitoring. Only in Florida Keys beach, a live-streaming webcam was installed on a sea turtle nest in 2014 in order to raise awareness on sea turtle conservation (<http://www.fl-keys.com/turtlecam/>).

Continuous camera monitoring may provide opportunities for sea turtle breeding beach monitoring by improving monitoring efficiency as well as providing detailed insights on hatchling behavior. There are currently different monitoring and excavation protocols for different research teams and volunteer groups (Henson and Boettcher, 2006; MEDASSET, 2017). For example, there is no standardized nest excavation time, although many management groups prefer to conduct an excavation within the few days of the last detected emergence. Furthermore, beach patrolling during hatchling emergence period is mostly conducted in the mornings (Henson and Boettcher, 2006; MEDASSET, 2017), while knowing temporal emergence patterns could facilitate the researchers to better allocate labor if encountering hatchlings is required. Therefore, detailed understanding of hatchling emergence behavior specific to breeding beaches through novel technologies and standardized data may lead to a more efficient decision on excavation dates and beach patrolling schedules. Furthermore, temporal patterns and group formation of sea turtle hatchling emergence might also be an important determinant of the survival of hatchlings (Carr and Hirth's 1961) and therefore a more detailed understanding of hatchling behavior may also be instrumental in conservation management.

Overall, quantitative and standardized observations on hatchling behavior using technological monitoring tools may provide a more comprehensive understanding of sea turtle breeding ecology and conservation. The aim of this study is testing a novel method – IR camera monitoring – and assess its efficiency in sea turtle hatchling monitoring of the temporal patterns and group formations of hatchling emergence as well as hatchling behavior.

MATERIAL AND METHODS

Study site

The study was conducted at the beach of the Institute of Marine Sciences, Middle East Technical University (METU

IMS), Turkey. The beach stretches along a 1.2 km long coast and is located in a heavily urbanized area of the eastern Mediterranean. The study site has restricted public access and the human activity is limited. The beach is mostly sandy and spans 15-25 m in width with insignificant tidal activity. It consists of natural sand dunes approximately 0.5-3.0 m above sea level, hosting natural coastal vegetation dominated by sand lily (*Pan-cratiium maritimum*, L.; Cihan, 2015). The activity of breeding sea turtles from May to August and hatchlings from July to September have been monitored since 2013 using conventional beach patrols.

Camera monitoring system

Conventional infrared (IR) security cameras (BALITECH BL-6150) with 200 m range, 8 mm stable lens and 650 TVL resolution were installed on wooden poles placed approximately 1.5-3.0 m away and 1.0-1.5 m above the nests (Fig. 1). All the cameras were connected to a digital video recorder (SAMSUNG SRD-1650D) with 16 channels and 1 TB memory, placed in a cabinet that was installed c. 20 m away from the most distant nest. Recordings were transferred every second day to an external 1 TB hard drive. The recordings were commenced after 51 days of egg deposition and lasted for c. 30 days. Five cameras in total were installed on loggerhead (4) and green turtle (1) nests.

Analyses of hatchling behavior and emergence activity

The video recordings were analyzed to elucidate the patterns in hatchling group size, emergence date and time. We pooled and analyzed green and loggerhead nest data together for the present analyses, although these two species significantly differ for other aspects of their breeding biology.

All video recordings were analyzed with automatic screen captures at 30-second intervals. When emergence activity was detected in photos, the corresponding video clip was examined, for the exact emergence date and time, hatchling count, crawling duration, orientation, behavior as well as any predation event. Emergence activity was accepted to start with the earliest time of a hatchling observed on the nest surface, end with disappearance of the last hatchling from camera view.

Emergence groups were categorized by the number of individuals: 1-3 as small, 4-10 as intermediate, more than 11 as large groups. Individuals appeared at the same time or subsequently (less than one minute between individuals) were taken as one group even if there was a lag between their crawling activities. Total days until first emergence, peak activity and last emergence were calculated from the night of nest deposition. The day when the largest emergence occurred was designated as the nest's day of peak activity. An emergence events were designated as day or night activity according to the time of sunrise (05:50-06:23 h) and sunset (18:51-19:46 h) during study period. The emergences that occurred 10 min before sunset and 10 min after sunrise were considered as night activity to be able to account for local shading. In Nest E11R, 30 hatchlings waiting on the top of the nest chamber were accidentally dug by chil-



Fig. 1. A sample setup of camera system around a sea turtle nest. Photographer: Korhan Özkan.

dren just before the sunset. The surveyor immediately noticed the event, monitored the nest and the hatchlings subsequently released under monitoring. We accepted that emergence as night emergence, since the event occurred just before the sunset, and the hatchlings were ready to emerge immediately that evening.

The hatchling orientation and predation events were also recorded to understand the effectiveness of beach management and efficiency of nest cages. The one side opened pyramidal shaped metal nest cages were placed on the nests' surface as open side was directed toward sea (Fig. 1). Orientation of each hatchling movement relative to a seaward direction was recorded. We classified hatchling crawls within +70° of the seaward direction as seaward orientated. Mortality or predation events were also recorded.

A nest excavation was performed after the end of camera monitoring. The total number of eggs were estimated from the remains and compared with the counts from the video recordings. The emergence success of each nest was calculated as the ratio of hatchlings those reached to the sea and the total clutch size (Miller, 1999).

RESULTS

The values of all the analyzed parameters for the single green turtle nest varied always within the range that was observed for the loggerhead turtle nests (Table 1). Accordingly, we did not discard the single green turtle nest data, instead, green turtle and loggerhead turtle nests were pooled together for the analyses. Camera recordings revealed that a total of 357 hatchlings in 71 groups emerged from five nests with 42-94 hatchlings per nest. In total 62% of hatchlings emerged in large groups, 17 % of hatchlings emerged in intermediate groups and 21% of hatchlings emerged in small groups (Table 1). At least one large group emergence was observed for each nest (Table 1). Additionally, 69 of the 72 groups (95.8%) emerged at night accounting for 352 of 357 hatchlings (98.6%; Fig. 2, 3a, 3b). All of the large and intermediate groups as well as 49 of the 51 small group emergences occurred during night (Fig. 2). The highest emergence

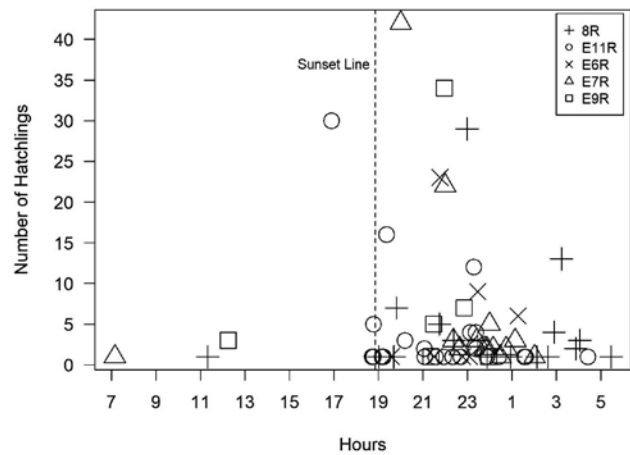


Fig. 2. The daily temporal patterns of hatchling emergence activity. Each symbol represents a different nest and the dashed line represents the approximate sunset time. The emergence activity was overwhelmingly nocturnal.

Table 1. Number of emergence groups and hatchlings for each nest with clutch size and incubation period. CM and CC denote for green and loggerhead turtle respectively. NG and NH denote for number of groups and total number of hatchlings respectively.

| Nest | Species | Large emergences | | Intermediate emergences | | Small emergences | | Incubation Duration | Clutch Size |
|--------|---------|------------------|-----|-------------------------|----|------------------|----|---------------------|-------------|
| | | NG | NH | NG | NH | NG | NH | | |
| 8R | CM | 2 | 42 | 3 | 16 | 13 | 20 | 53 | 97 |
| E11R | CC | 3 | 58 | 3 | 13 | 19 | 23 | 38 | 103 |
| E6R | CC | 1 | 23 | 2 | 15 | 4 | 4 | 64 | 50 |
| E7R | CC | 2 | 64 | 1 | 5 | 11 | 22 | 54 | 104 |
| E9R | CC | 1 | 34 | 2 | 12 | 4 | 6 | 54 | 71 |
| Total: | | 9 | 221 | 11 | 61 | 51 | 75 | | |

Table 2. Surveyed nests' characteristics and nest excavation records.

| Nest | 8R | E6R | E7R | E9R | E11R |
|--|-----------------------|------------------------|------------------------|------------------------|------------------------|
| Species | <i>Chelonia mydas</i> | <i>Caretta caretta</i> | <i>Caretta caretta</i> | <i>Caretta caretta</i> | <i>Caretta caretta</i> |
| Egg deposition date | 12/07/2014 | 6/06/2015 | 10/06/2015 | 16/06/2015 | 27/06/2015 |
| Camera installation date | 1/09/2014 | 12/07/2015 | 12/07/2015 | 12/07/2015 | 12/07/2015 |
| First emergence date | 3/09/2014 | 9/08/2015 | 3/08/2015 | 9/08/2015 | 4/08/2015 |
| Last emergence date | 14/09/2014 | 10/08/2015 | 14/08/2015 | 16/08/2015 | 26/08/2015 |
| Incubation duration (from egg deposition to first emergence) | 53 | 64 | 54 | 54 | 38 |
| Excavation date | 2/10/2014 | 23/08/2015 | 19/08/2015 | 21/08/2015 | 28/08/2015 |
| Emergence duration | 11 | 1 | 11 | 7 | 22 |
| Hatched/Empty eggs (from excavation) | 77 | 41 | 93 | 49 | 95 |
| Camera hatchling count | 78 | 42 | 91 | 52 | 94 |
| Clutch Size | 97 | 50 | 104 | 71 | 103 |
| Hatchlings reaching the sea | 76 | 42 | 91 | 50 | 94 |
| Hatchlings predated | 1 | 0 | 0 | 0 | 0 |
| Dead hatchlings (after emergence) | 1 | 0 | 0 | 3 | 0 |
| Early stage embryos | 9 | 4 | 2 | 12 | 2 |
| Middle stage embryos | 1 | 0 | 2 | 1 | 0 |
| Late stage embryos | 2 | 0 | 1 | 0 | 2 |
| Unfertilized eggs | 7 | 4 | 8 | 6 | 5 |

activity (60% of the group emergences) occurred between 21:00 and 00:00 (Fig. 3a and 3b). The total number of hatchlings captured with camera recordings and the number of empty eggs found in excavations were largely consistent with an error rate between 1% and 5.8% (only 1 to 3 differences have been found per nests, Table 2).

Total incubation period varied between 38-64 days since the egg depositions (mean = 52.6 days; Table 2). The day of the peak activity varied between 47 and 64 days (mean = 54.6 days; Fig. 4). The day of the last emergences was least variable among nests and varied between 60 and 65 days (mean = 63 days; Fig. 4). Total emergence

duration between the first emergence and last emergence had a large variation, changed between 1 and 22 days (mean = 10.4 days).

Overall, 121 hatchlings out of 357 (33.9%) emerged during the first day (24.2 hatchlings on average per nest). 221 (61.9%) hatchlings emerged over the first 5 days following the first emergence (8.8 hatchlings per day for the

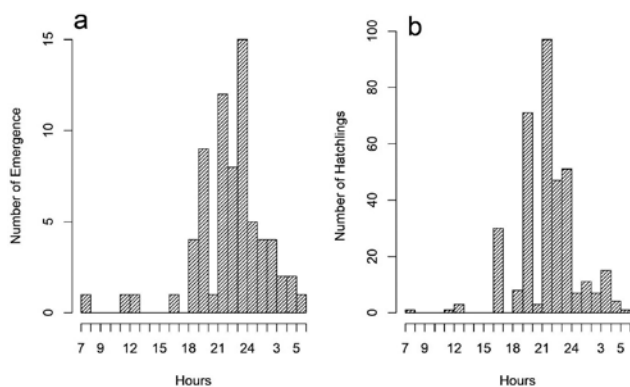


Fig. 3. The histogram of emergence activity by hour for number of emergence groups (a) and hatchlings (b).

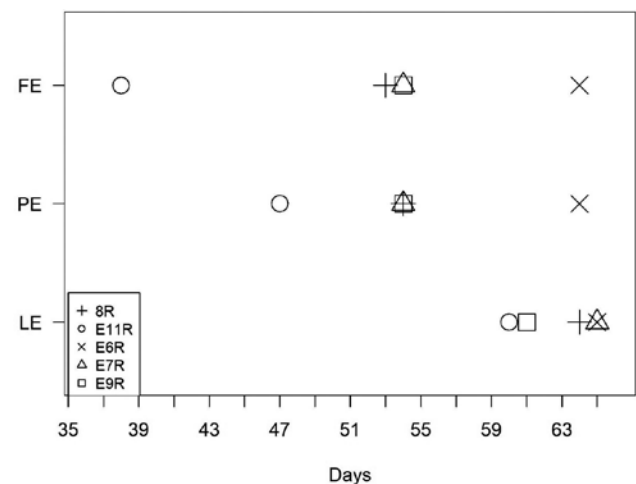


Fig. 4. The duration of the first emergence (FE), peak emergence (PE), last emergence (LE), calculated as the total number of days since egg deposition. The least variation was observed in the day of last emergence.

first five days). Three nests' peak activity occurred on the first day and one nest's peak activity occurred on the second day of emergence period.

The majority of the hatchlings (88.8%) oriented successfully towards the sea. Only three disorientated emergence groups (40 hatchlings) were recorded, but the predation cages re-directed them to the sea. The hatchling emergence success of the nests varied between 66% and 92% (Table 2) and no dead hatchlings were found within the nest chamber during excavations. A total of five dead hatchlings were observed due to overturning and subsequent heat shock (Table 2). Four of the deaths happened during the day, with only one happened during the night. Only one hatchling was predated by Hooded Crows during day.

DISCUSSION

The results of the present study showed that continuous camera monitoring can be an efficient tool, especially for hatchling behavior monitoring. Furthermore, the analyses of the recordings corroborated the previous findings on the patterns in emergence group sizes, timings and durations, as well as provided further insights on hatchling behavior. Continuous camera recordings with IR cameras provided data with very high temporal resolution on sea turtle hatchling behavior. Although the present study performed on a limited number of nests, the camera monitoring documented an exceptionally long emergence activity duration of 22 days. Previously, 18 days of emergence duration was reported as the longest emergence activity duration for loggerhead turtles in Japan (Moriya and Moriya, 2011). Our results suggest that longer emergence durations might be more frequent than expected and continuous video recordings may provide a more reliable estimation for the duration of hatchling emergence activity in comparison to conventional beach monitoring.

Continuous camera recordings also enabled us to study hatchling emergence behavior at temporal scales and with small sample sizes that are difficult to account for with conventional beach monitoring. For example, we observed a strong intra-nest asynchrony in hatchling emergences; i.e., hatchlings tended to emerge in several groups with different sizes in successive days. Synchronous emergence (emerging as one large group) has been proposed to reduce the probability of hatchling predation on land (Delm, 1990; Heithaus, 2013; Santos et al., 2016) and hatchlings might stimulate each other both during and after emergence (Carr and Hirth, 1961). However, several studies previously documented asynchronous emergence (Peters et al., 1994; Glen et al., 2005; Adam

et al., 2007; Moriya and Moriya, 2011), similar to our findings. This might also be due to a decrease in predation intensity for the hatchlings emerging in small groups (Pilcher et al. 2000) or due to ambient temperature differences in the nest (Adam et al., 2007).

Moreover, the present study demonstrated that the natural emergence activity since the egg deposition lasted between 60 and 65 days with a very limited variability among nests. However, the total emergence activity since the first hatchling emergence lasted between 1 and 22 days with a large variation. Accordingly, if the natural incubation and emergence process is preferred by the local conservation managers, 65 days after nesting or 22 days after the first emergence may be waited until any excavation, if the nesting beaches are not under high predation pressures.

We observed in the present study that the in-situ camera systems had considerable advantages over direct visual observations on effort, consistency and repeatability especially if the proper equipment is selected. However, we have also observed some limitations on the use of in-situ camera systems. The field of view of the cameras only enabled us to monitor close vicinity of the nest and prevented us following the hatchlings to the sea, which only documented the immediate survival of the hatchlings on the nest. We also encountered hardware and recording failures mostly due to corrosion. Therefore, using durable technical equipment and backing up data frequently are essential for successful in-situ camera applications. METU IMS Campus has limited access to public and thus it is well protected from robbery or vandalism, which enabled us to install electronic equipment freely. However, using this method in larger or remote breeding beaches would require necessary security precautions.

The analyses of hatchling emergence data in the present study strongly corroborated previous observations on loggerhead and green turtle nests monitored using conventional methods. The majority (98.6%) of the hatchling events in the present study occurred nocturnally similar to previous findings (Mrosovsky, 1968; Witherington et al., 1990; Hays et al., 1992; Glen et al., 2005), probably to avoid diurnal predators and lethal daytime temperatures (Glen et al., 2005). The peak emergence activity occurred between 21:00 and 00:00 h, similar to the observations in Florida (23:00 and 00:00 h, Witherington et al. 1990) and in Greece (00:30 and 01:00 h, Adam et al., 2007). Accordingly, the night patrolling efforts aiming at monitoring hatchlings could be prioritized for early evening, when man power is limited. Furthermore, nocturnal emergences occurred mostly (~80%) in large groups, while all diurnal emergences were in small groups (including single emergences) in the present

study, further corroborating previous studies (Glen et al., 2005).

The mean total incubation period (from egg deposition night to the first emergence) was 52.6 days (38–64 days) in the present study. This is in accord with previous observations for green turtles in Northern Cyprus (57.9 days; Ilgaz and Baran, 2001), for loggerhead turtles in Turkey, Greece and Northern Cyprus (varied between 49 and 55.2 days; Ilgaz and Baran, 2001; Taskin and Baran, 2001; Margaritoulis, 2005; Fuller et al., 2013). The difference between the incubation periods among different studies might be due to the differences in ambient temperature of the breeding beaches (Hays et al., 1992; Drake and Spotilla, 2002; Glen, 2005; Adam et al., 2007). Therefore, continuous camera recordings with temperature measurement devices might provide more accurate hatchling activity parameter estimates specific to different breeding beaches. It should also be noted that the number of the samples in the present study is limited and further studies with larger sample sizes is required for more accurate parameter estimations.

The great majority of the hatchlings (98.6%) reached to the sea successfully in the present study, indicating a very high survival rate in comparison to other observations in the region (49.9% in Ilgaz and Baran, 2001 and 43.5 % in Taskin and Baran, 2001). Only a single hatchling (in 357) was predated by Hooded Crows, which is very low predation rate (Carr and Hirth, 1961; Tomillo et al., 2010; Türkozan et al., 2011). The hatchling deaths occurred only in small group emergences in the present study. This is in accord with previous observations, where larger groups of hatchlings have been observed to be more motivated to reach the sea and more directional in their effort (Carr and Hirth, 1961; Burger and Gochfeld, 2014), while single emergences have had less chance to reach to sea than group emergences (Carr and Hirth, 1961). The high success rate probably reflected the efficiency of the conservation efforts at METU IMS beach (i.e., artificial light and human use management).

Overall, the present study showed that in-situ camera systems is an alternative or complementary tool to the conventional beach monitoring for sea turtle conservation with significant advantages on labor and efficiency. Furthermore, the high frequency data gathered through continuous camera monitoring even with small sample sizes provide important opportunities for studies on sea turtle hatchling behavior.

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