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A 21-year recovery trend in green turtle nesting activity: 2002–2022

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Abstract

1. Long-term monitoring and conservation are crucial for effective protection, since sea turtles migrate cyclically every 2–3 years and lay multiple nests during a breeding season. Therefore, this study aimed to investigate the long-term trend of nesting activities of green turtles over a 21-year period (2002–2022) on Samandağ beach.
2. An early morning survey was conducted every year during both nesting and hatching seasons. The trend analyses in nesting activities were performed using Mann–Kendall and Sen's slope tests together with the augmented Dickey–Fuller stationarity test.
3. The nest count and female abundance increased significantly, whereas clutch size, fecundity, and hatching success tended to decrease insignificantly. The percentage change between the most recent and oldest 3-year mean nest count and mean female abundance, which is performed to comply with the Red List assessment method used by the International Union for Conservation of Nature Marine Turtle Specialist Group, was 769% and 764% respectively.
4. Samandağ nesting population accounts for one-third of the Mediterranean's total nest count and one-fourth of its total female abundance. The decrease in clutch size and fecundity may be due to the recruitment of individuals with smaller body sizes or malnutrition as a result of population growth. There was an increase in the number of dead embryos and a decline in hatching success. This may be explained by density-dependent population regulation as a result of an increase in the number of nests.
5. It may be argued that adherence to a uniform strategy and the maintenance of continuous protection through collaboration with governmental and non-governmental organizations with scientifically rigorous methodology are significant factors contributing to the high recovery.
6. This study emphasizes the necessity of adopting a comprehensive conservation approach encompassing both foraging habitats and the significant role played by the population in Samandağ in the proliferation of Mediterranean green turtles.

KEYWORDS

abundance, Chelonia mydas, green turtle, nesting activity, recovery trend, Samandağ

1 | INTRODUCTION

Long-lived migratory species are more likely to face extinction, as they are more likely to experience numerous threats throughout their lifetime (Lascelles et al., 2014). As one of the long-lived migratory species, sea turtle populations have drastically declined and have dwindled to a fraction of their historical abundance in many locations (Kittinger et al., 2013; Van Houtan & Kittinger, 2014). This has led to basic protective measures along nesting beaches and has resulted in strong recovery trends for many populations (e.g. Mazaris et al., 2017; Blumenthal et al., 2021; Omeyer et al., 2021; Pritchard et al., 2022; Yılmaz, Oruç & Türkozan, 2022).

The Mediterranean is host to important habitats for both the green turtle (*Chelonia mydas*) and the loggerhead turtle (*Caretta caretta*) (Casale et al., 2018). The loggerhead and green turtle populations in the Mediterranean face threats such as coastal development, erosion and beach armoring, climate change, interaction with fisheries, marine debris and pollution, and elevated predation of eggs and hatchlings (Casale et al., 2018). For both species, regional management units (RMUs) have been defined, and 17 RMUs have been identified for green turtles globally (Wallace et al., 2010; Wallace et al., 2011). The Mediterranean area is one of them and is categorized as having 'high threats' (Wallace et al., 2010; Wallace et al., 2011). A minimum of three management units, recommended as MED1 (Akamas and Akdeniz), MED2 (Alagadi), and MED3 (North and South Karpaz, Israel, Samandağ, Akyatan, Sugözü, Kazanlı, and Davultepe), were suggested in a recent study for the Mediterranean population (Karaman et al., 2022). According to the International Union for Conservation of Nature (IUCN), the loggerhead turtle is categorized as 'Vulnerable' (VU) globally (Casale & Tucker, 2015), whereas the Mediterranean subpopulation is categorized as 'Least Concern' (LC) (Casale, 2015). Also, the population of green turtles in the Mediterranean is categorized as 'Endangered' (EN) (Seminoff, 2004).

It is challenging to study sea turtles since they have several habitats during their life cycles and regularly migrate from one habitat to another, especially in accordance with the seasons. Most of the research has been focused on monitoring sea turtle nesting populations worldwide (Blumenthal et al., 2021; Pritchard et al., 2022; Yılmaz, Oruç & Türkozan, 2022). On nesting beaches, nesting females or their nests can be easily observed (Ceriani et al., 2019; Yılmaz, Oruç & Türkozan, 2022). Studies on beach monitoring can gather information on things like nest counts, clutch sizes, hatching rates, incubation times, and embryonic development. Without monitoring the female, all these data can be gathered, and their long-term collection using standardized techniques could serve as a basis for sea turtle population assessments (Blumenthal et al., 2021; Pritchard et al., 2022). A projection of the sea turtle population status can be made using long-term variations or trends in nests and nesting females. As they can be consistently collected and compared across nesting regions, nest counts are the most popular indicator of sea turtle populations (Ceriani et al., 2019).

Sea turtles lay multiple clutches during one breeding season and migrate cyclically every 2–3 years, making it difficult to estimate the total breeding population in a study year when compared with species that produce a single clutch annually (Broderick et al., 2002). For effective conservation, nesting populations must be monitored over an extended period and protected (McClenachan, Jackson & Newman, 2006; Yılmaz, Oruç & Türkozan, 2022). In addition, the nest count also serves as a helpful indicator of population abundance when multi-year adult beach full counts are impractical (Ilgaz et al., 2007; Yılmaz, Oruç & Türkozan, 2022). For example, the IUCN Red List is evaluated through a variety of criteria based on population abundance because abundance is particularly important for species of conservation concern and is an important key parameter for characterizing animal populations (Casale et al., 2022).

Protection and monitoring activities on nesting beaches around the world are carried out within the framework of a standard protocol, such as early morning surveys, patrolling on the beach, recording nests and tracks, and excavating nests after hatchlings (Ceriani et al., 2019; Omeyer et al., 2021; Pritchard et al., 2022; Yılmaz, Oruç & Türkozan, 2022). To obtain accurate data and evaluate trends and changes in sea turtle nesting numbers, conservation organizations and researchers recommend a long-term, continuing conservation effort (Broderick, Godley & Hays, 2001; Yalçın-Özdilek, 2007). Owing to interannual differences in weather, it is possible to observe a dramatic fluctuation in the number of nests, which leads to inaccurate population density calculations (Broderick, Godley & Hays, 2001; Yalçın-Özdilek, 2007; Pritchard et al., 2022). Therefore, abundances at specific monitoring sites may change dramatically over time because of environmental conditions (Broderick, Godley & Hays, 2001). One-year studies have the potential to produce inaccurate population projections (Yalçın-Özdilek, 2007). As a result, monitoring studies conducted over a decade or more may reveal information about actual population trends (National Research Council, 1990). Such monitoring studies for assessing population trends are advantageous because they can overcome short-term fluctuations that obscure long-term trends (National Research Council, 1990; Ilgaz et al., 2007).

Apart from a few studies (Omeyer et al., 2021; Yılmaz, Oruç & Türkozan, 2022), abundance and trend results based on long-term monitoring and conservation studies of the Mediterranean green turtle population appear to be a deficiency. It has been stated that the total population abundance and trend results in the Mediterranean are limited due to the lack of information on some nesting beaches (Casale et al., 2018). This shows that the abundance and trend results of the Mediterranean green turtle population at each nesting beach will provide important information for estimating the current status of the Mediterranean population. However, a recent study estimated the Mediterranean population to have around 3,400 adults (Omeyer et al., 2021). This estimation was made based on multiple matrix model scenarios. The Mediterranean has 13 major nesting beaches, and the average annual number of nests is given as 2,204. About 78% of these nests are reported on six beaches on the Turkish coast (Casale et al., 2018). It has been stated that this number of nests may be minimal due to some beaches lacking nest count information (Casale et al., 2018). Samandağ beach is one of the major nesting beaches, and the last study on the status of the nesting population of green turtles in Samandağ was published in 2007 (Yalçın-Özdilek, 2007). In that study, covering the 2001–2005 nesting seasons, some nesting characteristics were evaluated, such as nesting and hatchling activities. In addition, Samandağ beach showed a 279% change in nest counts before 1999 and after the 2000 monitoring studies (Casale et al., 2018).

Samandağ beach has ecological significance owing to its characteristic sandy composition and the provision of many ecosystem services. These services include the provision of sustenance, the filtering of seawater, the dispersion of waves, the mitigation of storm impacts, and recreational opportunities. Moreover, it has significant value as a breeding habitat for green turtles (Yalçın-Özdilek, 2007; Casale et al., 2018). This sandy beach is the result of the deposition of alluviums transported by the Asi River, which have been subsequently moulded by prevailing wind patterns (Yalçın-Özdilek, Özdilek & Ozaner, 2007). The beach saw significant anthropogenic influence, particularly illegal sand extraction and the establishment of Asi River dams, which reduced alluvial deposits throughout the 2000s, prompting the initiation of conservation studies (Yalçın-Özdilek, 2007). On the other hand, the rise in sea levels has contributed to an escalation in beach erosion (Sönmez, Karaman & Turkozan, 2021). It has been stated that the sea level rise as a result of global climate change will cause the loss of one-third of Samandağ beach, and this may bring density-related problems (Sönmez, Karaman & Turkozan, 2021). The Samandağ population has a distinctive significance in the context of the green turtle population owing to its smaller adult body size in comparison with other beaches, as well as the observed decline in the size of the smallest individuals over time (Sönmez, 2019). This population's contribution to the genetic variability of the Mediterranean population further enhances its uniqueness (Karaman et al., 2022).

Updates to conservation efforts focused on the long term are crucial for Samandağ beach's due diligence given the need for long-term monitoring and protection of nesting populations for successful conservation (Broderick, Godley & Hays, 2001; Yalçın-Özdilek, 2007). Thus, reliable data about the green turtles on Samandağ beach will be gathered.

Therefore, answers to the following questions are expected to be found to show how effective and successful a long-term intensive conservation study on the Samandağ beach can be:

1. What is the long-term trend of green turtle nest and abundance between 2002 and 2022?
2. What are the temporal variations of the clutch size, fecundity, hatching success, and embryonic mortality?
3. What proportion of the Mediterranean population does the nest count and female abundance on Samandağ beach represent?

2 | MATERIALS AND METHODS

2.1 | Study area and monitoring

This study was conducted on the 14 km long Samandağ nesting beach (36°07′N, 35°55′E), located on the eastern Mediterranean coast of Turkey during the 2002–2022 nesting seasons (Figure 1). The beach is subdivided into three sections as Çevlik (5.5 km), Şeyh-hızır (4.1 km), and Meydan (4.4 km) subsections (Figure 1). The study was conducted from the middle of May to the end of September, and the beach was monitored by five or six people. Every year, a monitoring study was carried out as an early morning survey to detect the tracks left by the green turtles that emerged the previous night (Yalçın-Özdilek, 2007; Omeyer et al., 2021; Pritchard et al., 2022). During this, successful and unsuccessful nesting activities were recorded daily on the data form. Soft sand used as camouflage was used to identify nests, and the presence of nest chambers was verified by feeling an air pocket above the eggs with a stick (Yalçın-Özdilek, 2007; Omeyer et al., 2021). To prevent duplication, tracks were removed after each investigation. Each nest was marked with a stick or wood, numbered, and checked manually every day via checklist (Yalçın-Özdilek, 2007). All nests were protected in their original place (in situ), except that some nests (totalling 58 nests in 2004, 2008, and 2018) that were at risk of flooding due to their proximity to the sea were relocated to a safe area or hatchery.

During the morning survey, nests were examined for the presence of hatchling tracks. A week after the first hatchling emerged, the nests were excavated, and the remnants were studied. To determine the clutch size and examine the fate of nests that were assumed not to hatch (inundation nests), excavations were conducted 65 days after the lay date (Omeyer et al., 2021). The quantity of dead hatchlings, dead embryos, and hatched and unhatched eggs was counted during nest excavation. The clutch size was determined by counting the number of unhatched and hatched eggs. The success of hatchlings reaching the sea was tracked using tracks emanating from nests daily, and the number of hatchlings reaching the sea was calculated (Miller, 1999). The hatching success was calculated as a percentage of the clutch size divided by the number of hatched eggs. Nest density (km^{-1}) was calculated as the ratio of the total number of nests to the beach length (Casale et al., 2018).

To estimate the number of nesting females based on clutch frequency (CF), the observed CF (OCF; 2.9 nests per female) suggested by Broderick et al. (2002) and the estimated CF (ECF; six nests per female) proposed by Esteban, Mortimer & Hays (2017) were utilized. The OCF indicates the number of occasions a turtle has been observed and confirmed nesting during the nesting season, based on the tagging or passive integrated transponders (Johnson & Ehrhart, 1996; Broderick et al., 2002). If the female gets missed by the tagging team during the nightly patrols or if nesting occurs on an uncontrolled beach, OCF may underestimate the actual number of clutches a female deposits (Broderick et al., 2002). The typical method for calculating ECF is to assign extra nests during longer than mean inter-nesting intervals (Tucker, 2010). Using high-resolution GPS

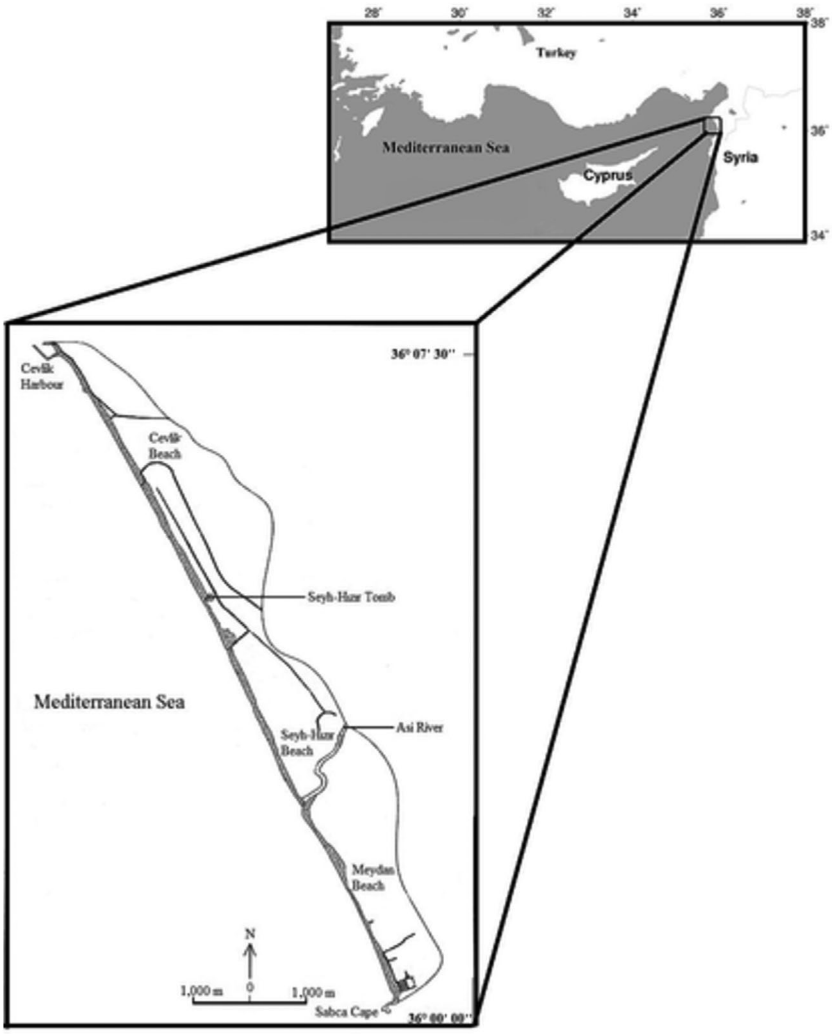

FIGURE 1 A general view of the 14 km long Samandağ beach where an early morning survey was conducted between 2002 and 2022.

satellite telemetry to track green turtles throughout the nesting season and assess when and where they nest provides a more accurate estimation of CF (Esteban, Mortimer & Hays, 2017). The number of nests found for the relevant year was divided by the corresponding CF in both techniques to get the number of nesting females. Additionally, fecundity, which is the mean number of eggs laid by a female, was calculated using OCF and ECF (multiplying the mean clutch size by OCF and ECF). In addition to the CF values previously indicated, the remigration interval (RI) for populations in the Mediterranean was estimated to be 3 years (Broderick et al., 2002). Thus, to compute the total mean nesting female numbers (FNs), the following formula was used:

$$\text{Mean FN} = \frac{\text{Total nest number}}{\text{CF}} \times \frac{\text{RI}}{\text{Total years}}$$

The current FNs (CFNs) in the last three nesting seasons (2020, 2021, and 2022) were calculated as follows:

$$\text{CFN} = \frac{\text{Mean nest number}}{\text{CF}} \times \text{RI}$$

Reproductive output (i.e. clutch size, fecundity, hatching, and dead embryos) is based on the information from nests that were excavated 1 week after hatching emergence, nests that were excavated after 65 days in inundation nests, and predated nests. In contrast, both abundance estimation and nest density are based on the total nest count. The difference between the oldest and most recent 3-year mean nest counts and female abundance was compared using the percentage change estimate in accordance with the IUCN Marine Turtle Specialist Group (MTSG) Red List assessment method (Omeyer et al., 2021).

2.2 | Data analyses

It has been examined the time-dependent variation of the variables nest count, abundance with OCF and ECF, nest density, clutch size, fecundity, dead embryo and hatching success. Before analysing the time change of these variables, a stationarity test was conducted using the augmented Dickey–Fuller (ADF) test (Cheung & La, 1995). This test is commonly used to determine whether a time series is stationary or not. The following equation represents the ADF test applied to the study:

$$\Delta Y_t = \mu + \beta t + \delta Y_{t-1} + \sum_{j=1}^{k} \alpha_1 \Delta Y_{t-j} + \varepsilon_t \tag{1}$$

where ΔY_t is the time series being tested for stationarity, δ is the unit root, μ and βt are the coefficients determining whether the time series has a constant term and a systematic trend, $\sum_{j=1}^{k} \alpha_1 \Delta Y_{t-j}$ is the lag differences, and ε_t is the random error term.

For trend analysis, the Mann–Kendall test and Sen's slope test on the series with statistically significant trend coefficients from the ADF test were used. The Mann–Kendall test is a non-parametric, rank-based test often used in ecology to determine whether a time series has a monotonic trend (Legendre & Legendre, 2012). Sen's slope test is also a non-parametric test and estimates the size of trends in *N* datasets via a linear model (Sen, 1968). Sen's slope analysis and Kendall's rank correlation are often used together (Yue et al., 2002).

The R program (v. 4.2.2) was used for trend analysis, statistical computations, and plots (R Core Team, 2022), and the level of statistical significance was set at $P \leq 0.05$. All means are presented with ±*SD* and min–max.

3 | RESULTS

3.1 | Nesting activity and reproductive output

In total, 36,259 green turtle emergences were recorded, with 16,249 (44.3%) resulting in nesting between 2002 and 2022 along the entire Samandağ beach. The mean number of nests was 774 and ranged from 14 to 1779 nests, and the mean nest density was 55.3 km^{-1} and ranged from 1 to 127 km^{-1} (Supporting Information Table S1). Throughout the incubation period, 77.3% (12,568 nests) of the nests survived (i.e. were able to produce hatchlings), and 2.7% (445 nests) were predated by jackals or domestic dogs (Supporting Information Table S1). Also, of the overall nests, 10.7% (1,745 nests) were lost and 9.1% (1,491 nests) did not produce hatchlings due to erosion, inundation, and human effects (Supporting Information Table S1).

A total of 1,497,987 eggs were deposited in 14,059 excavated green turtle nests, with an overall mean clutch size of 109.1 ± 7.6 eggs (range of a mean 95–127 eggs) (Supporting Information Table S2). The mean egg number per female (fecundity) was estimated as 316.4 ± 22.1 eggs with a range of 275.9–368.3 eggs (Supporting Information Table S2). In excavating these nests, 369,598 (24.7%) were found as dead embryos and 10,006 (0.7%) as unfertile eggs (Supporting Information Table S2). In total, 34,373 (2.3%) eggs were predated by jackals or domestic dogs. Of the total eggs, 1,084,010 (a hatching success of 72.3%) produced hatchlings, 836,032 (77.3%) of which were able to reach the sea (Supporting Information Table S2). In addition, the total number of hatchlings reaching the sea as a percentage of the total egg numbers was 55.8%.

3.2 | Nest count and abundance trend

The nest count showed a statistically significant monotonic upward trend across the long-term monitored beach consistently since 2002 (see Table 1 for detail; Figure 2). According to the Sen's slope result (Table 1), which gives an idea about the magnitude of the test, the magnitude of the significant upward trend in the nest count is 82.92. In other words, it can be said that there is a change of 82.92 for each year in the nest count. Using the IUCN MTSG Red List assessment method, nest count increased by 764% from 189 (2002–2004) to 1,639 (2020–2022) between the oldest and the most recent 3-year mean absolute nest count. In parallel with this upward trend in the nest count, nest density also shows a monotonic upward trend (Table 1, Figure 2). In contrast, clutch size, fecundity, and hatching success have a statistically insignificant monotonic decrease, whereas a statistically insignificant monotonic increase is observed in dead embryos (Table 1, Figure 3).

The estimated numbers of females according to nesting seasons are shown in Supporting Information Table S1. The number of nesting females in overall years was estimated by OCF as 5,603 and, 2,708 by ECF. Thus, the total mean number of nesting females on Samandağ

TABLE 1 Stationarity, Mann–Kendall trend and Sen slope analysis results of variables based on a 21-year long-term survey on Samandağ nesting beach in the eastern Mediterranean.

Variable	ADF	*P* value	Mann–Kendall tau	*P* value	Sen's slope	95% CI
Nest count*	−2.789	0.272	0.807	3.867×10^{-7}	82.917	68.692–102.92
Abundance with OCF*	−2.789	0.272	0.807	3.58×10^{-7}	27.639	22.900–34.308
Abundance with ECF*	−2.788	0.2719	0.807	3.58×10^{-7}	13.819	11.446–17.154
Nest density*	−2.789	0.272	0.807	3.58×10^{-7}	5.922	4.908–7.354
Clutch size	−0.914	0.933	−0.295	0.065	−0.568	−1.1–0.167
Fecundity	−0.911	0.934	−0.295	0.065	−1.692	−3.28–0.467
Dead embryo	−1.232	0.865	0.062	0.717	0.0920	−0.67–0.364
Hatching success	−1.293	0.842	−0.048	0.786	−0.061	−0.37–0.771

Abbreviations: ADF, augmented Dickey–Fuller; ECF, estimated clutch frequency; OCF, observed clutch frequency; CI, confidence interval.
*Test results are statistically significant.

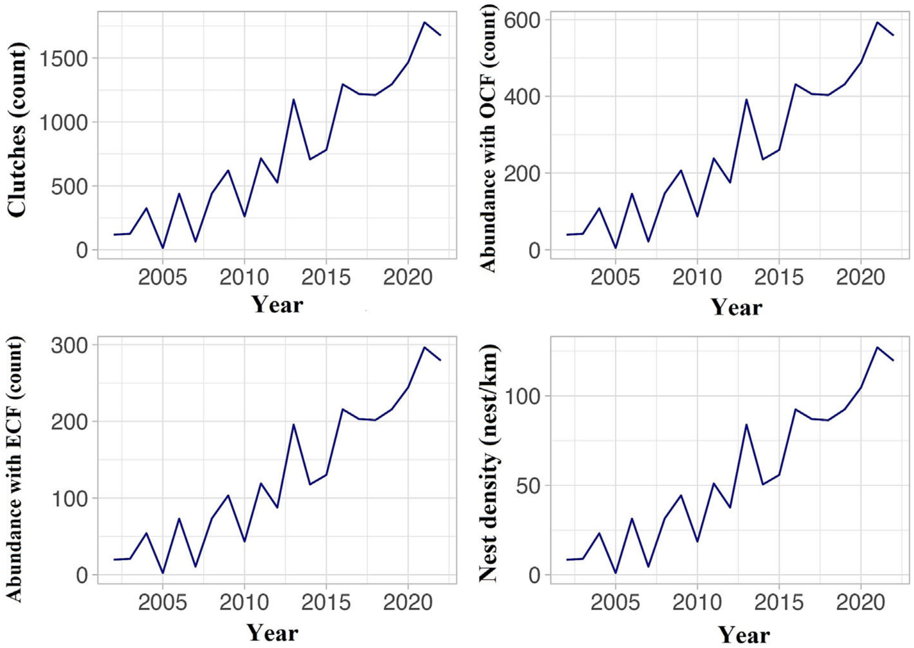

FIGURE 2 The monotonic non-parametric Mann–Kendall trend test results based on the 21-year long-term monitoring survey (see Table 1 for augmented Dickey–Fuller stationarity and trend analysis results). ECF, estimated clutch frequency; OCF, observed clutch frequency.

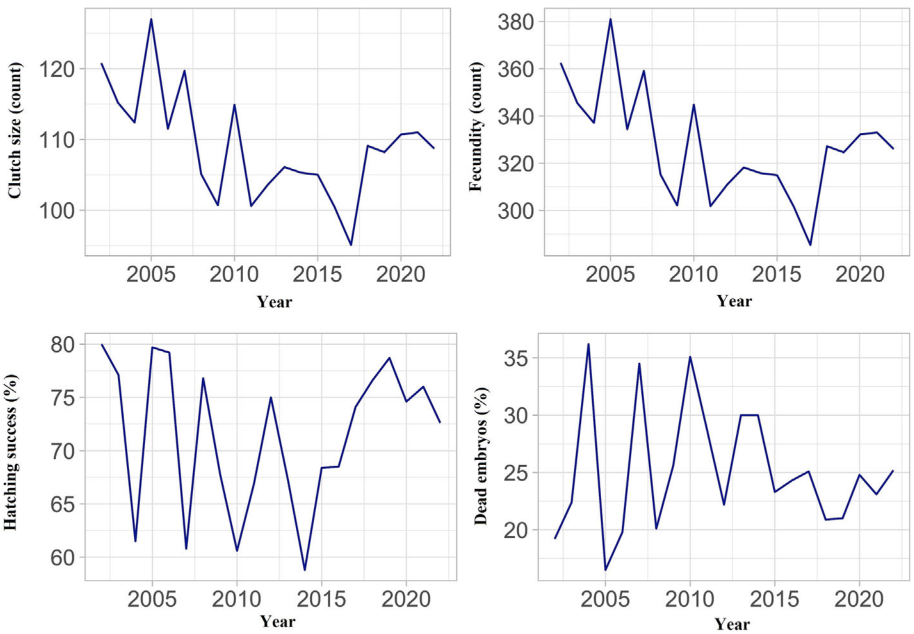

FIGURE 3 The monotonic non-parametric Mann–Kendall trend test results based on the 21-year long-term monitoring survey (see Table 1 for augmented Dickey–Fuller stationarity and trend analysis results).

beach was estimated as 800 by OCF and 387 by ECF. The current FN on Samandağ beach was estimated by OCF as 1,696 females and 820 females by ECF. The estimated population size of nesting females in the current year (2020–2022) was higher than in the overall years (2002–2022).

The estimated female abundance on both OCF and ECF methods showed a statistically significant monotonic upward trend (see Table 1 for details; Figure 2). According to the IUCN MTSG Red List assessment method, mean nester abundance increased by 769% from 65 (2002–2004) to 565 (2020–2022) females in the OCF method and by 764% from 31 to 273 females in the ECF method.

4 | DISCUSSION

4.1 | Nest count and abundance trend

The mean annual nest count on Samandağ beach was 774, and the percentage change between the oldest and the most recent 3 years was 764%. The percentage change in the nest count of green turtles in the Cayman Islands was reported as 1.126% (Blumenthal et al., 2021), and 173% in Aldabra Atoll (Pritchard et al., 2022). Similarly, the percentage change in the nest count on Alagadi beach in the Mediterranean was also reported as 307% (Omeyer et al., 2021).

Casale et al. (2018) reported that the percentage change in the mean nest count of Samandağ beach before 1999 (mean nest 56) and after 2000 (mean nest 212) was 279%. In this case, according to this study, the percentage change before 1999 was found to be 1,282%. Moreover, Samandağ beach represents 35% of the green turtle nests on the entire Mediterranean coast and 53% of the nests on the entire Turkish coast—see Casale et al. (2018, table S11) for details. It can be seen that Samandağ beach hosts a higher nest count than other nesting beaches in the Mediterranean. This shows that Samandağ beach is a critically important nesting beach for green turtles in terms of nest count data. However, it should not be forgotten that, as well as a higher nest count, the contribution of the Samandağ population to the genetic diversity is critical for the future of the population (Karaman et al., 2022).

The nest count has shown an increasing trend over the years, and it has been estimated that there is a change of 83 in the number of nests per year. Similarly, it was noted that approximately 75% of the seven sea turtle populations worldwide have shown a strong upward tendency (Mazaris et al., 2017). For instance, an upward trend has been reported for the largest loggerhead sea turtle population in Florida (USA) (Ceriani et al., 2019), as well as the olive ridley sea turtle population on the Pacific coast of northern Central America (Ariano-Sánchez et al., 2020). Moreover, the nesting populations of the green turtles on the Cayman Island in the Caribbean Sea (Blumenthal et al., 2021) and Aldabra Atoll in the western Indian Ocean (Pritchard et al., 2022) showed a similarly increasing trend. The number of green turtle nests in the Mediterranean has also increased by 47% (Casale et al., 2018). Also, although it was not statistically significant, the number of green turtle nests on Akyatan beach in the Mediterranean showed an upward trend (Yılmaz, Oruç & Türkozan, 2022). Three reasons can be used to explain why the number of nests on Samandağ beach has increased over the years. First, the recruitment of neophytes into the population to lay eggs for the first time may have increased significantly. Neophyte recruitment is a sign of population growth (Richardson et al., 2006), and it may be responsible for an increase in green turtle nesting populations (Stokes et al., 2014). On Alagadi beach, a significant association between the recruitment of neophytes and the quantity of nests has been noted (Omeyer et al., 2021). Second, nesting shifts throughout nesting beaches can be the cause, because, rather than being beach specific, green turtles' nest site fidelity appears to be region specific (Karaman et al., 2022). In addition, Yılmaz, Oruç & Türkozan (2015) suggested that there may be a nesting shift between Akyatan, Kazanlı, and Samandağ beaches, which are important nesting beaches for green turtles in the Mediterranean. Based on tagging, it has been reported that two green turtles nest at four different nesting beaches in the same nesting season (Sönmez, Türkecan & Jded, 2017). Yılmaz, Oruç & Türkozan (2022) stated that the decrease in the number of nests on Akyatan beach may be due to nesting shifts. Finally, an increase in nests may have occurred because of an alteration in the RI driven by global climate change. Sea-surface temperature (SST), for instance, plays a significant role in sea turtle reproduction (Mazaris et al., 2004). Solow, Bjorndal & Bolten (2002) stated that there is a significant positive relationship between the 2-year remigration probability and SST in green turtles. As a result of environmental change (SST driven by global climate change), an increase in nesting without an increase in female abundance may take place with a decrease in the mean RI. Long-term research on SST has revealed an increasing tendency in the Mediterranean region (Pisano et al., 2020); therefore, its impact on nest counts should not be disregarded.

CF is critical for estimating the absolute number of nesting individuals and fecundity in sea turtle populations (Esteban, Mortimer & Hays, 2017). Therefore, the CF value acquired by two separate approaches (observed and estimated) was used to prevent overestimating the number of females in nesting populations. Considering this, nester abundance on Samandağ beach was calculated by OCF to be 800 females and by ECF to be 387, and it had a monotonic upward trend throughout the 21-year period. Additionally, the percentage change between the oldest and the most recent 3 years was 769% for OCF and 764% for ECF. The percentage change in the number of oldest and most recent abundances at Akyatan beach was calculated as 1.3%—see Yılmaz, Oruç & Türkozan (2022, table 3). Alagadi beach's percentage change, however, is reported to be 337% (Omeyer et al., 2021). These two abundance values were computed using OCF and provided by two distinct sets of researchers. It should be noted that the upward trend in body size (i.e. curved carapace length) of green turtles that were found stranded on Samandağ beach (Sönmez, 2018) has the potential to have a negative impact on nester abundance. This is why it is so important to conduct studies on conservation and monitoring (e.g. fisheries activities or bycatch and encouraging marine protection areas) in Mediterranean marine habitats. For the Mediterranean, it is crucial to know how many females are nesting on the beach at Samandağ. In fact, according to OCF and ECF, Samandağ beach accounts for approximately 23.5% and 11.5% respectively of the total number of females nesting in the Mediterranean (Casale & Heppell, 2016).

These successful long-term protections of eggs and nesting females on Samandağ' nesting beach are likely contributing to the positive recovery rates there. Undoubtedly, in order to achieve adequate protection, it is vital to take into account both the decrease of negative effects offshore and the protection measures on shore. Regarding the quantity of juvenile and adult (male and female) populations, it is crucial that feeding, mating, and wintering habitats be safeguarded within biologically safe boundaries. Omeyer et al. (2021) ascribed the variations in recovery rates between loggerhead and green turtles in northern Cyprus to mortality rates rather than reproductive success based on the matrix model scenarios. Estimated survival rates are higher globally as the green turtle has less interaction with fisheries (Omeyer et al., 2019). However, one of the most important factors influencing the life history of the sea turtle is fishery bycatch (Casale, 2011). The Mediterranean has a relatively high bycatch rate (Casale, 2011), and 60% of those caught die (Snape et al., 2013). The rate of sea turtle population increase will be significantly impacted by improving survival across all age groups, particularly in the juvenile life stage (Omeyer et al., 2021). However, it has been noted that the majority of them are in the juvenile life stage when examining the findings of bycatch and stranded studies in the eastern Mediterranean (Oruç, 2001; Yalçın-Özdilek & Aureggi, 2006; Sönmez, 2018; Yalçın Özdilek, Sönmez & Sert, 2018). Though reproductive success has a positive impact on nesting population recovery rates, action must be taken to lower post-pelagic anthropogenic mortality rates in order to ensure the population's long-term survival. It should also be noted that only adult females represent this high recovery rate. Therefore, a male and juvenile abundance analysis in the eastern Mediterranean basin is required. In actuality, contrasting this high recovery rate with the historical population size is of utmost significance. There is no information available regarding the Samandağ nesting population's historical population size. Given that there were between 33 million and 39 million adult females in pre-Columbian periods (Jackson, 1997), it can be concluded that the high recovery rate of the present is too far compared with the historical size.

4.2 | Reproductive output trends

Fecundity and clutch size are crucial factors in sea turtle reproduction. In this study, both of them displayed a declining tendency; however, it was not statistically significant across the long-term monitored Samandağ beach. Perhaps the increase in female recruits is responsible for this. These females will be smaller, and as a result their clutches will also be smaller, because the smaller body size of the green turtle produces smaller clutch sizes in Mediterranean populations (Broderick et al., 2003). Additionally, it is well documented that green turtles that nest on Samandağ beach are becoming smaller overall (Sönmez, 2019). Although the large number of female recruits has a substantial impact on nest count and abundance, it might necessarily put pressure on the green turtle's reproductive output, namely the number of hatchlings. Additionally, mortality rates may be higher since these recruited small females migrate by following neritic waters (nutrient-rich but unsafe waters) (Seminoff et al., 2008; Yalçın Özdilek, Sönmez & Mestav, 2023).

Despite a negligible decline in hatching success, there was an upward trend in the number of dead embryos. On Samandağ beach, there have been reports of high embryonic mortality as a result of severe flooding and coastal erosion (Sönmez & Yalçın Özdilek, 2013). In order to protect nests that are less than 20 m from the tide line, nest relocation has been recommended (Sönmez & Yalçın Özdilek, 2013). During the 21-year long-term protection and monitoring period, 9.1% of the total nests could not produce hatchlings due to inundation and floods. As a result, reduced hatching success was caused by rising embryonic mortality. Furthermore, the increased abundance brought with it an increased number of nests, which may have introduced density-related problems on the nesting beach. This is because density-related problems include nest infection due to increased bacterial activity between adjacent nests (Fish et al., 2008) and nest destruction by congeners (Limpus et al., 2003), which will reduce hatchling production and thus affect population dynamics (Fuentes et al., 2010). The oldest and most recent 3-year mean nest density has changed by 767% on Samandağ beach. A very high change in nest density may have been brought about density-related problems.

4.3 | Conservation implications

Green turtles nesting on Samandağ beach have shown high recovery rates after gaining legal protection status in Turkey and more than 20 years of continuous conservation and monitoring. This situation confirms Yalçın-Özdilek's (2007) claim that Samandağ beach conservation and monitoring research should be ongoing to be successful. The population structure of green turtles on Samandağ beach has a stable pattern at a particular threshold when assessed from an extended conservation perspective. In this study, it should be noted that the effectiveness of conservation efforts for a subpopulation that reproduces in a defined geographical area and sustains itself with feeding activities in a specific location is limited to conservation activities only on the beach. In addition, in collaboration with scientists and governmental and non-governmental organizations, regular public awareness activities on the beach and sea turtles have been carried out every year before and/or during the nesting season. The continuation of these awareness-raising initiatives is crucial for minimizing anthropogenic implications.

In this study, approximately 20% of the overall nests were either lost or did not produce hatchlings as a result of flooding. This may have been due to the low elevation of the nesting beach (Sönmez, Karaman & Turkozan, 2021). The low elevation may facilitate the flow of seawater to the back of the beach, as a result of which the beach may be exposed to constant flooding. Similarly, the tendency to decrease hatching success or increase embryonic mortality may be related to the continuous flooding of the beach. Samandağ beach has a high nest moisture content, and it has been stated that moisture content has a greater effect on hatching success than other environmental factors, such as temperature, salinity, and electrical conductivity (Sönmez, Turan & Yalçın Özdilek, 2013). Considering that approximately one-third of Samandağ beach will be lost according to sea level rise scenarios (Sönmez, Karaman & Turkozan, 2021), it is essential to implement regulations to prevent beach destruction or erosion in the nesting habitat immediately. It has been stated that habitat loss can be prevented by protecting and restoring the ecosystem in the hinterland of the beach (Mazaris, Matsinos & Pantis, 2009). Therefore, effective protection with beach setback arrangements and beach restoration is important for the future of the nesting habitat.

Although a long-term effective conservation strategy on Samandağ beach is important for the increase of abundance and nest numbers, the possibility of density-related problems in the future should not be forgotten. First, it is important to determine the carrying capacity of Samandağ beach within biological boundaries. It is recommended that a spatial analysis be carried out to identify the areas where the densest nesting occurs on a microscale throughout the beach and then to determine the carrying capacity of these dense areas. In this way, it can be decided which type of protection plan (e.g. nest relocation) should be implemented in which part of the beach. However, the paradox between abundance, nest numbers, and density problems calls into question the continuity of effective conservation efforts. This situation will also affect the carrying capacity of foraging areas.

Green turtles are known to devote a specific period of 2–3 years to egg production, using specific foraging habitats during this time (Hamann, Limpus & Owens, 2003). The relatively low clutch size may be due to the lack of food resources available in the foraging areas for the increased population densities resulting from conservation measures. The population trends of green turtles in Mediterranean foraging areas are unclear, but the Samandağ beach case study highlights the need to monitor the carrying capacity of foraging and nesting habitats. This case highlights the need to implement comprehensive conservation initiatives that include not only nesting beaches but also foraging areas, thus addressing ecological constraints. On the other hand, Samandağ beach is one of the nesting sites for green sea turtles in the eastern Mediterranean. Though there are currently no data on nesting activity at other beaches and the correlation between clutch numbers and clutch sizes, there are reports of increasing nest numbers at several other beaches (Omeyer et al., 2021; Yılmaz, Oruç & Türkozan, 2022). Interestingly, green turtles nesting on all beaches in the eastern Mediterranean use foraging areas comparable to those found on Samandağ beach (Yalçın Özdilek, Sönmez & Mestav, 2023). In order to effectively manage conservation efforts, it is crucial to consider these aspects together.

5 | CONCLUSIONS

In conclusion, green turtles on Samandağ beach have a shown a high recovery rate during the 21-year period. Owing to the lack of data on historical population size data, it is challenging to determine whether this high recovery rate is adequate. Despite this, the results suggest that Samandağ beach accounts for one-third of the Mediterranean nests and nearly a quarter of the female abundance. Both the number of nests and the abundance of females showed a clear upward trend. Contrarily, the number of dead embryos increased, whereas clutch size, fecundity, and hatching success tended to decrease, although not significantly. The increase in nest count and female abundance may be related to the number of newly recruited females that were laying eggs for the first time. As at Samandağ beach, the long-term conservation goals are to increase the number of nests. However, the observed contrast between nest numbers and clutch size raises concerns about the effectiveness of conservation initiatives. The uncertainty surrounding the sustainability of these initiatives, which focus solely on the breeding environment, is evident in light of the aforementioned disparity. There is, therefore, a need to re-evaluate the objectives behind conservation efforts. It is imperative to recognize that the implementation of beach-based conservation measures alone is not sufficient; it is equally important to establish conservation measures in areas where feeding, wintering, and mating activities occur, including all life stages.

AUTHOR CONTRIBUTIONS

Bektaş Sönmez and Şükran Yalçın Özdilek conceived the ideas and designed the methodology; Bektaş Sönmez collected the data; Burcu Mestav and Şükran Yalçın Özdilek analysed the data; and Bektaş Sönmez led the writing of the manuscript. All authors contributed critically to the drafts and gave final approval for publication.

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CONFLICT OF INTEREST STATEMENT

The authors have no relevant financial or non-financial interests to disclose.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the authors, upon reasonable request.

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REFERENCES

Ariano-Sánchez, D., Muccio, C., Rosell, F. & Reinhardt, S. (2020). Are trends in Olive Ridley sea turtle (*Lepidochelys olivacea*) nesting abundance affected by El Niño Southern Oscillation (ENSO) variability? Sixteen years of monitoring on the Pacific coast of northern Central America. *Global Ecology and Conservation*, 24, e01339. https://doi.org/10.1016/j.gecco.2020.e01339

Blumenthal, J.M., Hardwick, J.L., Austin, T.J., Broderick, A.C., Chin, P., Collyer, L. et al. (2021). Cayman Islands sea turtle nesting population increases over 22 years of monitoring. *Frontiers in Marine Science*, 8, 461. https://doi.org/10.3389/fmars.2021.663856

Broderick, A.C., Glen, F., Godley, B.J. & Hays, G.C. (2002). Estimating the number of green and loggerhead turtles nesting annually in the Mediterranean. *Oryx*, 36(3), 227–235. https://doi.org/10.1017/S0030605302000431

Broderick, A.C., Glen, F., Godley, B.J. & Hays, G.C. (2003). Variation in reproductive output of marine turtles. *Journal of Experimental Marine Biology and Ecology*, 288(1), 95–109. https://doi.org/10.1016/S0022-0981(03)00003-0

Broderick, A.C., Godley, B.J. & Hays, G.C. (2001). Trophic status drives interannual variability in nesting numbers of marine turtles. *Proceedings of the Royal Society B: Biological Sciences*, 268(1475), 1481–1487. https://doi.org/10.1098/rspb.2001.1695

Casale, P. (2011). Sea turtle by-catch in the Mediterranean. *Fish and Fisheries*, 12(3), 299–316. https://doi.org/10.1111/j.1467-2979.2010.00394.x

Casale, P. (2015). *Caretta caretta* (Mediterranean subpopulation). The IUCN Red List of Threatened Species 2015. https://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. et al. (2018). Mediterranean sea turtles: current knowledge and priorities for conservation and research. *Endangered Species Research*, 36, 229–267. https://doi.org/10.3354/esr00901

Casale, P., Ceriani, S.A., Dodd, M.G., Pate, S.M., Godfrey, M.H., Griffin, D.B. et al. (2022). New methods to derive sea turtle nester abundance from nest counts: ground truthing and the bias of current approaches. *Biological Conservation*, 275, 109754. https://doi.org/10.1016/j.biocon.2022.109754

Casale, P. & Heppell, S.S. (2016). How much sea turtle bycatch is too much? A stationary age distribution model for simulating population abundance and potential biological removal in the Mediterranean. *Endangered Species Research*, 29, 239–254. https://doi.org/10.3354/esr00714

Casale, P. & Tucker, A.D. (2015). *Caretta caretta*. The IUCN Red List of Threatened Species 2015. https://doi.org/10.2305/IUCN.UK.2015-4.RLTS.T3897A83157651.en, e.T3897A83157651.

Ceriani, S.A., Casale, P., Brost, M., Leone, E.H. & Witherington, B.E. (2019). Conservation implications of sea turtle nesting trends: elusive recovery of a globally important loggerhead population. *Ecosphere*, 10(11), e02936. https://doi.org/10.1002/ecs2.2936

Cheung, Y.W. & La, K.S. (1995). Lag order and critical values of the augmented dickey-fuller test. *Journal of Business & Economic Statistics*, 13(3), 277–280. https://doi.org/10.1080/07350015.1995.10524601

Esteban, N., Mortimer, J.A. & Hays, G.C. (2017). How numbers of nesting sea turtles can be overestimated by nearly a factor of two. *Proceedings of the Royal Society B: Biological Sciences*, 284, 20162581. https://doi.org/10.1098/rspb.2016.2581

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 & Coastal Management*, 51(4), 330–341. https://doi.org/10.1016/j.ocecoaman.2007.09.002

Fuentes, M.M.P.B., Limpus, C.J., Hamann, M. & Dawson, J. (2010). Potential impacts of projected sea-level rise on sea turtle rookeries. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 20(2), 132–139. https://doi.org/10.1002/aqc.1088

Hamann, M., Limpus, C.J. & Owens, D.W. (2003). Reproductive cycles of males and females. In: Lutz, P.L., Musick, J.A. & Wyneken, J. (Eds.) *The biology of sea turtles, vol. II*. Boca Raton: CRC Press, pp. 135–161.

Ilgaz, Ç., Türkozan, O., Özdemir, A., Kaska, Y. & Stachowitsch, M. (2007). Population decline of loggerhead turtles: two potential scenarios for Fethiye beach, Turkey. In: Hawskworth, D.L. & Bull, A.T. (Eds.) *Vertebrate conservation and biodiversity*, vol. 5. Dordrecht: Springer, pp. 201–211. https://doi.org/10.1007/978-1-4020-6320-6_13

Jackson, J.B.C. (1997). Reefs since Columbus. *Coral Reefs*, 16(Suppl 1), S23–S32. https://doi.org/10.1007/s003380050238

Johnson, S.A. & Ehrhart, L.M. (1996). Reproductive ecology of the Florida green turtle: clutch frequency. *Journal of Herpetology*, 30(3), 246–251. https://doi.org/10.2307/1565180

Karaman, S., Turkozan, O., Carreras, C., Yılmaz, C., Sönmez, B., Candan, O. et al. (2022). Population genetic diversity of green turtles, *Chelonia mydas*, in the Mediterranean revisited. *Marine Biology*, 169(6), 77. https://doi.org/10.1007/s00227-022-04068-1

Kittinger, J.N., Houtan, K.S.V., McClenachan, L.E. & Lawrence, A.L. (2013). Using historical data to assess the biogeography of population recovery. *Ecography*, 36(8), 868–872. https://doi.org/10.1111/j.1600-0587.2013.00245.x

Lascelles, B., Notarbartolo Di Sciara, G., Agardy, T., Cuttelod, A., Eckert, S., Glowka, L. et al. (2014). Migratory marine species: their status, threats and conservation management needs. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 24(S2), 111–127. https://doi.org/10.1002/aqc.2512

Legendre, P. & Legendre, L. (2012). *Numerical ecology: developments in environmental modeling*. vol. 24. New York, Elsevier.

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. *Memoirs of the Queensland Museum*, 49(1), 349–440.

Mazaris, A.D., Kornaraki, E., Matsinos, Y.G. & Margaritoulis, D. (2004). Modeling the effect of sea surface temperature on sea turtle nesting activities by investigating seasonal trends. *Natural Resource Modeling*, 17(4), 445–465. https://doi.org/10.1111/j.1939-7445.2004.tb00145.x

Mazaris, A.D., Matsinos, Y.G. & Pantis, J.D. (2009). Evaluating the impacts of coastal squeeze on sea turtle nesting. *Ocean & Coastal Management*, 52(2), 139–145. https://doi.org/10.1016/j.ocecoaman.2008.10.005

Mazaris, A.D., Schofield, G., Gkazinou, C., Almpanidou, V. & Hays, G.C. (2017). Global sea turtle conservation successes. *Science Advances*, 3(9), e1600730. https://doi.org/10.1126/sciadv.1600730

McClenachan, L., Jackson, J.B. & Newman, M.J. (2006). Conservation implications of historic sea turtle nesting beach loss. *Frontiers in Ecology and the Environment*, 4(6), 290–296. https://doi.org/10.1890/1540-9295(2006)4[290:CIOHST]2.0.CO;2

Miller, J.D. (1999). Determining clutch size and hatching success. In: Eckert, K.L., Bjorndal, K.A., Abreu-Grobois, F.A. & Donnelly, M. (Eds.) *Research and management techniques for the conservation of sea turtles*. IUCN, SSC Marine Turtle Specialist Group, Washington DC, pp. 124–129 Publication No. 4.

National Research Council. (1990). *Decline of sea turtles. Causes and prevention*, Washington: National Academy Press, p. 259.

Omeyer, L.C.M., Fuller, W.J., Godley, B.J., Snape, R.T.E. & Broderick, A.C. (2019). The effect of biologging systems on reproduction, growth and survival of adult sea turtles. *Movement Ecology*, 7(2). https://doi.org/10.1186/s40462-018-0145-1

Omeyer, L.C.M., Stokes, K.L., Beton, D., Çiçek, B.A., Davey, S., Fuller, W.J. et al. (2021). Investigating differences in population recovery rates of two sympatrically nesting sea turtle species. *Animal Conservation*, 24(5), 832–846. https://doi.org/10.1111/acv.12689

Oruç, A. (2001). Trawl fisheries in the eastern Mediterranean and their impact on marine turtles. *Zoology in the Middle East*, 24(1), 119–125. https://doi.org/10.1080/09397140.2001.10637890

Pisano, A., Marullo, S., Artale, V., Falcini, F., Yang, C., Leonelli, F.E. et al. (2020). New evidence of Mediterranean climate change and variability from sea surface temperature observations. *Remote Sensing*, 12(1), 132. https://doi.org/10.3390/rs12010132

Pritchard, A.M., Sanchez, C.L., Bunbury, N., Burt, A.J., Currie, J.C., Doak, N. et al. (2022). Green turtle population recovery at Aldabra Atoll continues after 50 yr of protection. *Endangered Species Research*, 47, 205–215. https://doi.org/10.3354/esr01174

R Core Team. (2022). *R: a language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing. https://www.R-project.org/

Richardson, J.I., Hall, D.B., Mason, P.A., Andrews, K.M., Bjorkland, R., Cai, Y. et al. (2006). Eighteen years of saturation tagging data reveal a significant increase in nesting hawksbill sea turtles (*Eretmochelys imbricata*) on Long Island, Antigua. *Animal Conservation*, 9(3), 302–307. https://doi.org/10.1111/j.1469-1795.2006.00036.x

Seminoff, J.A. (2004). *Chelonia mydas*. The IUCN Red List of Threatened Species 2004, e.T4615A11037468.

Seminoff, J.A., Zarate, P., Coyne, M., Foley, D.G., Parker, D., Lyon, B.N. et al. (2008). Post-nesting migrations of Galapagos green turtles *Chelonia mydas* in relation to oceanographic conditions: integrating satellite telemetry with remotely sensed ocean data. *Endangered Species Research*, 4, 57–72. https://doi.org/10.3354/esr00066

Sen, P.K. (1968). Estimates of the regression coefficient based on Kendall's Tau. *Journal of the American Statistical Association*, 63(324), 1379–1389. https://doi.org/10.1080/01621459.1968.10480934

Snape, R.T.E., Beton, D., Broderick, A.C., Çiçek, B.A., Fuller, W.J., Özden, Ö. et al. (2013). Strand monitoring and anthropological surveys provide insight into marine turtle bycatch in small-scale fisheries of the Eastern Mediterranean. *Chelonian Conservation and Biology*, 12(1), 44–55. https://doi.org/10.2744/CCB-1008.1

Solow, A.R., Bjorndal, K.A. & Bolten, A.B. (2002). Annual variation in nesting numbers of marine turtles: the effect of sea surface temperature on re-migration intervals. *Ecology Letters*, 5(6), 742–746. https://doi.org/10.1046/j.1461-0248.2002.00374.x

Sönmez, B. (2018). Sixteen year (2002-2017) record of sea turtle strandings on Samandağ Beach, the eastern Mediterranean coast of Turkey. *Zoological Studies*, 57, e53. https://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. *Zoological Stududies*, 58, e16. https://doi.org/10.6620/ZS.2019.58-16

Sönmez, B., Karaman, S. & Turkozan, O. (2021). Effect of predicted sea level rise scenarios on green turtle (*Chelonia mydas*) nesting. *Journal of Experimental Marine Biology and Ecology*, 541, 151572. https://doi.org/10.1016/j.jembe.2021.151572

Sönmez, B., Turan, C. & Yalçın Özdilek, Ş. (2013). Comparison of the physical properties of two Green Turtle (*Chelonia mydas*) nesting beaches (Akyatan and Samandağ) in the eastern Mediterranean (Reptilia: Cheloniidae). *Zoology in the Middle East*, 59(1), 30–38. https://doi.org/10.1080/09397140.2013.795061

Sönmez, B., Türkecan, O. & Jded, A. (2017). Long distance movement between nesting sites for two green turtles in the eastern Mediterranean. *Marine Turtle Newsletter*, 153, 7–8.

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. *Russian Journal of Herpetology*, 20(1), 19–26.

Stokes, K.L., Fuller, W.J., Glen, F., Godley, B.J., Hodgson, D.J., Rhodes, K.A. et al. (2014). Detecting green shoots of recovery: the importance of long-term individual-based monitoring of marine turtles. *Animal Conservation*, 17(6), 593–602. https://doi.org/10.1111/acv.12128

Tucker, A.D. (2010). Nest site fidelity and clutch frequency of loggerhead turtles are better elucidated by satellite telemetry than by nocturnal tagging efforts: implications for stock estimation. *Journal of Experimental Marine Biology and Ecology*, 383(1), 48–55. https://doi.org/10.1016/j.jembe.2009.11.009

Van Houtan, K.S. & Kittinger, J.N. (2014). Historical commercial exploitation and the current status of Hawaiian green turtles. *Biological Conservation*, 170, 20–27. https://doi.org/10.1016/j.biocon.2013.11.011

Wallace, B.P., DiMatteo, A.D., Bolten, A.B., Chaloupka, M.Y., Hutchinson, B.J., Abreu-Grobois, F.A. et al. (2011). Global conservation priorities for marine turtles. *PLoS ONE*, 6(9), e24510. https://doi.org/10.1371/journal.pone.0024510

Wallace, B.P., DiMatteo, A.D., Hurley, B.J., Finkbeiner, E.M., Bolten, A.B., Chaloupka, M.Y. et al. (2010). Regional management units for marine turtles: a novel framework for prioritizing conservation and research across multiple scales. *PLoS ONE*, 5(12), e15465. https://doi.org/10.1371/journal.pone.0015465

Yalçın Özdilek, Ş., Sönmez, B. & Mestav, B. (2023). Body size-related polymorphic foraging strategy in adult green turtles. *Ocean & Coastal Management*, 237, 106538. https://doi.org/10.1016/j.ocecoaman.2023.106538

Yalçın Özdilek, Ş., Sönmez, B. & Sert, M. (2018). Stranded sea turtle records between 2010 and 2017 in northern Aegean and Sea of Marmara. *Regional Studies in Marine Science*, 24, 17–22. https://doi.org/10.1016/j.rsma.2018.07.002

Yalçın-Özdilek, Ş. (2007). Status of sea turtles (*Chelonia mydas* and *Caretta caretta*) on Samandağ Beach, Turkey: a five-year monitoring study. *Annales Zoologici Fennici*, 44(5), 333–347.

Yalçin-Özdilek, Ş. & Aureggi, M. (2006). Strandings of juvenile green turtles at Samandağ, Turkey. *Chelonian Conservation and Biology*, 5(1), 152–154. https://doi.org/10.2744/1071-8443(2006)5[152:SOJGTA]2.0.CO;2

Yalçın-Özdilek, Ş., Özdilek, H.G. & Ozaner, F.S. (2007). Possible influence of beach sand characteristics on green turtle nesting activity on Samandağ Beach, Turkey. *Journal of Coastal Research*, 2007(236), 1379–1390. https://doi.org/10.2112/06-0630.1

Yılmaz, C., Oruç, A. & Türkozan, O. (2015). Marine turtles (*Chelonia mydas* and *Caretta caretta*) nesting along the eastern Mediterranean coast of Turkey: results from six years of surveying. *The Herpetological Journal*, 25(4), 197–204.

Yılmaz, C., Oruç, A. & Türkozan, O. (2022). Abundance trend and nesting biology of green turtles *Chelonia mydas* (Testudines: Cheloniidae) during ten consecutive nesting seasons (2012–2021) at Akyatan Beach, Turkey. *Zoological Studies*, 61, e53. https://doi.org/10.6620/ZS.2022.61-53

Yue, S., Pilon, P., Phinney, B. & Cavadias, G. (2002). The influence of autocorrelation on the ability to detect trend in hydrological series. *Hydrological Processes*, 16(9), 1807–1829. https://doi.org/10.1002/hyp.1095

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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