Regional Studies in Marine Science 44 (2021) 101758

Contents lists available at ScienceDirect

Regional Studies in Marine Science

journal homepage: www.elsevier.com/locate/rsma

Nesting activity of loggerhead turtles (2013–2020) and 20 years abundance trend (2001–2020) on Çıralı Beach, Turkey

Bektaş Sönmez [a,*], Erdal Elginöz [b], Mustafa Ilgaz [b], Habib Altınkaya [b]

[a] Sivas Cumhuriyet University, Suşehri Timur Karabal Vocational School, 58600, Suşehri, Sivas, Turkey
[b] Ulupınar Environmental Protection, Development and Administration Cooperative, Ulupınar Villiage, Çıralı Centre, 07980 Kemer, Antalya, Turkey

ARTICLE INFO

Article history:
Received 9 December 2020
Received in revised form 16 March 2021
Accepted 16 March 2021
Available online 25 March 2021

Keywords:
Çıralı
Olympos
Loggerhead turtle
Nesting trend
Conservation

ABSTRACT

Long-term monitoring studies on sea turtles give reliable data on population size and nest density estimates. In this context, this study provides reliable data about nesting and hatching activities of the loggerhead turtle on Çıralı Beach based on an eight year (2013–2020) monitoring period. Moreover, the study evaluates long-term nesting trends over the years 2001–2020. A total of 852 nests with a mean of 107 nests per season was recorded during 2013–2020 on the Çıralı Beach. A total of 68,443 eggs were deposited and 41,080 (60%) of them were hatched, and 37,830 of the hatchlings (92%) were able to reach the sea. The mean clutch size and hatching success were 81.9 eggs and 60%, respectively, and show interannual variation. The mean incubation duration was 47.4 days, and show similarity across years. The loggerhead turtle nest tended towards an upward trend over the 20 consecutive years. Moreover, the current nesting population size of Çıralı loggerhead turtles are estimated as 96 females based on the clutch frequency calculation. This upward trend may raise from the nesting shift from the Tekirova beach. Çıralı sea turtle conservation activity has an exemplary practice in terms of supporting the local community with conservation activities during nesting seasons.

1. Introduction

Biological diversity, generally referred to as species diversity, is one of the main topics of ecology. The degree and scale of the risk of extinction in the marine area facing the biodiversity problem are poorly characterized (McClenachan et al., 2012). Therefore, conducting species conservation studies are important for the conservation of biodiversity in a region. Charismatic species especially present the best scenario regarding the status of marine biological diversity, and are likely to receive the greatest support for conservation efforts (McClenachan et al., 2012). The loggerhead turtle (*Caretta caretta*), one such charismatic species, is categorized as "Vulnerable" (VU) globally (Casale and Tucker, 2015), while the Mediterranean subpopulation is categorized as the "Least Concern" (LC) (Casale, 2015) according to the International Union for Conservation of Nature (IUCN).

The detailed sea turtle conservation efforts along the Mediterranean coast of Turkey began with the determination of the presence of nesting beaches in 1988. In this report, 17 nesting beaches were identified for both *C. caretta* and *Chelonia mydas* (Baran and Kasparek, 1989). Çıralı Beach was not included among the 17 nesting beaches due to very low nesting activity (only 4 emergences were reported). Taking the Tekirova beach, which is adjacent to the Çıralı Beach, into tourism investments within the framework of the South Antalya Tourism project, caused the shifting of the protection and monitoring activities on this beach to the Çıralı Beach (Oruç et al., 2007). After this, the priority was given to Çıralı Beach instead of Tekirova, and was reported to be an important nesting beach in 1994 (Yerli and Demirayak, 1996). From that year to the present, monitoring and protection activities are carried out regularly every year. However, the last report was published in 2010, and in this report, data just on 2010 monitoring and protection activities are presented (Durmuş and Oruç, 2010).

Turkey, as well as Greece, Libya and Cyprus, are the countries with the densest loggerhead turtle nesting activity in the Mediterranean, and Turkey has the second most important stock based on nest numbers (Margaritoulis et al., 2003). It was estimated that the average annual number of loggerhead nest is 1366 nest/season (Margaritoulis et al., 2003). Similarly, Türkozan et al. (2003) estimated 1267 loggerhead nests (ranging 663–1991) per season on the Mediterranean coast of Turkey. Another estimation of loggerhead nests on the Mediterranean coast of Turkey is 2000 nests/season for loggerhead turtle (Canbolat, 2004). Kaska et al. (2005) estimated 1360–2710 loggerhead turtle nests on Turkish beaches. It was estimated that loggerhead turtle nest numbers ranged from 769 to 3521 nests throughout the Mediterranean coast of Turkey (Türkozan and Kaska, 2010). In the recent review,

* Corresponding author.
E-mail addresses: bektass@gmail.com, bsonmez@cumhuriyet.edu.tr (B. Sönmez).

https://doi.org/10.1016/j.rsma.2021.101758
2352-4855/

it is stated that an average of 8179 loggerhead turtle nests per year are recorded in the entire Mediterranean in the most recent 5-year period, and 2822 of them were reported to be on the coast of Turkey (Casale et al., 2018). Also, besides the number of nests, the sea turtle conservation studies in Turkey have been diversified. For instance, the important studies that play a key role in the conservation of sea turtles have been carried out on sex ratio, genetics, predation, nest conservation and morphology (Türkozan and Yılmaz, 2008; Yılmaz et al., 2011; Kılıç and Candan, 2014; Sönmez, 2018a, 2019).

The continuous long-term annual monitoring activity is proposed to produce reliable and realistic solutions against special problems in all sea turtle nesting beaches (Yalçın Özdilek, 2007). In addition, population size and nest density estimates that are not based on long-term annual monitoring studies may give misleading results (Gerosa et al., 1998), because annual variations in weather conditions can cause fluctuations in the number of nests (Broderick et al., 2001), which causes a biased calculation of the population. Thus, a long-term and comprehensive study will provide important contributions to the loggerhead population on the Turkish coast of the Mediterranean. Therefore, this study aimed to provide reliable data about nesting and hatching activities of the loggerhead turtle, including temporal distribution, incubation duration, hatching and nesting success on Çıralı Beach based over an eight year (2013–2020) monitoring period. Furthermore, it was aimed to evaluate long-term nesting trends and abundance between the years of 2001–2020. The answers to questions such as what percentage of the Mediterranean population it represents, whether there are any differences in abundance, in nesting time, in clutch size, in incubation duration and in hatching success will be provided. Accordingly, the results of the last eight seasons will be compared with previous studies and a discussion on their relative importance and to evaluate their current state will be provided.

2. Materials and method

2.1. Study site

The study site is the Çıralı Beach, which is located within the borders of the Kemer district of Antalya province. It is approximately 3.2 km long and its width is between 50–100 m (Fig. 1). Çıralı is also located within the boundaries of Beydağları (Olympos) the Coastal National Park, as well as being a 1st Degree Nature Reserve (Durmuş and Oruç, 2010; Türkozan and Kaska, 2010). There is a rock formation in the southern and northern edges of the beach that borders the beach in both directions. Çıralı Beach consists of a low and horizontally stretched low coastal area and a sandy high coastal area, gradually rising towards the land.

2.2. Data collection

Data was collected on the nesting ecology of loggerhead turtles on Çıralı Beach over eight nesting seasons (2013–2020). The data includes number of nests, temporal nesting distribution, incubation duration (ID), hatching success, hatching and hatchling survival, and clutch size (CS). The study was conducted from the end of April to end of September, and the beach was monitored by three people every morning. The nesting emergence was recorded, and nest locations were determined from the egg chamber using a metal stick. Each nest was excavated 3 or 5 days after last hatchling emerged, and the remains examined. The numbers of dead hatchlings, dead embryos and unhatched eggs were recorded. The dead hatchling free of the eggshell was considered as hatched and recorded as a dead hatchling. Dead hatchlings

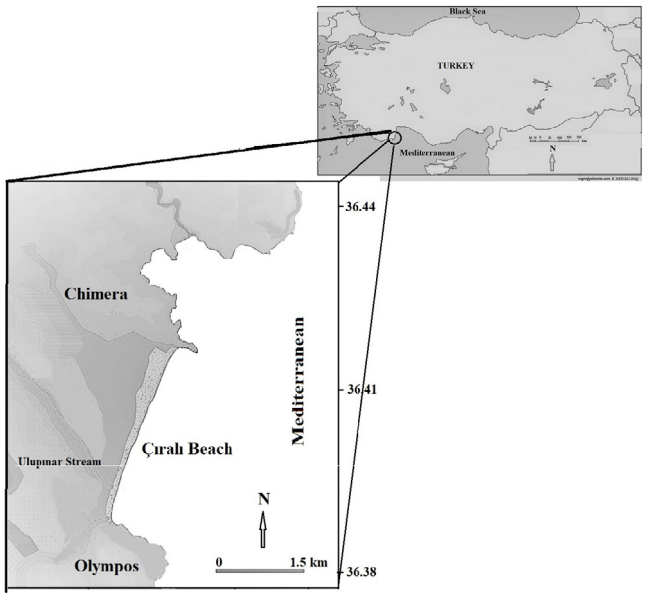

Fig. 1. The location of the Çıralı Beach on the Turkish coast (highlighted area with the circle shows the survey location).

that had pipped but had not emerged from the eggshell were considered as dead embryos (Matsuzawa et al., 2002). The CS was determined by counting the number of unhatched eggs (including dead embryos) and hatched eggs. The success of reaching the sea of the hatchlings were counted daily with the tracks emanating from nests, and the numbers of hatchlings reaching the sea were determined. The hatching success was calculated as a percentage of the hatched egg number to clutch size. Nest density was calculated as the ratio of the total number of nests to the beach length. The ID of nests was calculated as the time between the day the egg was laid and the day the first hatchlings emerged. Moreover, the number of nests from 2001 to 2020 was compiled to evaluate relative changes in nesting numbers over the years, derived from previously collected and/or published data.

The number of nesting females based on clutch frequency (CF) was calculated with the three different studies previously published in the Mediterranean, because no published data on the clutch frequency of the loggerheads nesting in Çıralı Beach are available. Firstly, the number of females were estimated based on the observed clutch frequency (OCF) proposed by Baran and Türkozan (1996) for the Fethiye nesting beach in Turkey (OCF-1). They estimated that mean CF is 1.4 nests per female, and ranging from 1 to 3. Secondly, the number of females were estimated with the OCF proposed by the Broderick et al. (2002) for the Alagadi beach in Cyprus (OCF-2). They estimated that the mean CF is 1.8 nests per female, and ranging between 1.5 and 2.1. Lastly, the number of females were estimated with the estimated clutch frequency (ECF) proposed by the Rees et al. (2020) for Kyparissia Bay in Greece. They estimated that the mean CF is 3.8 nests per female, and ranging from 2 to 5. Further to the mentioned above CF values, the remigration interval (RI) was considered as 2 years for the populations in the Mediterranean region (Broderick et al., 2002). Thus, the total nesting female numbers (FN) were calculated with the following formula:

$$FN = Total\ Nest\ Number/CF * (Total\ Years/RI)$$

The current female numbers (CFN) in the last two nesting seasons (2019 and 2020) were calculated following formula;

$$CFN = (Mean\ Nest\ Number/CF) * RI$$

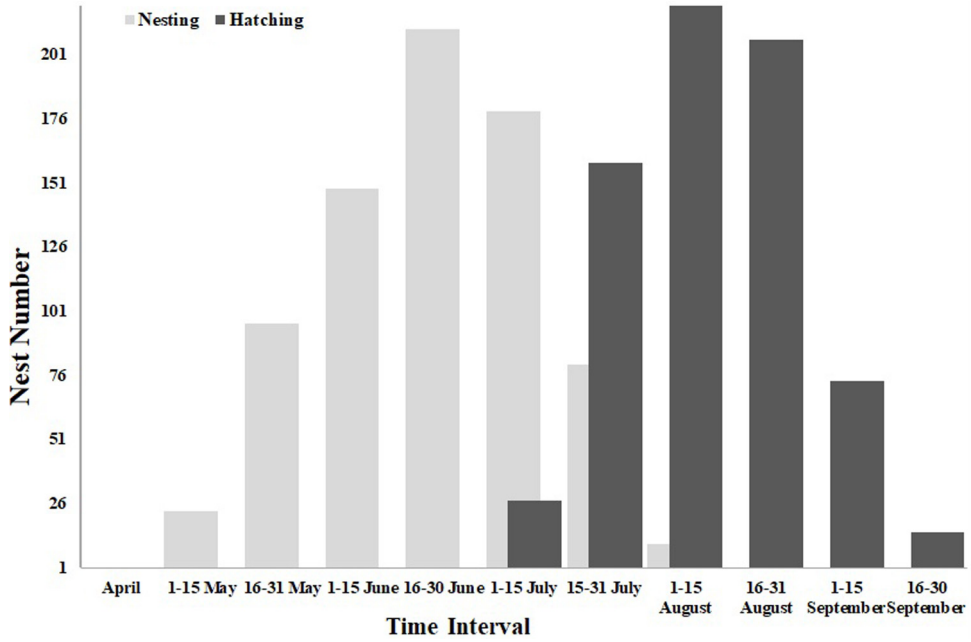

Fig. 2. The temporal distributions of loggerhead turtle nests and emergence of hatchlings on Çıralı Beach during the 2013–2020 nesting seasons.

Decimal fractions have been rounded up one number for both calculations.

2.3. Statistical analysis

The nesting data were not normally distributed in accordance with Levene's and Kolmogorov–Smirnov tests ($p < 0.05$). Therefore, non-parametric tests were used. The mean CS, hatching success and ID across years were compared with the Kruskal–Wallis H test in the IBM SPSS Statistics 20 software program.

The trend analysis for the nest numbers across the years were performed by means of nonparametric, and the non-seasonal Mann–Kendall Trend test (Hipel and McLeod, 1994). The Mann–Kendall trend test has been used in the long-term examination of sea turtles (da Silva et al., 2007; Marcovaldi et al., 2007; Sönmez, 2018b, 2019). In addition, the Theil–Sen regression and 95% confidence intervals were used to predict the regression constants based on the Mann–Kendall Trend test and Kendall correlation coefficient (Sen, 1968). The Mann–Kendall test is based on the calculation of Kendall's tau measure of association between two samples, which is based on the ranks within samples. The computations assume that the observations are independent and data are randomly ordered. However, the existence of positive autocorrelation in the data increases the probability of detecting trends when actually no trends exist or vice versa. Autocorrelation is the similarity of a time series over successive time intervals. It can lead to underestimation of the standard error and predictors can appear as significant when they are not. The presence of autocorrelation in the residuals of the regression models was tested using the Durbin–Watson statistic. The trend test was carried out using the XLSTAT 2018 statistical software (Addinsoft, NY, USA). All means are presented with ± SD and min–max.

3. Results

3.1. Nesting activity

In total, 1750 loggerhead turtle emergences were recorded, with 852 (48.7%) resulting in nesting during the 2013–2020 nesting seasons. The mean number of nestings were 107, ranged from 75 to 151 nests, and the mean nest density was 33.3 nests km^{-1} and ranged from 23.4 to 47.2 nests km^{-1}. The temporal distribution of the loggerhead turtle nests during 8 nesting seasons is shown in Fig. 2. The peak of nesting occurs from the last half of June (15–30 June) to the first half of July (1–15 July), and covered 54% of the total nestings. The first nest recorded was on April 29, 2018, and the last nest was recorded on 13 August 2017. The mean duration of the nesting period from first to last nesting was 83 days ranging from 76 days to 102 days. The temporal distribution of emergence of hatchlings during the 8 nesting seasons is shown in Fig. 2. The peak of hatchling emergences occurred in August and covered 61% of the total. The first hatchlings emerged on 26 June in the 2018 nesting season, and the last hatchlings occurred on 26 September in the 2017 nesting season. The mean hatching period was 67 days ranging from 56 days to 83 days.

A total of 68,443 eggs were deposited in 836 excavated loggerhead turtle nests, with a mean clutch size of 82 ±19.8 eggs. The maximum clutch size was 153 eggs in 2017, and the minimum clutch size was 10 eggs in 2014. Of these, 13,037 (19.1%) were found as dead embryos and 14,326 (20.2%) as unhatched eggs. Of the total eggs, 41,080 (a hatching success of 60%) were produced hatchlings, 37,830 of which (92%) were able to reach the sea. In addition, the total number of hatchlings reaching the sea as a percentage of the total egg numbers was 55.3%. Interannual variations of the CS, hatching success and survival are shown in Table 1. The mean clutch size showed differences among the years (Chi-Square = 35.615, df = 7, p = 0.001), and the years of 2017 and 2018 have a higher mean clutch size (see Table 1 for details). In addition, the hatching success rate showed differences among the years (Chi-Square = 85.577, df = 7, p = 0.001). This difference is due to the years 2016, 2018, 2019 and 2020 having lower hatching success rates (see Table 1 for details).

The ID of 706 nests was calculated in total, except for the 2013 nesting season. The overall mean ID was 47.4 (±4.24) days. The maximum ID was 74 days in 2018, and the minimum ID was 41 days in 2014, 2015 and 2020 nesting seasons. The mean ID showed similarity across the years ($P > 0.005$), and interannual variation of ID with a 95% confidence interval is shown in Fig. 3.

Table 1
Interannual variations of hatching success and hatchling survival of loggerhead turtle on Çıralı Beach between 2013–2020 nesting seasons.

Nesting seasons	n	Total egg number	Mean clutch size	Dead Embryo	Unhatched eggs	Hatched eggs	Dead hatchlings	Hatchlings reach to the sea	Hatching success (%)
2013	102	7911	77.5	839	1261	5811	356	5455	73.5
2014	87	6609	76	969	1107	4533	227	4306	68.5
2015	104	8451	81.2	1260	1294	5897	266	5631	89.8
2016	136	11 195	82.3	2770	3013	5412	378	5034	48.3
2017	75	6855	91.4	1228	1044	4583	322	4261	67
2018	151	12 696	85.7	2630	2505	7561	899	6662	59.6
2019	84	7005	83.3	1511	1840	3654	350	3304	52.2
2020	100	7721	77.2	1830	2262	3629	452	3177	47
Total	**836**	**68 443**	**82**	**13 037**	**14 326**	**41 080**	**3250**	**37 830**	**60**

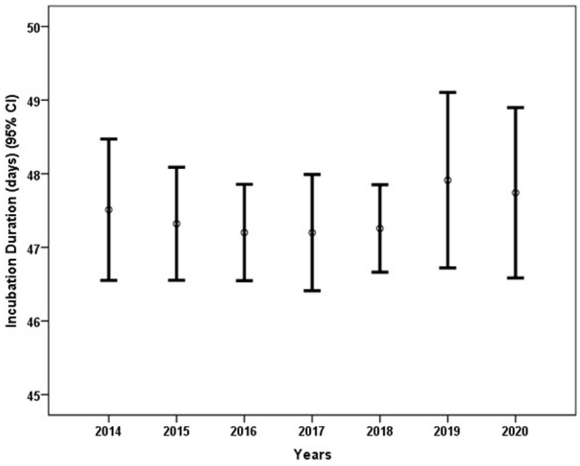

Fig. 3. Interannual variation of loggerhead turtle incubation duration on Çıralı Beach during a 7 year period (95% confidence interval in error-bar plot).

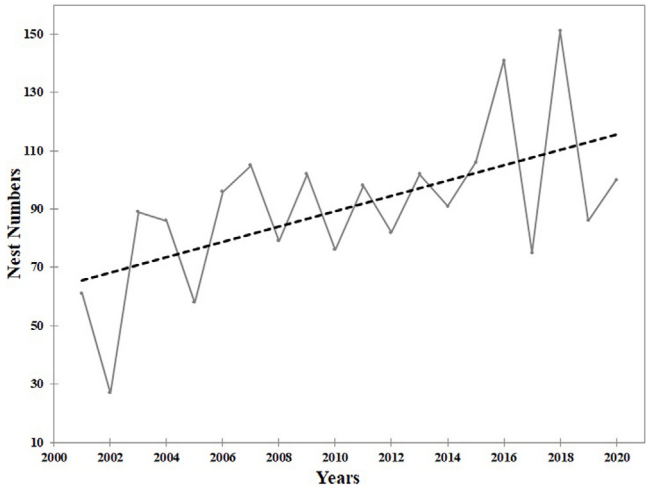

Fig. 4. The temporal trend in the number of loggerhead turtle nests over 20 consecutive years on the Çıralı Beach (Dashed line is Theil–Sen trend line).

3.2. Nesting trend and abundance

A total of 1811 loggerhead turtle nests were recorded during 20 consecutive years, with a mean of 90.5 nests per year on the Çıralı Beach. Interannual variations in the nest numbers are shown in Table 2. The number of nests showed an annual fluctuation, which ranged from a minimum of 27 nests in 2002, to a maximum of 151 nests in 2018, with a difference of 459.2%. The Durbin–Watson test showed no autocorrelation for nest numbers in the residuals (U = 3.3078, P = 0.999). The nest numbers in 20 consecutive years showed an upward trend (Fig. 4) (Kendall's tau = 0.3704, n = 20, p = 0.025), and was also supported by Sen's slope (Sen's slope = 2.0263, 95% confidence intervals −15.5 to 18.7).

The estimated numbers of females according to nesting seasons are shown in Table 2. The highest number of females in overall years was estimated by OCF-1 at 1344, followed by OCF-2 with 1045 females and ECF with 495 females. Thus, the average number of females nesting in Çıralı Beach is estimated to be 135 females by OCF-1, 105 females by OCF-2 and 50 females by ECF, with the overall mean being 97 females. The current female number on Çıralı Beach was estimated by OCF-1 with 133 females (being the highest), followed by OCF-2 with 104 females and ECF with 49 females, and with a mean of 96 females. The estimated population size of nesting female in the current year (2019–2020) and overall years (2001–2020) are similar. The temporal variation of the estimated number of nesting females based on three CF values is given in Fig. 5. Although the CF values were for the nesting loggerhead turtle in the Mediterranean, they estimated different numbers of females. OCF-1 estimated the maximum number of nesting female across the years, and ECF estimated the minimum amount of nesting females.

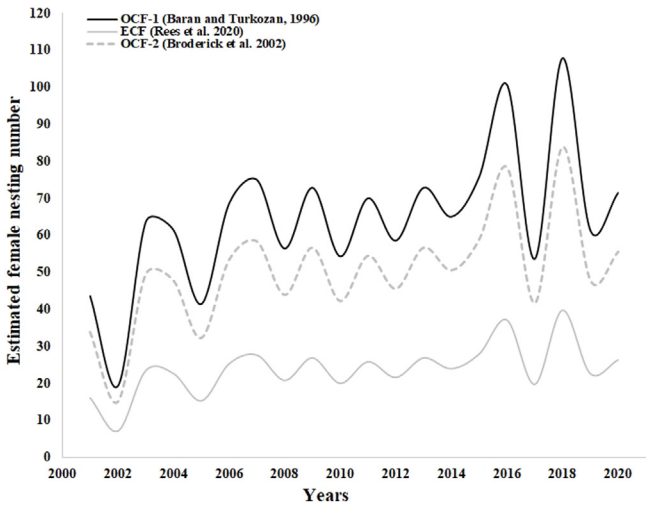

Fig. 5. The temporal change in the estimated number of nesting female loggerhead turtles based on three clutch frequency estimations over the years on Çıralı Beach.

4. Discussion

Previous studies indicated that the mean number of the nest for Çıralı Beach is 51 with a nesting density of the 16 nests km^{-1} between 1994–2006 (Oruç et al., 2007; Türkozan and Kaska, 2010). In addition, in the most recent 5 year period (2006–2010), the mean nest numbers is 86 with a nesting density of the 26 nests km^{-1} (Oruç et al., 2007; Türkozan and Kaska, 2010). As a

Table 2
The number of nests recorded over the years and the estimated number of females based on different clutch frequency studies in the Mediterranean region (the clutch frequency methods are given in material and methods, OCF = observed clutch frequency, ECF = estimated clutch frequency).

Years	Nest number[Reference]	The estimated number of nesting females based on clutch frequency in different studies					
		OCF-1	Max–Min	OCF-2	Max–Min	ECF	Max–Min
2001	61[a]	43.6	61.0–20.3	33.9	40.7–29.0	16.1	30.5–12.2
2002	27[a]	19.3	27.0–9.0	15.0	18.0–12.9	7.1	13.5–5.4
2003	89[a]	63.6	89.0–29.7	49.4	59.3–42.4	23.4	44.5–17.8
2004	86[a]	61.4	86.0–28.7	47.8	57.3–41.0	22.6	43.0–17.2
2005	58[a]	41.4	58.0–19.3	32.2	38.7–27.6	15.3	29.0-11.6
2006	96[a]	68.6	96.0–32.0	53.3	64.0–45.7	25.3	48.0–19.2
2007	105[a]	75.0	105.0–35.0	58.3	70.0–50.0	27.6	52.5–21.0
2008	79[b]	56.4	79.0–26.3	43.9	52.7–37.6	20.8	39.5–15.8
2009	102[b]	72.9	102.0–34.0	56.7	68.0–48.6	26.8	51.0–20.4
2010	76[b]	54.3	76.0–25.3	42.2	50.7–36.2	20.0	38.0–15.2
2011	98[c]	70.0	98.0–32.7	54.4	65.3–46.7	25.8	49.0-19.6
2012	82[c]	58.6	82.0–27.3	45.6	54.7–39.0	21.6	41.0–16.4
2013	102*	72.9	102.0–34.0	56.7	68.0–48.6	26.8	51.0–20.4
2014	91*	65.0	91.0–30.3	50.6	60.7–43.3	23.9	45.5–18.2
2015	106*	75.7	106.0–35.3	58.9	70.7–50.5	27.9	53.0–21.2
2016	141*	100.7	141.0–47.0	78.3	94.0–67.1	37.1	70.5–28.2
2017	75*	53.6	75.0–25.0	41.7	50.0–35.7	19.7	37.5-15.0
2018	151*	107.9	151.0–50.3	83.9	100.7–71.9	39.7	75.5–30.2
2019	86*	61.4	86.0–28.7	47.8	57.3–41.0	22.6	43.0-17.2
2020	100*	71.4	100.0–33.3	55.6	66.7–47.6	26.3	50.0–20.0

[a]Oruç et al. (2007).
[b]Durmuş and Oruç (2010).
[c]Unpublished report that prepared by the Ulupınar Environmental Protection, Development and Administration Cooperative
*This study.

result of these nest densities and nest numbers, Çıralı Beach has been classified as a moderately dense beach (Casale et al., 2018). The fact that the average number of nests in the last eight nesting seasons (2013–2020) in the present study is 107 nests indicates that the Çıralı Beach should be classified as having high nesting activity. This is because Casale et al. (2018) classified nesting beaches based on the number of nests, and stated that a beach with an average number of nests between 100–300 nests year^{-1} should be classified as having high nesting activity.

The mean number of nests for loggerhead turtles ranged between 5031 and 8179 nests/season for the whole of the Mediterranean, and 1267 and 2822 nests/season for Turkish coasts (see introduction for details) (Margaritoulis et al., 2003; Türkozan et al., 2003; Canbolat, 2004; Casale et al., 2018). The 8 years mean number of nests in Çıralı Beach represent the total loggerhead turtle nests in the Mediterranean at rates ranging from 1.3% to 2.1% with a mean of 1.7%, whereas this value ranges between 3.8% and 8.5% with a mean of 6.4% for Turkey's coasts. Canbolat (2004) indicated that the Çıralı Beach has 1.7% relative importance of sea turtle nesting beaches in Turkey according to percentage nesting values. The current nest numbers and the apparent long-term upward trend of the Çıralı population increases the claim that this is an important loggerhead turtle nesting beach.

Reported average nest numbers shows variation among studies, both in the Mediterranean and in the Turkey. Casale et al. (2018) stated that the average number of nests they reported should be considered as a minimum because nesting also occurs in other non-monitored nesting sites, and these are non-reported nests. In this way, the monitoring of nesting beaches and reports of nests are important. It is inevitable that these actual results will contribute to priorities of site specific protection, management such as relocating and/or hatchery localities, reproductive output, predation and beach management programs; because a nesting beach has its own problems that threaten sea turtles. For example, while the exposure of flooding of nests on Samandag beach is the main problem (Sönmez and Yalçın-Özdilek, 2013), mammal predation causes less problems (Sönmez, 2018a). In contrast, mammal predation is the main problem while flooding is not with Dalyan nesting beach in Turkey's western Mediterranean (Türkozan and Yılmaz, 2008).

The temporal distribution of nests is compatible with the previous studies in Turkey and Cyprus (Broderick and Godley, 1996; Türkozan and Yılmaz, 2008). Broderick and Godley (1996) reported that the first nest was recorded on 24 May 1995, and the last nest on 19 August 1995 in Cyprus. Furthermore, Margaritoulis (2005) reported the earliest and the latest nest records as 19 May 2001 and 14 September 1984, respectively for Zakynthos Island, Greece. Türkozan and Yılmaz (2008) gives the earliest nest as 5 May 2004, and the last nest on 15 August 2005 for Dalyan, Turkey. These results show that nesting in Turkey starts and finishes earlier than in Cyprus and Greece. The mean nesting period in Çıralı Beach has a longer period from Cyprus with 79 days (Broderick and Godley, 1996), but shorter than Greece with 87 days (Margaritoulis, 2005) and Fethiye with 95 days (Türkozan and Yılmaz, 2008). The fact that Çıralı Beach is the earliest nesting beach may have been a response to climate change over time, and thus they may have started nesting earlier. Mazaris et al. (2009) stated that the warmer the sea surface temperature (SST) on the foraging grounds in the Mediterranean triggered an earlier start of nesting in loggerhead turtles. Considering that the nearest possible foraging ground to Çıralı Beach is Fethiye Göcek Special Protection Area (approximately 200 km westward) (Baskale et al., 2018), this may be possible. Moreover, it was reported that the projected rise in air and ocean temperature could cause the nesting season of the loggerhead turtle to shift to an earlier date by as much as 50 to 74 days in the Mediterranean by the year 2100 (Patel et al., 2016).

The CS ranges between 70 and 129.1 eggs for the loggerhead turtle in the Mediterranean, including Turkish, Greek, Cypriot and Lebanese nesting populations (Baran and Türkozan, 1996; Broderick and Godley, 1996; Newbury et al., 2002; Margaritoulis et al., 2003; Margaritoulis, 2005; Türkozan and Yılmaz, 2008). The Çıralı Beach has smaller CS than the Greek populations, i.e. 116.5 eggs for Laganas Bay (Margaritoulis, 2005) and 129.1 eggs for Lakonikos Bay (Margaritoulis et al., 2003). It is seen that the Çıralı nesting population has a middle range CS for the Mediterranean. This may be related to differing migration and foraging areas of

the nesting females. Also, considering that the CS and nesting female body size is positively related with each other for Mediterranean loggerhead turtles (Hays and Speakman, 1992), it is seen that the nesting female body size of Çıralı Beach has a medium body size.

The mean hatching success was reported as 71.5% in Laganas Bay, Greece (Margaritoulis, 2005), 79.1% in Northern Cyprus (Broderick and Godley, 1996), 61.7% in Dalyan, Turkey (Türkozan and Yılmaz, 2008), and 68.4% in Fethiye, Turkey (Baran and Türkozan, 1996). The hatching success rate of Çıralı Beach is lower than these beaches mentioned above. The sea turtle embryo can be effected from the micro-environmental condition of the nest during incubation. For instance, saltwater and freshwater exposure of the nest for more than 6 hours can lead to embryonic mortality (Limpus et al., 2020), which means higher mortality resulting as the nest moisture content increases (McGehee, 1990). Furthermore, incubation temperature can affect the mortality rates of the embryos. The higher dead embryos rate was related to maximum incubation temperatures (Kobayashi et al., 2017). There is no available information on the micro-environmental conditions and nest temperatures of nests for Çıralı Beach, neither in this present study nor in previous studies.

The ID showed a variation over the nesting beaches on the Mediterranean, where all of them have a higher ID than Çıralı nesting beach. It was reported that the mean ID for Cyprus is 48 days (Broderick and Godley, 1996) and 55.2 days for Laganas Bay (Margaritoulis, 2005), 52.1 days for Lakonikos Bay (Margaritoulis et al., 2003), 52.3 days for Dalyan (Türkozan and Yılmaz, 2008), 55 days for Fethiye (Baran and Türkozan, 1996) and 50.8 days for Göksu Delta (Candan, 2018). Different temperature profiles and sand features of each nesting beach may have caused variations in ID. Considering that ID and nest temperature are negatively correlated (Mrosovsky and Yntema, 1980), and ID can be used as an index in the sex ratio of hatchlings (Marcovaldi et al., 1997), it can be said that Çıralı Beach produces a higher rate of female hatchlings. Furthermore, the mean ID of Çıralı Beach is well below the pivotal incubation duration of 59.2 days for loggerhead turtles in the Mediterranean (Godley et al., 2001).

Contrary to the upward trend in the number of nests on Çıralı Beach, a downward trend was reported for Fethiye nesting beach, Turkey (Ilgaz et al., 2007), and also for Florida, USA (Witherington et al., 2009). On the other hand, in another study, the numbers of nests over a 19-year period showed neither an upward nor a downward trend for Dalyan nesting beach in Turkey (Türkozan and Yılmaz, 2008). Moreover, Margaritoulis (2005) reported no linear trend over the 19 years in Laganas Bay, Greece. The recent IUCN Red List assessment of the Mediterranean subpopulation reported an increasing trend for the loggerhead turtle (Casale, 2015). This may be a result of long-term conservation activities. As a result of these activities, the 459% fluctuation over 20 years on Çıralı Beach is the highest observed in the region. For instance, a 401% fluctuation over 19 years for Dalyan nesting beach was reported (Türkozan and Yılmaz, 2008), a 229% fluctuation over 13 years for Fethiye beach (Ilgaz et al., 2007), and a 224% fluctuation over 17 years in Kyparissia Bay (Margaritoulis and Rees, 2001). Casale et al. (2018) stated that, compared to before and after 2000, the highest change in the mean number of loggerhead turtle nests in the Mediterranean was in Belek beach with 392%. In the same study, mean nest number change was given as 95% for the Çıralı Beach. However, this rate of change may not reflect the real value because the conservation studies on the Çıralı Beach before 2000 were generally carried out to determine the number of nests in June. After the year 2001, the conservation studies that continue until today are conducted with a same period and by the same team.

The overall nesting female numbers (2001–2020) and current nesting female numbers (2019–2020) are similar; this similarity may indicate that the number of turtles nesting on Çıralı Beach has remained stable over the years or the natality and mortality rate are close to the each other. There might be several explanation on how nest numbers are showing an increasing trend when numbers of nesting female remaining. Firstly, it can be that the CF per female in the Çıralı population may have tended to increase over time or the inter-nesting interval shortened. This can be supported with the earliest nestings occurring on Çıralı Beach. This situation can be attributed to SST due to global climate change. It was stated that higher SST may have induced earlier onset of vitellogenesis (Mazaris et al., 2008), and triggered an earlier start of nesting in loggerhead turtles (Mazaris et al., 2009). Secondly, the increase in CF may be linked to the decrease in CS. The clutches may become smaller but they may have become more numerous, because the Çıralı population has a smaller CS compared to most other nesting beaches in the Mediterranean. The final explantation could be a nesting shift over time between the Tekirova and Çıralı Beaches, which are close to each other. Following the implementation of the South Antalya Tourism project at Tekirova, the nesting activity may have shifted to the Çıralı Beach over time. Similarly, the possible nesting shift was reported by the Türkozan and Yılmaz (2008) for the loggerhead turtle between Dalyan and Fethiye nesting beaches, which are also close to each other

4.1. Implications for conservation and management

It was found that the nesting and hatching periods on Çıralı Beach are earlier than many other nesting beaches. This situation could be a response to global climate change. In the near future, it is strongly recommended to investigate the relationship between the loggerhead turtle nesting phenology and climate change on Çıralı Beach. Although the number of nests in Çıralı Beach has increased, hatching success is lower than many other beaches. In this context, protection measures such as relocation of nests at risky areas where there is low hatching success should be taken to increase the hatchling production of nests. Therefore, it is recommended to carry out spatial analysis of hatching success rates throughout the nesting beach, relocation of the nests, or establishing of a hatchery in areas with the higher hatchling production.

The fact that the nesting population of Çıralı has a mid-range clutch size may be related to body size of nesting females. It is recommend that the relationship between morphology, i.e carapace size and reproductive output of Çıralı nesting population should be investigated in the near future. The shorter ID in Çıralı beach may both increase embryonic mortality and affect the sex ratio and locomotor performance of the hatchlings (Kılıç and Candan, 2014; Reboul et al., 2021). Moreover, considering that shorter ID is associated with higher nest temperature, it is inevitable that it will threaten loggerhead turtle populations. Reboul et al. (2021) reported the positive effect of artificial and natural shading on green turtle hatchlings against rising atmospheric temperatures on the island of Regand, Malaysia. It is recommended to firstly investigate the temperature profiles of the nests, and according to the result, to discuss whether protection measures such as natural or artificial shading are necessary. The increasing trend in the number of nests may bring with it density-related problems such as nest infection (Fish et al., 2008) and destruction of nests by co-specifics (Limpus et al., 2003) in the future. Perhaps new studies can be designed to determine the carrying capacity of Çıralı Beach.

Çıralı Beach is an important touristic area, and therefore, brings some problems such as uncontrolled tourist activities. Thus, effective conservation and management of nesting beaches are not easy, mainly because of the complex relationship between

the biology of sea turtles, socio-economic factors and political interests. It is also possible to encounter some problems such as light pollution, sunbeds and umbrellas, and evening boat tours (especially at full moon time) that threaten sea turtles of Çıralı. Thus, raising awareness and training activities for local and foreign tourists should be provided during the nesting season. In particular, long term and sustainability is the most important factor. Thus, it is recommended that conservation studies continue and are supported within this framework.

Conclusion

The Çıralı Beach has high nesting activity, and contributes to the nesting populations of the Mediterranean by 1.7%, and by 6.4% to the Turkish nesting population. In addition, nesting period earlier on Çıralı Beach, as well as hatchling emergence time.

There is lower hatchings success, hence higher unhatched eggs, and a shorter ID on Çıralı Beach. This could have an impact on sex ratios as well as a negative impact on embryonic mortality. Besides this, the nest number on the Çıralı Beach showed an upward trend between 2001 and 2020. The last, but important conclusion is that Çıralı have an successfully implemented loggerhead turtle conservation activities within the triangle of NGOs, local community and Government. This latest report for Çıralı Beach will not only contribute to the Mediterranean population, but also contribute to the future management plans and conservation strategies of Çıralı Beach.

CRediT authorship contribution statement

Bektaş Sönmez: Conceptualization, Methodology, Software, Writing - review & editing. **Erdal Elginöz:** Conceptualization, Methodology, Software, Investigation, Writing - review & editing. **Mustafa Ilgaz:** Investigation, Writing - review & editing. **Habib Altınkaya:** Investigation, Writing - review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

This study did not receive any specific grant from funding agencies in the public, commercial or not-for-profit sectors. We would like to thank the 6th Regional Directorate of Nature Conservation and National Parks, the Kemer District Governorship, Kemer Municipality and Antalya Metropolitan Municipality as well as the volunteers of Ulupınar Environmental Protection, Development and Administration Cooperative supporting this study: İsmail Tunalı, Faika Nuran Yeşildağ, Güngör Akkelle, Mustafa Köylüoğlu and Şafak Okdemir. We also would like to thank the Çıralı and Ulupınar villagers for their contribution to *Caretta Caretta* turtles, by monitoring and conservation activities at Çıralı Beach.

References

Baran, I., Kasparek, M., 1989. Marine tuftles of Turkey: status survey 1988 and recommendations for conservation and managentent. Heidelberg, pp. l2.

Baran, I., Türkozan, O., 1996. Nesting activity of the loggerhead turtle, Caretta caretta, on Fethiye Beach, Turkey in 1994. Chelonian Conserv. Biol. 2 (1), 93–96.

Başkale, E., Sözbilen, D., Katılmış, Y., Azmaz, M., Kaska, Y., 2018. An evaluation of sea turtle strandings in the Fethiye-Göcek specially protected area: An important foraging ground with an increasing mortality rate. Ocean Coast. Manage. 154, 26–33. http://dx.doi.org/10.1016/j.ocecoaman.2018.01.003.

Broderick, A.C., Glen, F., Godely, B.J., Hays, G.C., 2002. Estimating the number of green and loggerhead turtles nesting annually in the Mediterranean. Oryx 36, 227–235.

Broderick, A.C., Godley, B.J., 1996. Population and nesting ecology of the Green Turtle, Chelonia mydas, and the Loggerhead Turtle, Caretta caretta, in northern Cyprus. Zool. Middle East. 13, 27–46.

Broderick, A.C., Godley, B.J., Hays, G.C., 2001. Trophic status drives inter-annual variability in nesting numbers of marine turtles. Proc. R. Soc. Bond. B 268, 1481–1487.

Canbolat, A.F., 2004. A review of sea turtle nesting activity along the Mediterranean coast of Turkey. Biol. Conserv. 116, 81–91.

Candan, O., 2018. Impact of nest relocation on the reproductive success of Loggerhead Turtles, Caretta caretta, in the Göksu Delta, Turkey (Reptilia: Cheloniidae). Zool. Middle East. 64 (1), 38–46.

Casale, P., 2015. Caretta caretta (mediterranean subpopulation). In: The IUCN Red List of Threatened Species 2015. http://dx.doi.org/10.2305/IUCN.UK.2015-4.RLTS.T83644804A83646294.e, e.T83644804A83646294.

Casale, P., Broderick, A.C., Camiñas, J.A., Cardona, L., Carreras, C., Demetropoulos, A., Fuller, W.J., Godley, B.J., Hochscheid, S., Kaska, Y., et al., 2018. Mediterranean sea turtles: current knowledge and priorities for conservation and research. Endanger. Species Res. 36, 229–267.

Casale, P., Tucker, A.D., 2015. Caretta caretta. In: The IUCN Red List of Threatened Species 2015. http://dx.doi.org/10.2305/IUCN.UK.2015-4.RLTS.T3897A83157651.en, e.T3897A83157651.

Durmuş, H., Oruç, A., 2010. ÇıRalı, Maden Koyu, Beycik Bükü, Boncuk Bükü, Küçük Boncuk Koyu Ve Mehmetli (Tekirova) Bükü Kumsalları Deniz Kaplumbağası (*Caretta Caretta*) Ve Yumuşak Kabuklu Nil Kaplumbağası (*Trionyx Triunguis*) Popülasyonlarının Araştırı Lması, izlenmesi ve Korunması çalışması. ISBN: 978-605-61279-4-6.

Fish, M.R., Cote, I.M., Horrocks, J.A., Mulligan, B., Watkinson, A.R., Jones, A.P., 2008. Construction setback regulations and sea level rise: Mitigating sea turtle nesting beach loss. Ocean Coast. Manage. 51 (4), 330–341. http://dx.doi.org/10.1016/j.ocecoaman.2007.09.002.

Gerosa, G., Aureggi, M., Casale, P., Yerli, S.V., 1998. Green turtle nesting at Akyatan Beach, Turkey, 1994 1997. Mar. Turtl. Newsl. 81, 4–5.

Godley, B.J., Broderick, A.C., Mrosovsky, N., 2001. Estimating hatchling sex ratios of loggerhead turtles in Cyprus from incubation durations. Mar. Ecol. Prog. Ser. 210, 195–201.

Hays, G.C., Speakman, J.R., 1992. Clutch size for Mediterranean loggerhead turtles (*Caretta caretta*). J. Zool. 226, 321–327. http://dx.doi.org/10.1111/j.1469-7998.1992.tb03842.x.

Hipel, K.W., McLeod, A.I., 1994. Time Series Modeling of Water Resources and Environmental Systems. Elsevier, Amsterdam, the Netherlands.

Ilgaz, Ç., Türkozan, O., Özdemir, A., Kaska, Y., Stachowitsch, M., 2007. Population decline of loggerhead turtles: two potential scenarios for Fethiye beach, Turkey. Biodivers. Conserv. 16, 1027–1037.

Kaska, Y., Başkale, E., Katılmış, Y., Urhan, R., 2005. The nesting population and spatial distrubition of loggerhead sea turtles nest on Dalaman beach, Turkey. In: Second Mediterranean Conference on marine turtles. Antalya-Turkey.

Kılıç, Ç., Candan, O., 2014. Hatchling sex ratio, body weight and nest parameters for *Chelonia mydas* nesting on Sugözü Beaches (Turkey). Anim. Biodiv. Conserv. 37, 177–182.

Kobayashi, S., Wada, M., Fujimoto, R., Kumazawa, Y., Arai, K., Watanabe, G., Saito, T., 2017. The effects of nest incubation temperature on embryos and hatchlings of the loggerhead sea turtle: Implications of sex difference for survival rates during early life stages. J. Exp. Mar. Biol. Ecol. 486, 274–281.

Limpus, C.J., Miller, J.D., Parmenter, C.J., Limpus, D.J., 2003. The green turtle, chelonia mydas, population of raine island and the northern great barrier reef: 1843–2001. Mem. Queensl. Mus. 49, 349–440.

Limpus, C.J., Miller, J.D., Pfaller, J.B., 2020. Flooding-induced mortality of loggerhead sea turtle eggs. Wildl. Res http://dx.doi.org/10.1071/WR20080.

Marcovaldi, M.A., Godfrey, M.H., Mrosovsky, N., 1997. Estimating sex ratios of loggerhead turtles in Brazil from pivotal incubation durations. Can. J. Zool. 75, 755–770.

Marcovaldi, M.A., Lopez, G.G., Soares, L.S., Santos, A.J.B., Bellini, C., Barata, P.C.R., 2007. Fifteen years of hawksbill sea turtle (*Eretmochelys imbricata*) nesting in northern Brazil. Chelonian Conserv. Biol. 6, 223–228.

Margaritoulis, D., 2005. Nesting activity and reproductive output of loggerhead sea turtles, Caretta caretta, over 19 seasons (1984–2002) at Laganas Bay, Zakynthos, Greece: The largest rookery in the mediterranean. Chelonian Conserv. Biol. 4 (4), 916–929.

Margaritoulis, D., Argano, R., Baran, I., Bentivegna, F., Bradai, M.N., Camiñas, J.A., Casales, P., De Metrio, G., Demetropoulos, A., Gerosa, G., et al., 2003. Loggerhead turtles in the mediterranean sea: present knowledge and conservation perspectives. In: Bolten, A.B., Witherington, B.E. (Eds.), Loggerhead Sea Turtles. Smithsonian Books, Washington DC, pp. 175–198.

Margaritoulis, D., Rees, A., 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. Zool. Middle East 24, 75–90.

Matsuzawa, Y., Sato, K., Sakamoto, W., Bjorndal, K.A., 2002. Seasonal fluctuations in sand temperature: effects on the incubation period and mortality of loggerhead sea turtle (*Caretta caretta*) pre-emergent hatchlings in Minabe. Japan. Mar. Biol. 140, 639–646.

Mazaris, A.D., Kallimanis, A.S., Sgardelis, S.P., Pantis, J.D., 2008. Do long-term changes in sea surface temperature at the breeding areas affect the breeding dates and reproduction performance of Mediterranean loggerhead turtles? Implications for climate change. J. Exp. Mar. Biol. Ecol. 367 (2), 219–226.

Mazaris, A.D., Kallimanis, A.S., Tzanopoulos, J., Sgardelis, S.P., Pantis, J.D., 2009. Sea surface temperature variations in core foraging grounds drive nesting trends and phenology of loggerhead turtles in the Mediterranean sea. J. Exp. Mar. Biol. Ecol. 379 (1–2), 23–27.

McClenachan, L., Cooper, A.B., Carpenter, K.E., Dulvy, N.K., 2012. Extinction risk and bottlenecks in the conservation of charismatic marine species. Conserv. Lett. 5, 73–80. http://dx.doi.org/10.1111/j.1755-263X.2011.00206.x.

McGehee, A.M., 1990. Effects of moisture on eggs and hatchlings of loggerhead sea turtles (*Caretta caretta*). Herpetologica 46, 251–258.

Mrosovsky, N., Yntema, C.L., 1980. Temperature-dependence of sexual differentiation in sea turtles: implications for conservation practices. Biol. Conserv. 18 (4), 271–280.

Newbury, N., Khalil, M., Venizelos, L., 2002. Population status and conservation of marine turtles at El-Mansouri, Lebanon. Zool. Middle East 27, 47–60.

Oruç, A., Türkecan, O., Yerli, S., 2007. Çıralı, Maden Koyu, Beycik Bükü, Küçük Boncuk Koyu ve Tekirova Bükü Kumsalları Deniz Kaplumbağası (*Caretta Caretta*) Ve Yumuşak Kabuklu Nil Kaplumbağası (*Trionyx Triunguis*) Populasyonlarının Araştırı Lması, izlenmesi ve Korunması çalışması. ISBN: 978-9944-5919-4- 2.

Patel, S.H., Morreale, S.J., Saba, V.S., Panagopoulou, A., Margaritoulis, D., et al., 2016. Climate impacts on sea turtle breeding phenology in Greece and associated foraging habitats in the wider mediterranean region. PlosOne 11 (6), e0157170. http://dx.doi.org/10.1371/journal.pone.0157170.

Reboul, I., Booth, D., Rusli, U., 2021. Artificial and natural shade: Implications for green turtle (*Chelonia mydas*) rookery management. Ocean Coast. Manage. 204, 105521. http://dx.doi.org/10.1016/j.ocecoaman.2021.105521.

Rees, A.F., Theodorou, P., Margaritoulis, D., 2020. Clutch frequency for loggerhead turtles (*Caretta caretta*) nesting in kyparissia bay, Greece. Herpetol. Conserv. Biol. 15 (1), 131–138.

Sen, P.K., 1968. Estimates of regression coefficient based on Kendall's tau. J. Amer. Statist. Assoc. 63, 1379–1389.

da Silva, A.C.C.D., de Castilhos, J.C., Lopez, G.G., Barata, P.C.R., 2007. Nesting biology and conservation of the olive ridley sea turtle (*Lepidochelys olivacea*) in Brazil, 1991/1992 to 2002/2003. J. Mar. Biol. Assoc. UK 87, 1047–1056. http://dx.doi.org/10.1017/S0025315407056378.

Sönmez, B., 2018a. Investigation of temporal and spatial variation of mammalian predation in green sea turtle (*Chelonia mydas*) nests on Samandağ beach, eastern Mediterranean Turkey. Int. J. Agricul. Wildlife Sci. (IJAWS) 4 (1), 79–88. http://dx.doi.org/10.24180/ijaws.400827.

Sönmez, B., 2018b. Sixteen year (2002-2017) record of sea turtle strandings on Samandağ beach, the eastern Mediterranean coast of Turkey. Zool. Stud. 57. http://dx.doi.org/10.6620/ZS.2018.57-53.

Sönmez, B., 2019. Morphological variations in the green turtle (*Chelonia mydas*): A field study on an eastern mediterranean nesting population. Zool. Stud. 58. http://dx.doi.org/10.6620/ZS.2019.58-16.

Sönmez, B., Yalçın-Özdilek, Ş., 2013. Conservation technique of the green turtle (*Chelonia mydas* L. 1758) nests under the risk of tidal inundation with hatcheries, on Samandağ beach. Turkey. Russ. J. Herpetol. 20, 19–26.

Türkozan, O., Kaska, Y., 2010. Turkey. In: Casale, P., Margaritoulis, D. (Eds.), Sea Turtles in the Mediterranean: Distribution, Threats and Conservation Priorities. Gland. IUCN, Switzerland, pp. 257–294.

Türkozan, O., Taşkavak, E., Ilgaz, Ç., 2003. A review of the biology of the loggerhead turtle, caretta caretta, at five major nesting beaches on the South-western Mediterranean coast of Turkey. Herpetol. J. 13, 27–33.

Türkozan, O., Yılmaz, C., 2008. Loggerhead turtles, Caretta caretta, at Dalyan Beach, Turkey: nesting activity (2004–2005) and 19 year abundance trend (1987–2005). Chelonian Conserv. Biol. 7, 178–187.

Witherington, B., Kubilis, P., Brost, B., Meylan, A., 2009. Decreasing annual nest counts in a globally important loggerhead sea turtle population. Ecol. Appl. 19, 30–54. http://dx.doi.org/10.1890/08-0434.1.

Yalçın Özdilek, Ş., 2007. Status of sea turtles (*Chelonia mydas* and *Caretta caretta*) on Samandağ Beach, Turkey: Evaluation of five-year monitoring study. Ann. Zool. Fennici 44, 333–347.

Yerli, S.V., Demirayak, F., 1996. Türkiye'de Deniz Kaplumbagalari ve üreme Kumsallari üzerine Bir Degerlendirme'95. DHKD. Rapor No: 96/4.

Yılmaz, C., Türkozan, O., Bardakcı, F., 2011. Genetic structure of loggerhead turtle (*caretta caretta*) populations in Turkey. Biochem. Syst. Ecol. 39, 266–276.