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Marine turtles (*Chelonia mydas* and *Caretta caretta*) nesting along the eastern Mediterranean coast of Turkey: Results from six years of surveying

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The nesting biology of green and loggerhead sea turtles (*Chelonia mydas* and *Caretta caretta*) on Akyatan, Ağyatan, Tuzla and Yumurtalık Nature Reserve beaches along the eastern Mediterranean coast of Turkey was investigated during six consecutive nesting seasons (2006–2011). A total of 2198 *C. mydas* and 104 *C. caretta* nests were recorded, with an annual mean of 366 and 17 nests, respectively. Akyatan was the main breeding site for both species. We recorded a total of 5879 *C. mydas* emergences, with 2171 (37%) resulting in nests (mean of 362 nests per year); the mean nesting density was 16 nests km^{-1}. A total of 1335 (61%) *C. mydas* nests from Akyatan beach were excavated. We recorded 151,758 eggs, 116,309 of which (77%) hatched, producing 88,673 hatchlings which were able to reach the sea. The annual number of nests ranged from 170 (2007) to 562 (2006), with a statistically non-significant decrease throughout the study period (Spearman r=-0.20, p>0.05). The main threats were predation of eggs and hatchlings by jackals, plastic pollution and vehicle ruts that hindered the hatchlings progress to the sea.

Key words: Chelonia mydas, *Caretta caretta*, marine turtles, Mediterranean, Turkey

INTRODUCTION

Marine turtles are highly migratory, geographically widespread animals and therefore require trans-boundary conservation strategies. Six of the seven sea turtle species are globally categorised as Vulnerable, Endangered or Critically Endangered (IUCN, 2013). A total of 58 Regional Management Units (RMUs) have been identified for all sea turtle species around the world (Wallace et al., 2010). Of these RMUs, 17 were described for *C. mydas*, with the Mediterranean region being one of them (Wallace et al., 2010). As a region facing low risk and high threats (Wallace et al., 2011), research and conservation activities are imperative in order to consolidate and improve the conservation status of marine turtles in the Mediterranean.

Chelonia mydas is globally categorised as Endangered (IUCN, 2013). Nesting in the Mediterranean is confined to Turkey, Cyprus, Syria, Lebanon, Israel and Egypt (Kasparek et al., 2001, Rees et al., 2008), with foraging areas in Greece and Libya (Casale & Margaritoulis, 2010). However, almost 95% of Mediterranean nesting activity occurs in Turkey and Cyprus (Kasparek et al., 2001). In the Mediterranean, about 1500 nests are documented each year (Casale & Margaritoulis, 2010), representing approximately 339–360 female green turtles nesting annually (Broderick et al., 2002). *Caretta caretta* is also classified as Endangered globally (IUCN, 2013) with the largest Mediterranean nesting rookeries occurring in Greece, Turkey, Cyprus and Libya. These countries also hold the most important foraging areas in the Mediterranean (Casale & Margaritoulis, 2010). For the entire Mediterranean, over 7200 nests are reported annually (Casale & Margaritoulis, 2010), which constitutes approximately 2280-2287 nesting female *C. caretta* (Broderick et al., 2002).

In the Mediterranean, *C. mydas* shows a high degree of genetic structuring based on nuclear DNA, while low genetic variation was observed in terms of mtDNA; each nesting beach is regarded as a distinct management unit (Bağda et al., 2012). Similar structuring has also been reported for *C. caretta* (Clusa et al., 2013), for which the nesting beaches in Turkey can be divided into five distinct management units (Yılmaz et al., 2011). Eastern Turkey (ETR) represents one management unit, and appears to have been a key source population enabling the re-colonisation of the Mediterranean during glacial fluctuations of the Pleistocene (Clusa et al., 2013).

A total of 21 main nesting grounds were described for marine turtles in Turkey (Türkozan & Kaska, 2010). Nesting by *C. mydas* is mostly confined to the eastern beaches of Kazanlı, Akyatan and Samandağ (Durmuş, 1998; Kasparek

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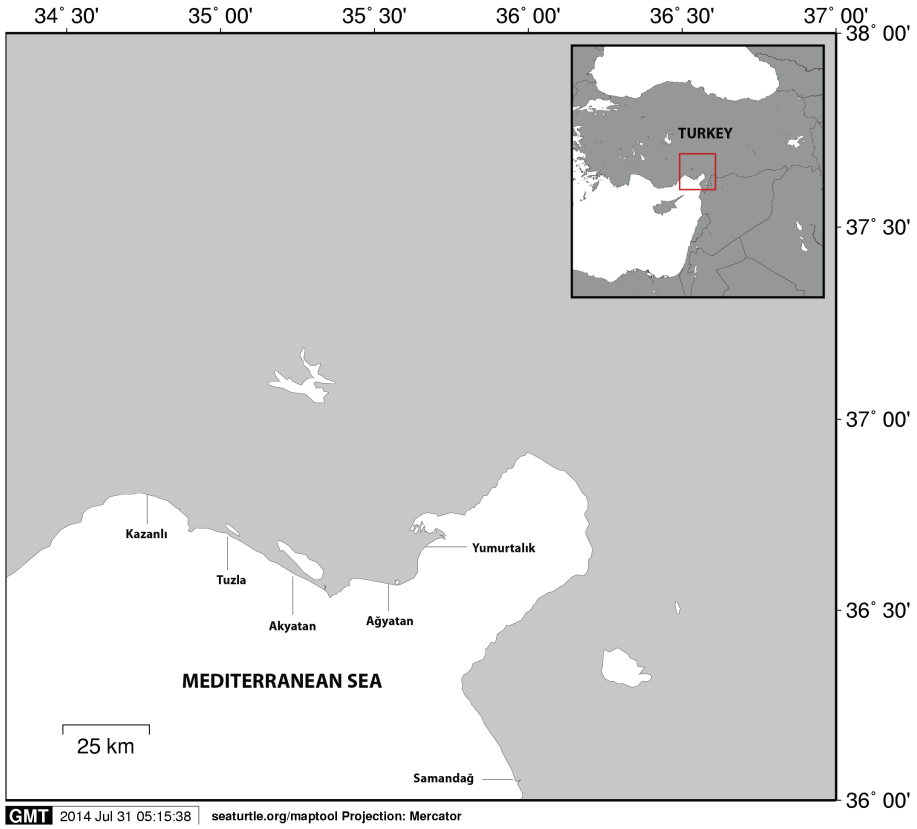

Fig. 1. The locations of studied beaches (Tuzla, Akyatan, Ağyatan and Yumurtalık) and the beaches where possible nesting shifts may have occurred (Kazanlı and Samandağ).

et al., 2001; Türkozan & Kaska, 2010; Ergene et al., 2013; Sönmez, 2013). However, nesting has also been recorded from 16 other sites, totalling to 452–2051 nests annually (Türkozan & Kaska, 2010). *Caretta caretta* are present on almost all nesting beaches, reaching 769–3521 nests per year (Türkozan & Kaska, 2010).

Akyatan beach (22 km long) is the most important nesting ground for *C. mydas* in the Mediterranean, accounting for 50% of nests (Kasparek et al., 2001). *Caretta caretta* also nests on this beach in lower numbers (3–31 nests, Türkozan & Kaska, 2010). Previous research has focused on nesting surveys (Gerosa et al., 1998), mammal predation (Brown & Macdonald, 1995), temperature-dependent sex determination (Casale et al., 2000) and nest site preferences (Türkozan et al., 2011). The other study sites (Ağyatan, Tuzla and Yumurtalık Nature Reserve, totalling 70 km) have previously been only monitored with short-term surveys (Baran & Kasparek, 1989; Yerli & Demirayak, 1996; Oruç et al., 2003) and thus require prolonged assessment in order to accurately determine their importance. This study presents long-term results on marine turtle nesting activities along the eastern Mediterranean coast of Turkey.

METHODS

We collected information on the nesting ecology of *C. mydas* and *C. caretta* over six nesting seasons (2006–2011). Beaches were surveyed between 1 June and 15 September each year. Akyatan was monitored daily, while Ağyatan, Tuzla and Yumurtalık Nature Reserve beaches (Fig. 1) were patrolled at 10–15 day intervals. All surveys were undertaken in the morning. For Tuzla beach, only the western 12.5 km of the beach was monitored since no nesting was recorded elsewhere. For Akyatan beach, during the first two nesting seasons the core nesting area was identified (14 km) which was then monitored daily on foot, with the remaining 8 km (approx. 4 km from both end of the beach section) being patrolled every 3 days. Surveying teams consisted of two groups of three people. Nesting activity was recorded (including non-nesting emergences) daily and nests were raked over to avoid duplicate counting. The location of clutches within a nest was determined by carefully probing the sand with a long, thin metal pole. The distance of nests and the apex of non-nesting emergences from the high tide line were measured using a flexible tape measure. All clutch locations were individually marked and caged with wire mesh screen to prevent nest predation by mammals. Depredated eggs were counted and moved to another location on the same beach and reburied, undamaged eggs were re-buried in their or iginal location. Clutches laid in areas where they were at risk from flooding were relocated to an area at lower risk. For each relocated clutch, an artificial nest was created mirroring the dimensions of the original nest.

During hatchling emergence (July – end-September), the numbers of hatchling tracks emanating from nests were counted daily, and numbers of hatchlings reaching the sea were determined. Counted tracks were raked over to avoid recounting. When the tracks were interrupted by predator tracks, such as the golden jackal (*Canis aureus*) or crabs (e.g., *Ocypode cursor*), we assumed that those predators preyed upon the hatchlings. After 3 or 5 days from the first emergence of hatchlings, nests were excavated by hand or using a shovel. Nest contents were sorted and classified into one of: hatched eggs, unhatched eggs (eggs without visible embryos or blood formation),

Table 1. The hatching and hatchling survival of *C. mydas* and *C. caretta* nests on Akyatan beach.*depredated nests were excluded from all analysis including the calculation of total number of eggs laid on the beach. (*Caretta caretta n*=21, *Chelonia mydas n*=1335)

	Caretta caretta	*Chelonia mydas*
Total number of eggs	1508	151758
Unhatched eggs	24	5328
Embryo	656	30121
Hatchlings	828	116309
dead in nest	15	1564
reaching the sea	735	88673
depredated	78	24838
dead on the beach	-	1234

developmentally delayed eggs (containing an embryo), or abnormal eggs (unhatched eggs with unusual shape). Excavation was undertaken for almost 95% of all recorded nests. Hatching success represented the proportion of the clutch hatched. When fragmented egg shells were found, egg shell pieces were reassembled to represent one egg. Predated nests were not considered to assess hatching success. Incubation duration was defined as the number of days from the date of nesting to the date of first hatchling emergence.

RESULTS

Akyatan beach

A total of 6093 emergences were recorded, 2265 of which (37%, annual range=180–593) resulted in clutch deposition. Of these nests, 2171 (95.8%, annual range=170–562) were *C. mydas*, and 94 (4.2%, annual range=3–31) were *C. caretta*. The annual mean number of nests was 362 and 16 for *C. mydas* and *C. caretta*, respectively. A total of 726 (33.4%) *C. mydas* nests and 71 (75.5%) *C. caretta* nests were completely or partially predated by mammals. Annual numbers of nests showed a non-significantly decreasing trend (Spearman r=-0.20, p>0.05).

Due to predation and the risk of flooding, 9 *C. caretta* and 57 *C. mydas* nests were relocated. For *C. mydas*, there was no statistical difference between original and relocated nests with regard to incubation duration, number of unhatched eggs, mid-stage embryos, late embryos and hatching success (t-test: p>0.05), whereas the number of early stage embryos was higher in relocated nests (t-test: p<0.001). For *C. caretta*, there were no differences between original and relocated nests (Mann Whitney U-test, p>0.05 in all cases).

Table 2. The mean incubation durations of *C. mydas* according to years (depredated nests are excluded).

Year	*n*	Mean±SD	Range
2006	291	54.5±4.2	45–70
2007	92	51.5±3.1	46–62
2008	246	53.3±3.2	45–62
2009	141	53.4±3.4	48–66
2010	120	53.05±2.9	47–64
2011	156	49.69±2.2	45–55

A total of 151,758 eggs were deposited in 1335 excavated *C. mydas* nests, with a mean clutch size of 113.7±0.8 eggs (range: 14–229). Of these eggs, 116,309 (76.5%) produced hatchlings, 88,673 of which (76.0%) were able to reach the sea. For *C. caretta*, a total of 1508 eggs were laid in 21 nests, with a mean clutch size of 71.8±5.3 eggs (range: 7–113). Of these, 828 (54.9%) produced hatchlings, 735 of which (88.7%) were able to reach the sea. The hatching success and survival of both species are presented in Table 1. Hatching success was 76.1±26.2 (n=1335, range=0–100) and 56.1±37.5 (n=21, range 0.0–98.6) for *C. mydas* and *C. caretta* nests, respectively. A total of 30,121 dead embryos were counted in 1335 nests. For *C. mydas*, 76.4% were early stage embryos, 4.4% were mid-stage embryos, and 19.2% were late stage embryos.

The mean overall incubation duration was 50.8±3.4 days (n=10; range 47–58) for *C. caretta* and 52.9±3.8 (n=1046; range=45–70) for *C. mydas*. The mean incubation duration of *C. mydas* nests differed between study years (ANOVA F=45.69; p<0.001), with a maximum in 2006 and a minimum in 2011 (Table 2).

The nesting season on Akyatan beach commenced in May, before the onset of surveys (1st June). The last nests were recorded for the 7th August (2008). The average peak-nesting season on Akyatan beach was in the period of June 19–28 (Fig. 2). Hatching started during the third week of July (except in 2007), with an annually fluctuating peak (Fig. 3). The average distance of *C. mydas* nests from the tideline was 41.7±17.3 m (n=2106, range 4.2–123.9; Fig. 4). The average distance of *C. caretta* nests from the tideline was 22.7±9.7 m (n=94, range 3–61.9). Nesting densities were higher on the eastern sector of the beach (1390 nests compared to 875 nests), with the exception of 2007.

A total of 726 (33.4%) *C. mydas* nests and 71 (75.5%) *C. caretta* nests were completely or partially predated, leading to at least 4118 *C. caretta* eggs and 46,803 *C. mydas* eggs being destroyed. The golden jackal (*Canis aureus*) had the highest impact on egg predation for both species (3369 or 82.2% and 32,920 or 79.9% eggs for *C. caretta* and *C. mydas*, respectively). Other predators

Table 3. Recorded *C. mydas* nest numbers from previous studies at Akyatan beach (a: Baran & Kasparek, 1989; b: Whitmore, 1991; c: Brown & McDonald, 1995; d: Gerosa et al., 1998; e: Yerli & Canbolat, 1998; f: Aureggi et al., 2000; g: Oruç, 2001; h: Oruç et al., 2002). nk=not known.

	1988	1991	1992	1994	1995	1996	1997	1998	2000	2001
Duration of the study (days)	7	3	uk	81	74	84	85	uk	57	81
Length of the beach studied (km)	nk	nk	9	13	nk	nk	nk	nk	8	6
No of nests	108	210	120	496	504	179	231	735	223	159
Source	a	b	c	d	d	e	d	f	g	h

included wild boar (*Sus scrofa*), red fox (*Vulpes vulpes*, recorded only in 2006) and badgers (*Meles meles*). Of the 71 *C. caretta* nests affected, 56 (78.9%) were predated by golden jackals, 6 (8.4%) by wild boars, and 9 (12.7%) by unknown predators. Of the 726 *C. mydas* nests, 474 (65.4%) were predated by golden jackals, 132 (18.2%) by wild boar, 4 (0.6%) were by badgers, 1 (0.1%) by a fox and 114 (15.7%) were affected by unknown predators.

A total of 24,242 (20.8%) *C. mydas* hatchlings were predated from 621 nests, while 78 (9.4%) hatchlings were depredated from four *C. caretta* nests. Of the predated *C. mydas* hatchlings, 23,357 (96.3%) hatchlings were predated by jackals, 833 by crabs, 7 by seagulls and 43 by wild boars. For *C. caretta*, jackals predated 71 (91%) and crabs predated 7 (9%) hatchlings. Furthermore, 1234 (1%) of *C. mydas* hatchlings were found dead on the beach without predation.

The main anthropogenic threat on the beach was caused by tractors which compacted the sand to affected hatchling emergence and left tracks which trapped hatchlings. Furthermore, discarded fishing nets also prevented hatchlings from safely reaching the sea. Human disturbance on the beach at night was low.

Other sites

On Tuzla beach, a total of 23 *C. mydas* and 3 *C. caretta* nests were recorded from Tuzla beach. *C. mydas* nest numbers ranged from 1 (2011) to 9 (2006) with a mean of 4 nests. A total of 1292 eggs were counted in 13 *C. mydas* nests with a mean of 99.4 eggs. Of these eggs, 737 hatchlings emerged.

On Ağyatan beach, seven *C. caretta* emergences were recorded in 2006, resulting in two nests with a total of 131 eggs. Of these eggs, 68 were found empty, 5 were found containing embryos, and the remaining 58 were found predated. Between 2007 and 2011, up to eight *C. caretta* emergences and up to two nests (*C. caretta* and *C. mydas*) were recorded, none of which resulted in recorded hatchlings.

During our six years survey of Yumurtalik Nature Reserve, only a single loggerhead nest and a single green turtle nest were recorded (2006).

DISCUSSION

Over 1500 *C. mydas* nests are recorded each year in the Mediterranean, with major nesting sites defined as those containing >40 nests (Casale & Margaritoulis, 2010). The annual mean number of nests on Akyatan beach (362) constitutes almost a quarter of the overall nesting in the Mediterranean. Akyatan was previously reported to represent 43% of the overall nesting in the Mediterranean for *C. mydas*, followed by Kazanlı and Samandağ (Kasparek et al., 2001). In a recent review (Türkozan & Kaska, 2010), a total of 452–2051 *C. mydas* nests were estimated for Turkish nesting beaches. The minimum and maximum nesting numbers on Akyatan beach constitutes 37.6% and 27.4% of the recorded range of total nests on the Turkish coasts. The annual means of other study sites (Tuzla, Ağyatan and Yumurtalık) were low in comparison. During the same nesting seasons (2006–2011), nest numbers ranged from 65–716 nests on Samandağ beach (Sönmez,

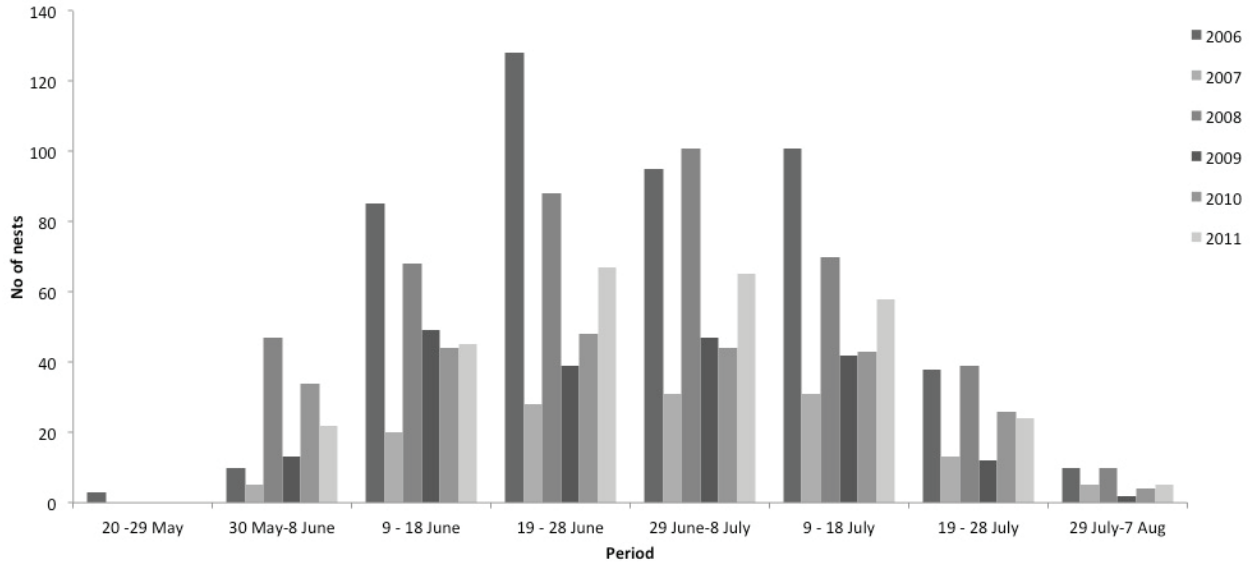

Fig. 2. Temporal distribution of *C. mydas* nests on Akyatan beach, Turkey (Data are grouped into 10 day bins).

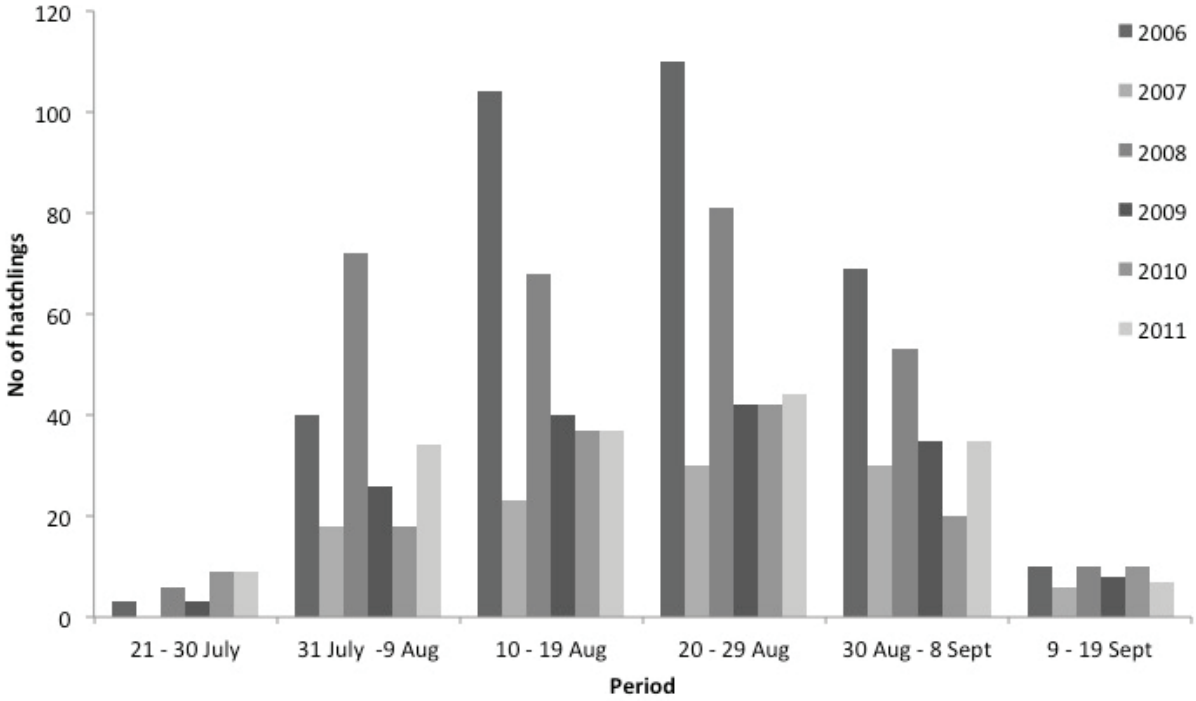

Fig. 3. Temporal distribution of *C. mydas* hatching on Akyatan beach, Turkey (Data are grouped into 10 day bins).

2013) and 176–562 nests on Kazanlı beach (Ergene et al., 2012). The decline in Akyatan in 2009 and 2011 is followed by an increase of turtles at Samandağ and Kazanlı, suggesting an exchange of nesting females (Fig. 5). Bağda et al. (2012) used genetic means to provide evidence for a regional site fidelity in *C. mydas*, as opposed to a fidelity to specific nesting beaches. Weishampel et al. (2003) reported that *C. mydas* emergences show a biennial pattern. This pattern was also observed for the first three years of our study. Other nesting beaches (Tuzla, Ağyatan and Yumurtalık) were represented by only 2–9 nests per year, similar to what was observed previously by Yerli & Canbolat (1998) and Yerli & Demirayak (1996).

Focusing on the 9 km to the east of the developed area during July, Brown & Macdonald (1995) estimated a total of 320 nests for Akyatan beach, and other previous studies recorded 108–735 nests (Table 4). However, these results are not directly comparable with our data. In other regions, a total of 273 *C. mydas* nests were reported from Latakia, Syria along a 12 km beach (Rees et al., 2010), and the mean numbers of nests in Cyprus were 104 and 48 for two regions (Casale & Margaritoulis, 2010). Overall, our long-term numbers shows that Akyatan remains the most important nesting ground for *C. mydas* in the Mediterranean.

The annual mean number for *C. caretta* is 17 nests per year, and the average annual number of nests in the Mediterranean is reported as 7200 nests (Casale & Margaritoulis, 2010). In Turkey, a total of 769–3521 nests were estimated annually (Türkozan & Kaska, 2010). The low number of *C. caretta* nests in the present region is due to its location in the eastern Mediterranean.

The mean clutch size recorded for *C. mydas* at Akyatan beach (113 eggs) is comparable to other sites (e.g., Kazanlı beach: 110.7 eggs, Ergene et al., 2013). The mean clutch size for *C. caretta* (71.8 eggs) is also within the range of other records from the Mediterranean (e.g., Dalyan Beach: 76 eggs, Türkozan & Yılmaz, 2008). Mean

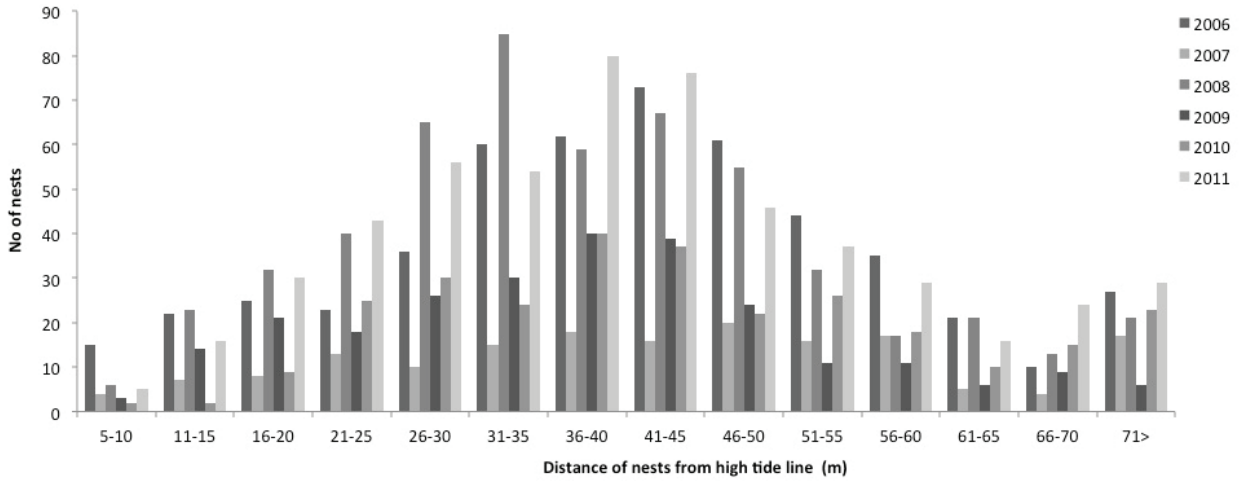

Fig. 4. Spatial distribution of green turtle nests on Akyatan beach.

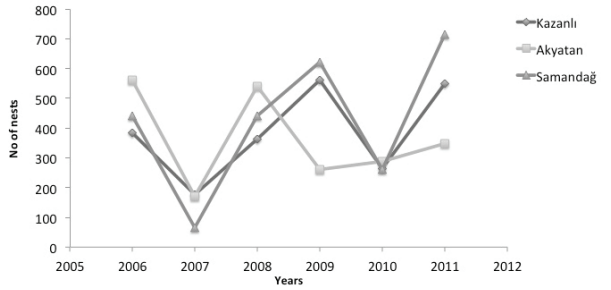

Fig. 5. The nesting trend of neighbouring *C. mydas* nesting beaches. The data for Kazanlı and Samandağ were provided from Ergene et al. 2012 and Sönmez, 2013 respectively.

values from elsewhere in the Mediterranean are 82 eggs in Israel (Silberstein & Dmi'el, 1991), 70 eggs in Northern Cyprus (Broderick & Godley, 1996), 117.7 eggs in Greece (Margaritoulis 1988), 64.7 eggs in Egypt (Campbell et al., 2001), 80.1 eggs in Patara, Turkey (Taşkın & Baran, 2001) and 72.7 eggs in Lebanon (Newbury et al., 2002). For loggerhead turtles, clutch size was positively correlated with the female's access to productive foraging grounds (Cardona et al., 2014).

Hatching success for *C. mydas* was 76% on Akyatan beach, comparing to 82.97% in Kazanlı (Ergene et al., 2013), 69.9% in Samandağ (Sönmez & Yalçın-Özdilek, 2013), and 84.2% in Northern Cyprus (Broderick & Godley, 1996). For *C. caretta* on Akyatan beach, hatching success was 56.1%, comparing to 56.8–66.1% on Dalyan Beach (Türkozan & Yılmaz, 2008), 58.1–67.8% on Fethiye beach (Türkozan, 2000), 71.5% for Laganas Bay, Greece (Margaritoulis, 2005) and 79.1% for northern Cyprus (Broderick & Godley, 1996). Hatching success can be influenced by fungal infections (Limpus et al., 1983), and moisture (McGehee, 1990 on *C.caretta,* but see also Wood & Bjorndal, 2000; Huerta, 1995 on *Lepidochelys olivacea,*). Hewavisenthi & Parmenter (2002) reported a positive relationship between hatching success and clutch size in flatback turtles. Türkozan et al. (2003) studied *C. caretta* hatchlings in Turkey and concluded that none of the factors they examined was correlated with hatching success. Of the determined embryonic deaths in *C. mydas nests,* 76.4% were early stage, 4.4% were mid-stage and 19.2% were late stage embryos. Rafferty et al. (2011) found that in leatherback turtles the nesting season significantly influenced early or late stage embryonic death, with environmental variables such as precipitation and temperature playing a significant role. The mean overall incubation duration for *C. caretta* and *C. mydas* were in the range of values reported elsewhere (*C. mydas*: Broderick & Godley, 1996; Sönmez & Yalçın-Özdilek, 2013; Durmuş, 1998; *C. caretta*: Broderick & Godley, 1996; Uçar et al., 2012; Türkozan & Yılmaz, 2008; Margaritoulis, 2005). Variation in incubation durations from different nesting beaches are a result of different temperature profiles and sand characteristics.

In northern Cyprus, hatching success of *C. mydas* nests did not differ between relocated and natural nests, at however higher frequencies of dead embryos in relocated nests (Özdemir & Türkozan, 2006). Hatching success was previously reported to be lower in natural nests of *C. mydas* on Samandağ beach (Sönmez & Yalçın-Özdilek, 2013), combined with smaller carapace lengths and lower mass of hatchlings from relocated nests (Türkozan & Yılmaz, 2007). For *C. caretta,* however, hatching success was higher in hatcheries than in original nests (Dalyan beach: Türkozan & Yılmaz, 2008). Concerns exist about nest relocation and hatchery techniques as a conservation strategy, due to potential negative effects of hatcheries such as sex ratio alteration (Godfrey & Mrosovky, 1999) and distortion of gene pools (Mrosovsky, 2006, see also Mortimer, 1999; Türkozan & Yılmaz, 2007).

The peak nesting season for green turtles fell between 19–28 June on Akyatan beach (Fig. 2), with the last nesting event always in the first week of August. The peak season in Northern Cyprus is reported to be between 12–19 June (Broderick & Godley, 1996). For *C. caretta*, in Anamur, Turkey, July was reported to be main nesting season, and in Greece the last nests were in late August or first week of September (Margaritoulis, 2005). Earlier nesting of *C. caretta* was found to be correlated with sea surface warming (Weishampel et al., 2005). Nest distribution does generally not follow a geographical pattern, despite *C. mydas* preferring nesting in vegetated areas, leading to higher hatching success (Türkozan et al., 2011). According to Gerosa et al. (1996), 43% of the nests were laid between 13 and 17 km along Akyatan beach, before turtles shifted their nesting sites eastward.

Predation rate (33.4 and 75.5% for *C. mydas* and *C. caretta*, respectively) were high on Akyatan beach, despite the use of wire mesh nest protection. As recorded in other studies, mammals were the main predators. For Akyatan beach, the golden jackal (*C. aureus*) had the highest impact on egg predation for both species. Brown & Macdonald (1995) reported that 63.8% of *C. mydas* and 100% *C. caretta* nests were predated by canids (*C. aureus* and *Vulpes vulpes*) on Akyatan beach. They reported that nest location had no effect on the likelihood of predation, and that predation occurred over at least 4 weeks of egg laying. Aureggi et al. (1999) recorded 26.6% nest predation rates in Akyatan, stating that jackals were less common nest predators than foxes. The killing of nesting females by golden jackals has also been recorded from Goksu Delta (Peters & Verhoeven, 1992; Akçınar et al., 2006). Since *C. caretta* nests were shallower in comparison to *C. mydas* nests, they were more often subjected to predation. *Chelonia mydas* further prefers to nest in vegetation, providing additional protection (Türkozan et al., 2011). In our study fox predation was only observed in 2006, which might be due to foxes and jackals outcompeting each other (Brown & Macdonald, 1995).

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