

Emergence pattern of loggerhead turtle (*Caretta caretta*) hatchlings from Kyparissia Bay, Greece

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Abstract The present study describes the emergence pattern of loggerhead sea turtle hatchlings (*Caretta caretta*) from a nesting beach in Kyparissia Bay (Greece). We try to establish the role played by hatchling biometry, nest relocation and distance from nest to the sea on this emergence pattern. We surveyed a total of 32 nests, and found long emergence periods (mean = 6.7 nights). The majority of emergences occurred at night, mainly between 0030 and 0100 hours, and in small groups. Most of the hatchlings emerged from the nests the first night. We found no clear trend when we studied the effect of hatchling biometry between successive emergence days. We also found that relocation of the nests did not significantly affect the emergence pattern. However, we noted that in the relocated nests, hatchlings emerged in smaller groups. Emergence periods were inversely related to distance from the sea. In short, factors such as climate conditions, relocation and nest distance to the sea appear to have some effect on the emergence pattern. Therefore, they should be taken into account in both biological studies and management plans for sea turtle nesting

beaches. Our results suggest leaving an extended period between the first emergence of hatchlings and the excavation of nests by researchers in future studies in the area.

Introduction

The loggerhead sea turtle (*Caretta caretta*) is a globally endangered species (MTSG 1996). Significant resources are currently devoted to numerous conservation and management projects at loggerhead nesting areas. One of most important and costly activities in management projects is the monitoring of beaches to protect nests and hatchlings from anthropogenic threats, such as artificial light sources, and ensure a high hatching success and safe arrival of hatchlings to the sea.

Richardson (1999) remarks that a complete study of all aspects related to nesting biology is essential for the selection and application of adequate management measures for the conservation of sea turtle populations. One of these measures is the relocation of clutches from their original location to another place in the same beach or elsewhere. Boulon (1999) lists some circumstances in which relocation is adequate in order to mitigate some threats that reduce hatchling success. However, nest relocation can have a detrimental effect, even when undertaken with a proper technique. Relocation of clutches may affect the natural incubation conditions, thus modifying the emergence rates of hatchlings from the nest and the timing of these emergences, with negative consequences to their survivorship (Glen et al. 2005).

Traditionally, it was thought that almost all hatchlings emerged together from the nests en masse.

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Recent studies have given evidence on more asynchronous emergence patterns. Several authors have observed emergence periods lasting several days (Hays et al. 1992; Peters et al. 1994; Houghton and Hays 2001; Glen et al. 2005). Furthermore, several studies have also found that emergence of hatchlings during the night usually occurs in different events and at different hours (Hays et al. 1992; Witherington et al. 1990; Glen et al. 2000, 2005; Rees 2005). Some studies on emergence patterns have analyzed the reasons why hatchlings more commonly emerge at night and have found a fundamental intolerance to daytime surface sand temperature and predator avoidance to be important (Mrosovsky 1968; Drake and Spotilla 2002). Such types of studies need to be developed in every nesting area to determine general common patterns and to improve sea turtle management conservation projects. It is therefore necessary to not only know the duration of the emergence period, but also the hours at which emergences are at a maximum, to effectively manage the reduction of hatchling loss through disorientation or predation.

Hatchling survivorship is further compromised on beaches where human activities are prevalent, such as certain beaches in Kyparissia Bay (Greece). In such places it is important to describe the emergence patterns of hatchlings, and the role of possible factors such as distance from nest to the sea or hatchling biometry in determining this pattern. Additionally, comparative studies of emergence patterns between relocated and non-relocated nests are essential in order to assess the effectiveness of this conservation measure.

Materials and methods

Study area

Kyparissia Bay is located on the Western coast of Peloponnesus (Greece). It is delimited by Cape Katakolon at 37°38'N/21°19'E to Cape Kounelos at 37°10'N/21°34'E, and three rivers flow into the Bay. During the summer, winds from NW make it susceptible to high surf. The loggerhead nesting population at Kyparissia Bay and its conservation status has been studied previously (Margaritoulis and Rees 2001 and references therein; Rees et al. 2002). The area studied here comprises a 1,500 m long stretch of beach at Kalonero, located in the south of Kyparissia Bay. In this part, the beach width ranges from approximately 15–30 m. The average slope of the beach is 11° (SD = 3.8, range = 1–17). Detailed description of the beach, including sand colour and presence of vegetation, can be found in

(Margaritoulis and Rees 2001). At night, approximately 900 m of the beach is illuminated by artificial lighting.

Nest protection and data collection

The present study sample consists of 32 clutches laid between the 1st and the 30th of July 2002. The incubation period was defined here as the number of days from the morning after the night of laying to the morning after first hatchling emergence. The nests were protected from predation by fixing metal screens over each nest (Margaritoulis et al. 1996). In order to avoid disorientation of hatchlings caused by artificial lighting that illuminates the beach; wooden boxes were placed above the nests each night from the 45th day of incubation period. “Boxing” involved placing open-bottomed and partly open-topped wooden boxes over the nests, as in previous studies (Rees 2005). The boxes were placed at sunset (about 20:00 local time) and removed at sunrise (about 07:00). This procedure was useful for our study of the pattern of hatchling emergence by facilitating the counting of hatchlings in the different emergences.

The following variables were recorded: (1) the emergence period (i.e. the period in days from the first to the last emergence), (2) the daily emergence pattern (i.e. the number of hatchlings emerged each day from first emergence), (3) the number of emergence events per nest, (4) the number of hatchlings per emergence, and (5) the timing of the emergences.

The latter variable was recorded by checking each box just once between 20:00 and 23:00 and every half an hour from 23:00 to 07:30. During daylight hours, the nests were checked twice to count the tracks of the hatchlings emerged, the first time from 07:30 to 12:00 and the second from 12:00 to 20:00. We defined *emergence day* as the period between 12:00 and 12:00 of the next day. We established an *emergence event* when we found one or more hatchlings in the box, completely emerged from the sand or tracks on the beach in the case of daytime emergences.

Nests were excavated 12 days after the last emergence of hatchlings to assess hatchling emergence success used in other analyses.

Biometry of hatchlings

We analysed the differences that may exist in both the emergence period and daily emergence pattern with respect to biometric variables. First, we aimed to check whether the size and weight of the hatchlings could affect the duration of the emergence period. Second, we analysed the variation in length and weight of the hatchlings in relation to the emergence day within each

nest. Five nests were flooded by the sea; thus, biometric analysis was limited to the remaining 27 nests. The following measurements were taken: minimum Straight Carapace Length (SCL_{\min} , Bolten 1999), maximum Straight Carapace Width (SCW_{\max} , Bolten 1999), and weight. We used callipers (accuracy 0.05 mm) to measure SCL_{\min} and SCW_{\max} , and a spring-scale (accuracy 1 g) for weight. We measured all the emerged hatchlings when the emergences involved 10 or less individuals. For emergences with a greater number of hatchlings, we randomly selected 10 for measurements. After measuring the hatchlings, we released them 10 m from the high tide line on a non-artificially illuminated area of the beach to allow for imprinting. The daily variation in size and weight of the hatchlings according to the daily emergence pattern was grouped together according to the emergence day. The hatchlings emerged on the seventh day or later were grouped for homogeneity of sample size in the analyses.

Relocation

It should be noted that 12 clutches were relocated within 12 h of egg-laying as they were susceptible to flooding if left in situ. We investigated the possible influence of nest relocation on: (1) the emergence period, (2) the daily emergence pattern, (3) the number of hatchlings per emergence and (4) the timing of emergences.

Regarding the emergence period, the means of the above mentioned measurements were compared for two groups: one with relocated nests, and the other with non-relocated nests. Second, we counted the number of hatchlings per emergence day in both groups to compare their daily emergence pattern. To study the influence on the daily emergence pattern, all the hatchlings emerged between the 7th day and the 11th were put together in only one group for homogeneity of sample size in the analyses, as above. Third, the mean number of hatchlings per emergence in both relocated and non-relocated nests was compared. Finally, to study the temporal pattern of emergences, the mean number of hatchlings per hourly interval for both relocated and non-relocated nests was compared.

Distance from the sea

We also examined the possible influence of the variable distance from the sea on the duration of the emergence period. Flooded nests were excluded from this analysis. We measured the distances from each nest to the high tide line on the day of egg-laying and on the day of excavation using a flexible 30 m tape measure. We used the mean of both measurements for analyses.

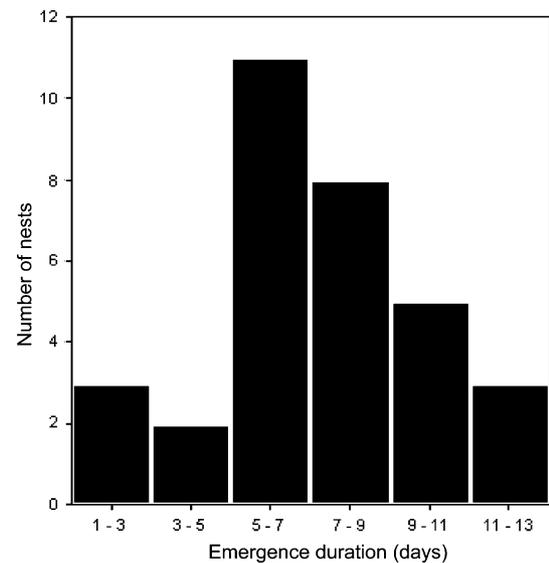


Fig. 1 Emergence period (in days) for the 32 nests analysed

Statistical analyses

In order to assess the relationship between biometric variables and emergence patterns and between nest relocation and the emergence pattern, parametric and non-parametric comparison tests and correlations were run taking into account the normality of the distributions and homogeneity of the variances.

For the daily emergence pattern analysis, the total number of hatchlings per day was compared in both samples through a matched samples non-parametric test (Wilcoxon). The Wilcoxon test was also used to analyse the effect of relocation on the number of hatchlings per emergence.

We also explored the effect of the distance from the sea on the emergence pattern and the effect of relocation on the timing of the hatchlings emergence. A 5% significance level was assumed throughout the analysis.

Results

Emergence pattern

Figure 1 shows the duration of the emergence period (in days) for the 32 nests (mean = 6.7, SD = 2.6, range = 1–11). For 27 nests, the hatchlings emerged for more than 4 days.

A total of 2,555 hatchlings emerged from the 32 nests studied. When we investigated the daily emergence pattern, we found that 61% of the hatchlings emerged on the first day of emergence (mean = 49

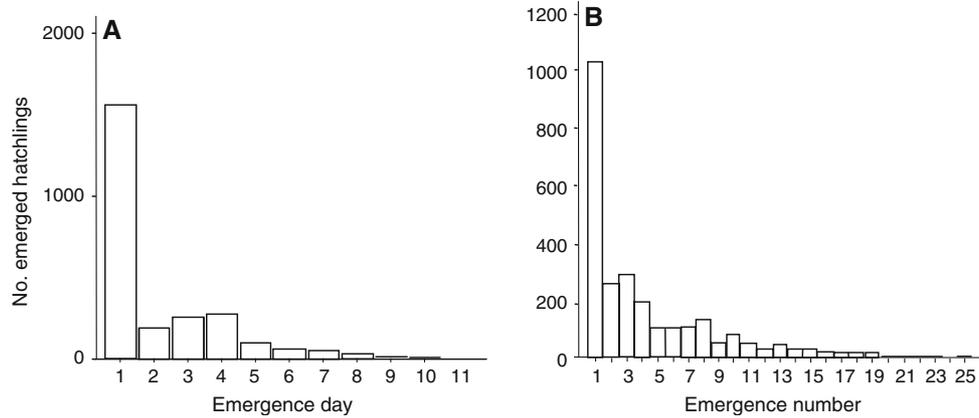


Fig. 2 **a** Total number of emerged hatchlings in each day of emergence of the 32 nests analysed. **b** Total number of emerged hatchlings in each emergence event of the 32 nests analysed

hatchlings/nest), 28% between the second and the fourth day (mean = 8 hatchlings/nest), and 11% after the fifth day (Fig. 2a).

The mean number of emergence events per nest was 11.8 (SD = 6.1, range = 1–25). When considered as a whole, the first emergence of hatchlings from a given nest was typically the largest one (mean = 32 hatchlings/nest), followed by the emergences from the second to the fourth day (mean = 8 hatchlings/nest grouping the second, third and fourth emergence) (Fig. 2b). The highest value of emergence events was found on the first day (mean = 3.4 emergences/nest).

The temporal pattern of the emergences is shown in Fig. 3. Only 3% of the hatchlings emerged, in daylight, between 07:30 and 20:00. After setting the boxes, 37% of the hatchlings emerged between 20:00 and 23:00 (mean = 10 hatchlings/h per nest). Between 23:00 and 01:00, 26.7% of the hatchlings emerged producing the highest emergence rate (mean = 11 hatchlings/h per nest). Finally, 33.3% of the hatchlings emerged between 01:00 and 07:30 (mean = 4 hatchlings/h per nest).

Relation of biometric variables and emergence pattern

The means values of the biometric parameters for the hatchlings measured in 27 nests were as follow: mean weight = 15.7 ± 1.7 (range: 10–21 g); mean SCL_{\min} = 4.1 ± 0.2 (range: 3.2–4.6 cm); mean SCW_{\max} = 3.2 ± 0.1 (range: 2.7–3.7 cm) ($N = 1,089$). We found no significant relationship between the duration of the emergence period and hatchling weight (Spearman correlation, $R_s = -0.093$, $P = 0.644$), SCL_{\min} (Spearman correlation, $R = -0.2$, $P = 0.3$) or SCW_{\max} (Spearman correlation, $R = -0.4$, $P = 0.1$). The means of the biometrical measures amongst days were compared by a Kruskal–Wallis non-parametric test. No significant differences were found either in the variable SCL_{\min} (Kruskal–Wal-

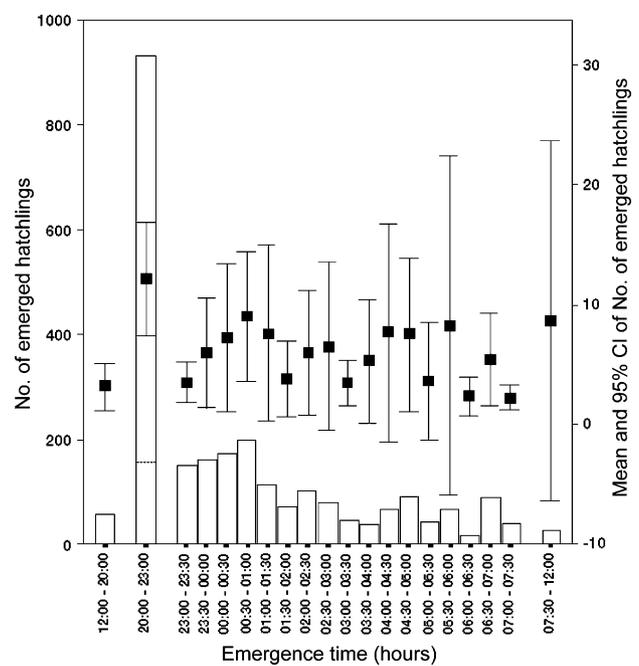


Fig. 3 Temporal pattern of emergences. Broken line in the second column shows the mean of emerged hatchling per half hour

lis, $\chi^2 = 11.8$, $df = 7$, $P = 0.1$) or in weight (Kruskal–Wallis, $\chi^2 = 13.4$, $df = 7$, $P = 0.063$) according to the day of emergence. However, there were significant differences when we compared the SCW_{\max} across days of emergence (Kruskal–Wallis, $\chi^2 = 27.6$, $df = 7$, $P < 0.001$). A post hoc comparison showed that wider hatchlings tend to emerge in the first day of emergence, however, there was no clear trend in subsequent days.

Relocation

The mean duration of the emergence period in relocated nests was 1.8 days higher than in non-relocated nests, although the differences were not

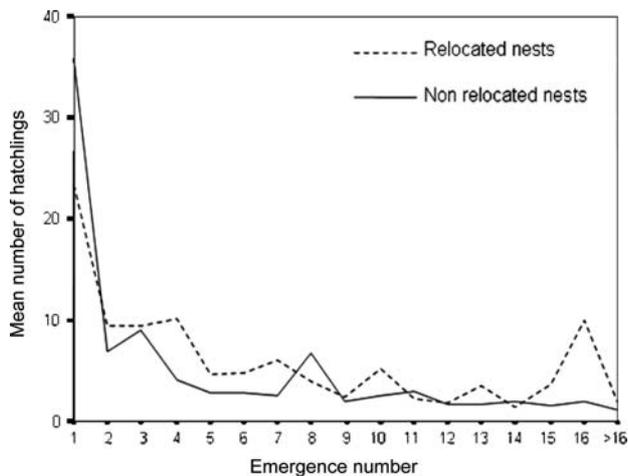


Fig. 4 Mean number of hatchlings per emergence in relocated and non-relocated nests

significant (t -test, $t = -1.9$, $df = 30$, $P = 0.07$). Moreover, no significant differences were observed in the number of daily-emerged hatchlings between relocated and non-relocated nests (Wilcoxon test, $P = 0.3$).

In non-relocated nests, the mean number of emergence event per nest was 10, whereas in relocated nests it was 15. Although no significant differences were found in the mean number of hatchlings per emergence between relocated and non-relocated nests (Wilcoxon test, $P = 0.05$), the non-relocated ones seemed to have less hatchlings in the first emergence and a more extended emergence period (Fig. 4).

Finally, we found no significant differences between relocated and non-relocated nests concerning the hourly emergence pattern (t -test, $t = -2.6$, $df = 20$, $P = 0.8$).

Distance from nests to the sea

We found a negative relationship between the duration of the emergence period and the distance from the nest to the high tide line (Pearson correlation, $R = -0.4$, $P = 0.045$). Thus, the emergence period was shorter in nests that were furthest from the sea.

Discussion and conclusions

The emergence pattern of hatchlings has been studied in different sea turtle species (e.g., Mrosovsky 1968; Moran et al. 1999; Drake and Spotilla 2002; Glen et al. 2005). It has been observed that loggerheads hatchlings do not always emerge simultaneously from the nest; rather, they do so in different groups and even on different days (Hays et al. 1992; Peters et al. 1994; Glen et al. 2005).

Results obtained in the present study show long-lasting emergence periods, similar to the ones obtained in Cephalonia, Greece (mean = 8.3 days, Hays et al. 1992). Houghton and Hays (2001) suggested that differences in incubation temperatures between the upper and lower part of nests result in differences in the embryonic development rate inside the nest, thus explaining asynchrony in the emergence pattern. Mass emergence from the nest is facilitated by the hatchlings' synchronised movements during their climb to the surface (Carr and Hirth 1961). However, this cooperation can also occur within small groups of individuals when there is asynchrony in the emergence (Houghton and Hays 2001). Although it is expected that natural selection favours few emergences with a high number of hatchlings (Glen et al. 2005), asynchrony in the emergence pattern and smaller emergence groups can be positive for survivorship, since it has been shown that aquatic predation is lowered when the number of hatchlings being released into the sea at any one time is decreased (Wyneken et al. 1998; Pilcher et al. 2000 in Glen et al. 2005).

In the present study, a high percentage of hatchlings (61%) emerged during the first night, which is higher than previous investigations in the same area (39.7%; Rees 2005). These differences may be due to variability in nest management, circumstances affecting incubation temperature and sample size. However, both emergence values are far lower than that reported for the same species from the northern coast of Cyprus (>80%; Glen et al. 2005). We propose two possible explanations: (1) Glen et al. (2005) reported high sand temperatures (see below), which reduce incubation duration, and we could expect that shorter incubation periods will favour synchrony in the emergence (see below). However, Glen et al. (2005) found a negative relationship between incubation duration and emergence duration, possibly caused by inhibition of hatchling movement at very high temperatures. The air temperature profile during the nesting season in Kyparissia (Rees et al. 2002) suggests lower sand temperatures and longer incubation periods than in north Cyprus. It is possible that the existence of within-nest thermal variation, which negatively affects synchronised hatchling emergence, becomes more apparent with longer incubation periods. Further work is necessary in order to determine these relationships and their effect on synchrony of hatchling emergence. (2) Glen et al. (2005) reported high levels of predation of hatchlings on beach by foxes and ghost crabs. Foxes and feral dogs also predate on hatchlings at Kyparissia beaches, whereas ghost crabs are not present in the Bay (A.F. Rees, Personal Obs.). It could be possible

that the higher synchrony reported in Cyprus is an adaptation to minimise the effect of predation by crabs. These comparative results reveal the importance to monitor emergence patterns through different nesting seasons and in diverse nesting areas in order to determine common patterns and factors affecting them.

We observed that daytime emergences were very scarce and occurred after rainy nights, during the subsequent cooler days. Most of the hatchlings emerged between 00:30 and 01:00. These results are consistent with the previous work in the same area (Rees 2005), but contrast with emergence timing reported in the northern coast of Cyprus, between the 02:00 and the 03:30 (Glen et al. 2000). Sand temperature is the main factor affecting hatchling emergence (Mrosovsky 1968; Witherington et al. 1990; Hays et al. 1992; Drake and Spotilla 2002). Night-time emergences keep hatchlings away from the desiccating effects of high temperatures and solar rays (Hays et al. 1992). Furthermore, emerging at night, hatchlings can avoid aerial predation. Diurnal predation of hatchlings by crows and gulls has been observed in Kyparissia Bay (Margaritoulis and Rees 2001). Hatchling emergence during daytime is generally believed to be due to either sudden changes in temperature or the decrease in sand-temperature in cooler days, after heavy rain (Mrosovsky 1968; Witherington et al. 1990), although there are exceptions (Glen et al. 2005). Determining timing of emergences is useful in order to increase nest monitoring at the times with greater number of emergences in order to optimize resources in future conservation strategies.

Although our study does not provide any differences with regard to the variables SCL_{min} and weight on successive emergence days, there is a significant difference in the variable SCW_{max} among different emergence days. However, despite finding wider hatchlings in the first emergence, a clear trend is not found when carrying out the post hoc analysis among successive emergence days. Peters et al. (1994) observed that smaller hatchlings experienced more difficulty in emerging, whereas Hays et al. (1992) did not find any differences in hatchlings size between the first and the last emergence days. Glen et al. (2000) observed no differences concerning width, length and weight of hatchlings that emerged during different nights. It is possible that size affects the hatchling emergence pattern, but to a lesser extent than other factors, such as the location of the egg in the nest and, consequently, the incubation temperature (see Glen et al. 2005).

Clutch relocation remains a somewhat controversial practice in sea turtle conservation since it involves a high degree of manipulation of nests and alteration of natural conditions of incubation. Although more evidence is

needed, we observed some effect of relocation on the emergence pattern of hatchlings: firstly, hatchlings in relocated nests emerge in smaller groups, particularly in the first emergence. Second, relocated nests show longer emergence periods (Fig. 4). The unusual egg arrangement within the nest that may be caused by artificial manipulation can modify incubation conditions such as within nest temperature, which can influence resulting emergence patterns (see above). Consequently, to minimise the effect on incubation conditions, it is important that eggs in relocated nests are placed in a manner that closely mimics the original nest.

The nests nearest to the sea experience differences in humidity and temperature compared to the furthest nests. The present study found a significant negative correlation between the duration of the emergence period and distance from the sea. Incubation conditions seem to be more uniform in nests more distant from the sea. However, further research, such as studies with in-nest temperature logging, are necessary to explain this relationship.

To sum up, factors such as climate conditions, relocation and distance from the sea may have some effect on the emergence pattern of hatchlings. They should therefore be taken into account in management plans of beaches, e.g. to prolong the time period between the first emergence and the excavation of nests to study hatching success, and also to focus monitoring efforts on the hours at which the number of emergences is at a maximum.

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References

- Bolten AB (1999) Techniques for measuring sea turtles. In: Eckert KL, Bjorndal KA, Abreu-Grobois FA, Donnelly M (eds) Research and management techniques for the conservation of sea turtles. IUCN/SSC marine turtle specialist group publication no. 4, pp 110–114
- Boulon RH (1999) Reducing threats to eggs and hatchlings: in situ protection. In: Eckert KL, Bjorndal KA, Abreu-Grobois FA, Donnelly M (eds) Research and management techniques for the conservation of sea turtles. IUCN/SSC marine turtle specialist group publication no. 4, pp 169–174
- Carr A, Hirth H (1961) Social facilitation in green turtle siblings. *Anim Behav* 9:68–70

- Drake DL, Spotilla JR (2002) Thermal tolerances and timing of sea turtles hatchling emergence. *J Therm Biol* 27:71–81
- Glen F, Godley BJ, Broderick AC, Furness RF (2000) Patterns of emergence of hatchling loggerhead and green turtles in northern Cyprus, eastern Mediterranean. In: Abreu-Grobois FA, Briseño-Dueñas R, Marquez-Millan R, Sarti-Martinez L (eds) Proceedings of the 18th international sea turtle symposium. NOAA technical memorandum NMFS-SEFSC-436, pp 224–227
- Glen F, Broderick AC, Godley BJ, Hays GC (2005) Patterns in the emergence of green (*Chelonia mydas*) and loggerhead (*Caretta caretta*) turtle hatchlings from their nests. *Mar Biol* 146:1039–1049
- Hays GC, Speakman JR, Hayes JP (1992) The pattern of emergence by loggerhead turtle (*Caretta caretta*) hatchlings on Cephalonia, Greece. *Herpetologica* 48(4):396–401
- Houghton JDR, Hays GC (2001) Asynchronous emergence by loggerhead turtle (*Caretta caretta*) hatchlings. *Naturwissenschaften* 88:133–136
- Margaritoulis D, Hiras G, Pappa C, Voutsinas S (1996) Protecting loggerhead nests from foxes at the Bay of Kiparissia, Western Greece. In: Keinath JA, Barnard DE, Musick JA, Bell BA (eds) Proceedings of the 15th annual workshop on sea turtle biology and conservation. NOAA technical memorandum NMFS-SEFSC-387, pp 188–190
- Margaritoulis D, Rees AF (2001) The loggerhead turtle, *Caretta caretta*, population nesting in Kyparissia Bay, Peloponnesus, Greece: results of beach surveys over seventeen seasons and determination of the core nesting habitat, vol 24. *Zoology in the Middle East*, Heidelberg, pp 75–90
- Marine Turtle Specialist Group (1996) *Caretta caretta*. In: IUCN 2006. 2006 IUCN red list of threatened species
- Moran KL, Bjorndal KA, Bolton AB (1999) Effects of the thermal environment on the temporal pattern of emergence of hatchling loggerhead turtles (*Caretta caretta*). *Mar Ecol Prog Ser* 189:251–261
- Mrosovsky N (1968) Nocturnal emergence of hatchling sea turtle: control by thermal inhibition of activity. *Nature* 220:1338–1339
- Peters A, Verhoeven KJF, Strijbosch H (1994) Hatching and emergence in the Turkish Mediterranean loggerhead turtle, *Caretta caretta*: natural causes for egg and hatchling failure. *Herpetologica* 50(3):396–373
- Pilcher NJ, Enderby S, Stringell T, Bateman L (2000) Nearshore turtle hatchling distribution and predation in Sabah, Malaysia. In: Kalb H, Wibbels T (eds) Proceedings of the 19th annual symposium on sea turtle conservation and biology. NOAA technical memorandum NMFS, vol 443, pp 27–29
- Rees AF, Tzovani E, Margaritoulis D (2002) Conservation activities for protection of the loggerhead sea turtle (*Caretta caretta*) in Kyparissia Bay, Greece, during 2001. *Testudo* 5(4):45–54
- Rees AF (2005) A preliminary study emergence pattern of loggerhead hatchlings in Kyparissia Bay, Greece. In: Coyne MS, Clarke RD (eds) Proceedings of the 21st annual symposium on sea turtle biology and conservation, NOAA technical memorandum NMFS-SEFSC-528, pp 290–291
- Richardson JI (1999) Priorities for studies of reproduction and nest biology. In: Eckert KL, Bjorndal KA, Abreu-Grobois FA, Donnelly M (eds) Research and management techniques for the conservation of sea turtles. IUCN/SSC marine turtle specialist group publication no. 4, pp 9–11
- Witherington BE, Bjorndal KA, McCabe CM (1990) Temporal pattern of nocturnal emergence of loggerhead turtle hatchlings from natural nests. *COPEIA* 4:1165–1168
- Wyneken J, De Carlo L, Glenn L, Salmon M, Davidson D, Weege S, Fisher L (1998) On the consequences of timing, location and fish for hatchlings leaving open beach hatcheries. In: Byles R, Fernandez Y (eds) Proceedings of the 16th annual symposium on sea turtle biology and conservation. NOAA technical memorandum NMFS, vol 412, pp 155–156