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The effect of nest relocation on embryonic mortality and sex ratio of Loggerhead Turtles, *Caretta caretta* (Reptilia: Cheloniidae), at Dalyan Beach, Turkey

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Abstract
Marine turtles are globally endangered and one important conservation technique is nest relocation. This study assesses the relationship between nest site factors (wet nest depth, dry nest depth, total nest depth, nest diameter, distance to sea, moisture, clutch size and incubation duration) and embryonic mortality of natural and relocated nests at Dalyan beach, Turkey. Principal component analyses (PCA) revealed a three-factor structure for the natural nests and a four-factor structure for the relocated nests. The clutches in natural and relocated nests had a total of mortality ratio of 21% and 12%, incubation duration of 52 and 50 days, and estimated female ratio of 80% and 88%, respectively. Thus, mortality was lower and incubation faster in the relocated nests, but the proportion of females was higher. Hatching success in relocated nests (84.4%) was significantly higher than in natural nests (72.7%).

Keywords: *Nest relocation, embryonic mortality, nest site factor,* Caretta caretta, *Dalyan*

Introduction

The loggerhead turtle, *Caretta caretta* (Linnaeus, 1758), is a large, hard-shelled marine turtle and is listed as globally endangered according to IUCN Red List categories (IUCN 2008). In the Mediterranean, most of the nesting takes place in the eastern basin (Margaritoulis et al. 2003), although rare nesting activity has been reported from the western basin (Llorente et al. 1992; Tomas et al. 2002; Delauguerre & Cesarini 2004). Greece, Turkey, and Cyprus are major nesting grounds for loggerhead turtle in the region (Groombridge 1990; Broderick et al. 2002; Margaritoulis et al. 2003). Egypt, Lebanon, Israel, Italy, Syria, and Tunisia have also been reported as minor nesting grounds (Margaritoulis et al. 2003; Mingozzi et al. 2007). Dalyan Beach is among the most important Turkish nesting grounds for *C. caretta* and the beach has been protected nationally since 1988 (according to the Barcelona Convention) as part of the Köyceğiz–Dalyan Special Environmental Protection Area (SPA) by the Turkish Ministry of Environment and Forestry (Ilgaz & Baran 2001; Türkozan et al. 2003b; Canbolat 2004; Başkale & Kaska 2005).

All sea turtle species share a core set of nesting behaviors. The general pattern includes seven steps: (1) emerging from the surf and ascending the beach; (2) excavating the body pit; (3) digging the egg chamber; (4) oviposition; (5) filling in the egg chamber; (6) filling the body pit; and (7) returning the sea (see Miller et al. 2003). Loggerhead nesting beaches generally tend to be sandy, wide, open beaches backed by low dunes and fronted by a flat, sandy approach from the sea (Miller et al. 2003). Females deposit from one to seven clutches during a single nesting season every two or three years (Dodd 1988). Loggerhead turtles lay white, spherical, cleidoic eggs with flexible, aragonite shells (Miller 1985; Packard & DeMarco 1991). Eggs incubate for approximately 2 months, after which time developed hatchlings emerge and run across the sand and into the sea (Ackerman 1997). The early stages of embryonic

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and hatchling life represent a crucial period in the life history of sea turtles when mortality levels are high (Richardson & Richardson 1982; Stancyk 1982). Biotic and abiotic factors such as salinity, moisture, gas flow, temperature, rainfall, tidal inundation, erosion, sand grain size and type, predation, nest depth and slope affect the nest environment of embryonic sea turtles (Hendrickson 1958; Bustard & Greenham 1968; Prange & Ackerman 1974; Fowler 1979; Limpus et al. 1979; Ackerman 1980; Mrosovsky 1980; Stancyk et al. 1980; Blanck & Sawyer 1981; Miller 1985; Yerli et al. 1997; Wallace et al. 2004; Özdemir et al. 2008).

The survival of this species depends primarily on the nesting beaches, as well as on the protection of mating, feeding, migration, and wintering grounds (Başkale & Kaska 2005). One of the most prevalent threats to sea turtle nest in the Mediterranean is inundation from the sea during the common periods of high surf (Baran & Kasparek 1989; Peters et al. 1994; Yerli & Demirayak 1996; Kuller 1999; Newburry et al. 2002; Margaritoulis et al. 2003; Rees & Margaritorulis 2004; Margaritoulis 2005). One key conservation technique is the relocation of nests in order to reduce threats to eggs and hatchlings (Margaritoulis 1988; Silberstein & Dmi'el 1991; Türkozan 2000; Ilgaz & Baran 2001; Sak & Baran 2001; Taşkın & Baran 2001; Türkozan & Yılmaz 2007). This approach is typically recommended when the nests are positioned in clearly disadvantageous sites, e.g. on sandy roads used by vehicles, directly at the waterline, or under permanently installed beach umbrellas and the like. Sak and Baran (2001), for example, suggested that nests laid in front of hotels may benefit from protection by being fenced off from human activities. Dutton et al. (2005) demonstrated that a relatively simple and inexpensive management intervention (beach protection and egg relocation) can be an effective tool for increasing leatherback populations at the US Virgin Islands. Başkale and Kaska (2005) reported that relocation, screening, and fencing clearly increased the hatching success rate and provided effective protection of sea turtle nests against inundation and predation on Fethiye, Dalyan and Dalaman beaches, Turkey.

The developmental success of sea turtle embryos is influenced by beach characteristics and environmental conditions (Hamann et al. 2003). Nest site choice has an influence on sex ratio and could be effectively heritable. Where unisex broods predominate, the thermal environment may severely constrain the evolution of sex ratios, with potentially grim consequences on the future of the population (Hulin et al. 2008). For those reasons, we investigated patterns of nest site factors, embryonic mortality, and sex ratio in relocated and natural nests on Dalyan beach, Turkey. The results may promote successful hatchery management.

Material and methods

Study site

Dalyan, situated at the connection zone of Aegean Sea and Mediterranean, has a partially different typical Mediterranean climate. While the winter season is rainy and moderately warm like the typical Mediterranean climate, the summer is not as hot and dry because of the breeze blowing from sea to land except for a few days a year. Sea temperature ranges from 15 to 28°C; air temperature can climb as high as 36°C in July and August.

Fieldwork took place at Dalyan Beach (36°48′N–28°37′E), situated in southwest Turkey. Dalyan beach is located in Muğla Province, Turkey, and is approximately 4.7 km long (Figure 1). The crescent-shaped extensive beach consists of two subsections: İztuzu beach (4.25 km long and from 75 to 200 m wide) and a small separate beach (approximately

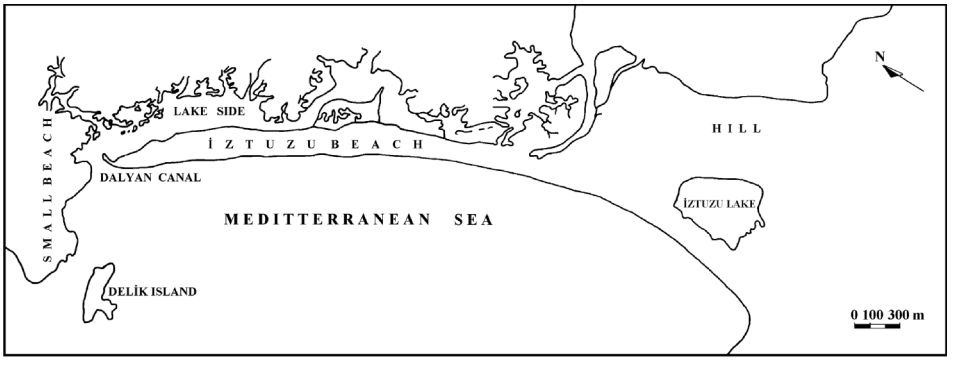


Figure 1. Map of Dalyan (İztuzu) beach.

450 m and 30–100 m wide) to its southwest. The eastern border of İztuzu beach is formed by a Red Pine (*Pinus brutia*) forest-covered hill and the western border by the outlet of a wetland into the sea. The Dalyan lagoon system, situated behind the western two-thirds of the İztuzu beach, is an extensive wetland with a labyrinth of reedy channels. It is connected to Köyceğiz Lake. Behind the eastern third is a small lake, İztuzu Lake, which is separated from the Dalyan estuary by a mountain ridge. There are cafes, showers, and bathing facilities at both the east and west ends of the İztuzu beach. During the daytime there is a high level of tourism activity at both ends of the İztuzu beach; however, beach umbrellas and sun beds are only used at the water's edge along those stretches where loggerhead turtle clutches are laid. The nesting surface area itself is kept free. There is no natural shading of the beach and the climate is typical of the eastern Mediterranean. The small beach is situated at the south-western part of the connection of the wetland to the sea. There are no tourist activities on this beach. Predation constitutes one of the major impacts on sea turtle populations (Magnuson et al. 1990). Major nest predators on eggs and hatchlings are Red Fox (*Vulpes vulpes*) and Sand Crab (*Ocypode cursor*) (Ilgaz & Baran 2001; Başkale & Kaska 2005) on Dalyan beach. Previous studies showed that an important amount of the loggerhead eggs and hatchlings were predated by Red Fox (*Vulpes vulpes*) on Dalyan beach. Başkale and Kaska (2005) stated that the total number of predated eggs and hatchlings as a percentage of the total egg number was 41.5% in the 2001 nesting season. This value was calculated as 24.4% in 2004 and 2005 nesting seasons on Dalyan beach (Türkozan & Yılmaz 2008). Due to the high rate of nest predation and inundation, Dalyan Beach was selected in order to study the relocation of nests.

Data collection and analyses

A total of 59 relocated nests (relocation to safety area) and 70 natural nests (none of which were inundated or predated) were examined in 2004. The positions of all nests were recorded in relation to marker posts placed at approximately 100 m intervals at the back of the beach. In the İztuzu subsection there is a line of 283 numbered wooden posts sunk into the sand, which run the entire length of the beaches at regular intervals of approximately 15 m. The fixed posts are used by researchers to periodically measure the positions of nests, and also to prevent tourists from sunbathing in the area and damaging nests.

The hatchery site was constructed in the middle part of the beach. This site had displayed ideal sand temperatures (between 27.5 and 32.1°C) for both sexes in previous years (Ç. Ilgaz, unpublished data), and had high hatching success (75.8%) (Ilgaz 1998). Only nests within 7 m of the sea threatened by tidal inundation and facing high rate of nest predation were transferred to the hatchery site. Relocation of the nests always occurred within the first 12 h after laying. The hatchery site was constructed to be sufficient to accommodate 59 nests and was high enough not to be inundated by high tides. Fencing extended to a depth of 0.5 m below and 2 m above the sand surface to prevent larger animals such as foxes from digging below or leaping over the fence. While transferring the eggs to the hatchery site, a plastic bucket with 5 cm of sand in the bottom was used in order to prevent the possibility of damage to the eggs. The eggs from each clutch were carefully transferred to separate nests in the hatchery. Relocated nests except those threatened by tidal inundation (only two nests) were constructed according to the original nest dimensions such as total nest depth, nest diameter and distance to sea. The distance between nests was set at 1 m in order to prevent any interaction. Natural nests for the topic of this study were randomly selected on the beach. Both natural and relocated nests were caged with wire cage placed at the centre of the nests with 0.2 m below the sand surface to prevent animal predation such as Red Fox (*Vulpes vulpes*). None of the nests including natural and relocated were predated owing to the metal cages.

The data on seven nest site factors [wet nest depth (distance from the bottom of the egg chamber to the lowest point of dry sand in the nest in cm), dry nest depth (distance from the lowest point of dry sand to the highest point of the nest surface in cm), total nest depth (distance from the bottom of the egg chamber to the highest point of the nest surface in cm), nest diameter (measured at the middle point of total nest depth in cm), distance to sea (distance to the high water mark in m), moisture, and clutch size] were obtained in both natural and relocated nests. During the hatchling emergence season, the numbers of hatchling tracks coming from each natural nest were counted daily, and the numbers of hatchlings reaching the sea were determined by following the tracks. The counted tracks were raked over to prevent any confusion during subsequent surveys. When tracks were interrupted by tracks of predators such as foxes, birds, or crabs, we assumed that the hatchlings had been predated. All destroyed hatchlings and eggshells found were also counted and disposed of elsewhere. Nests were opened and checked for their content including the number of

retained hatchlings, empty eggshells, undeveloped eggs and dead embryos after a period of 48 h with no hatchling emergence from the nests. The clutch size was calculated as the sum of empty eggshells, undeveloped eggs and dead embryos. Hatching success was the percentage of eggs that produced hatchlings. Hatching success was ascertained by counting hatched eggshells. When eggshells were fragmented, pieces were grouped together to represent one egg. This methodology caused as much as ± 4 eggs error. The stages of dead embryos (early, middle, and late) were determined using morphological features (see Whitmore & Dutton 1985; Özdemir et al. 2008). The classification was based on the following criteria. Early dead embryo: blood formation on yolk or extra embryonic membranes, small (approximately ≤10 mm) white embryo, usually with eyes, without an obvious carapace. Middle dead embryo: white embryo with a carapace, without dark scutes (approximately 10–30 mm). Late dead embryo: large embryo (approximately ≥ 30 mm) with fully formed scutes. Undeveloped eggs: an egg without visible development of an embryo or an egg with a decaying yolk. Incubation duration was defined as the number of days from the date after the night a clutch was laid until the date of observation of the first hatchling track. For calculation of moisture content (Head 1992), some wet sand samples from the middle depth of nests were weighed and transferred to the laboratory. Samples were dried to a constant mass at 105–110°C and moisture content was calculated as the ratio of water loss to dry mass multiplied by 100 (Head 1992).

Two equations (equations calculated from Kaska et al. 2006) were used to estimate sex ratios from incubation duration. First, middle third of incubation temperature (MTIT) = 44.220–0.254 × incubation duration ($F_{1,23}$ = 310.897, P = 0.000 with $P < 0.001$, r^2 = 0.93), and second, %female = –346.998 + 13.835 × estimated MTIT ($F_{1,23}$ = 22260.808, P = 0.000 with $P < 0.001$, r^2 = 0.99).

All descriptive statistics, independent sample t-tests, principal component analyses (PCA), and multiple regressions were performed with Statistica 6.0. All P-values were compared to an alpha level of 0.05.

Results

Distance from sea, dry nest depth, wet nest depth, total depth, nest diameter, moisture, clutch size and incubation duration recorded for the natural and relocated nests are presented in Table I. The distance to sea and dry nest depth were higher in relocated nests (t = –2.617, df = 127, $P < 0.05$; t = –3.391, df = 127, $P < 0.01$), while wet nest depth, moisture and incubation duration were higher in natural nests (t = 2.484, df = 127, $P < 0.05$; t = 2.997, df = 111, $P < 0.01$; t = 4.596, df = 105, $P < 0.01$). The mean percentage of dead embryos (Figure 2) differed among stages (Natural Nest (NN): F = 15.523, $P < 0.05$ and Relocated Nest (RN): F = 14.990, $P < 0.05$). It was highest in early (NN: 12.36%, RN: 9.00%), followed by middle (NN: 0.64%, RN: 0.10%) and late (NN: 8.20%, RN: 2.53%) stages. t-test analyses for two group comparisons showed that the two nest types did not differ in early and middle embryonic mortality (Early: t = 1.137, df = 127, $P > 0.05$ and Mid: t = 1.509, df = 127, $P > 0.05$). Late stage and total embryonic mortality for natural nests were significantly greater than for relocated nests (Late: t = 2.534, df = 127, $P < 0.05$ and Total: t = 2.707,

Table I. Descriptive statistics of nest factors and comparison of differences in natural and relocated nests.

Parameters	Natural nests	Relocated nests	*t*-test		
	Mean ± SE	Mean ± SE	*t*-value	df	*P*
Wet nest depth (cm)	27.27 ± 0.79	24.59 ± 0.72	2.484	127	**0.014**
Dry nest depth (cm)	21.29 ± 0.73	24.64 ± 0.65	–3.391	126	**0.001**
Total nest depth (cm)	48.56 ± 0.66	49.12 ± 0.72	–1.044	127	0.298
Diameter (cm)	20.67 ± 0.49	21.00 ± 0.23	–0.576	127	0.566
Distance to sea (m)	20.46 ± 1.05	23.75 ± 0.55	–2.617	127	**0.010**
Moisture	5.30 ± 0.39	3.91 ± 0.20	2.997	111	**0.003**
Clutch size	76.33 ± 2.99	71.95 ± 2.45	1.104	127	0.272
Incubation duration (days)	52.51 ± 0.41	50.26 ± 0.28	4.596	105	**0.000**
Estimated MTIT	30.88 ± 0.11	31.45 ± 0.07	–4.593	105	**0.000**
Estimated female (%)	80.26 ± 1.45	88.17 ± 0.99	–4.596	105	**0.000**
Early (%)	12.36 ± 1.62	9.00 ± 2.02	1.317	127	0.190
Middle (%)	0.64 ± 0.32	0.10 ± 0.05	1.509	127	0.134
Late (%)	8.20 ± 2.03	2.53 ± 0.36	2.534	127	**0.012**
Total mortality (%)	21.20 ± 2.65	11.63 ± 2.15	2.707	127	**0.008**

Note: MTIT, middle third of incubation temperature.

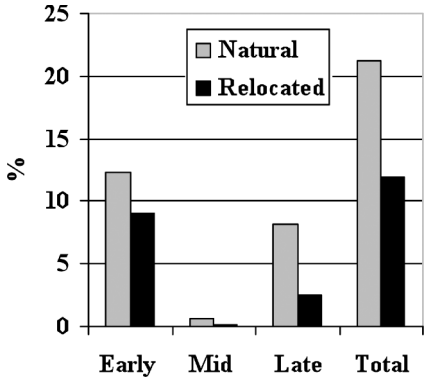


Figure 2. Early, middle, and late stage embryonic mortality in natural and relocated nests.

df = 127, $P < 0.01$). Clutches in natural and relocated nests showed a total of mortality ratio of 21% and 12%, respectively.

This study provides support for a three-factor structure of distance from sea, dry nest depth, wet nest depth, total depth, nest diameter, moisture, clutch size, and incubation duration in natural nests (Table II). The best exploratory variables (loadings ≥70) were wet nest depth and total depth in Factor 1, distance from sea and moisture in Factor 2, and dry nest depth in Factor 3. A four-factor structure of variables was found in relocated nests. The best exploratory variables (loadings ≥0.70) were wet and dry nest depth in Factor 1, total depth and nest diameter in Factor 2, distance from sea and moisture in Factor 3, and clutch size and incubation duration in Factor 4. Of total variance, 59.32% was explained for natural nests, 75.66% for relocated nests (Table II).

Based on multiple regression analyses (Table III), the significant variables of the models in natural nests were clutch size (Beta = –0.33) for early stage, nest depth (Beta = 0.19) and nest diameter (Beta = 0.84) for middle stage, wet nest depth (Beta = 0.28) and nest depth (Beta = –0.35) for late stage. In relocated nests, incubation duration for early stage was the best predictor of the model. Total dead embryos (three stages combined), nest diameter (Beta = 0.39) and nest depth (Beta = –0.29) were significant predictor variables in natural nests, and incubation duration (Beta = 0.78) in relocated nests.

Table II. Factor loadings for the rotated factors.

Parameters	Natural nests			Relocated nests			
	Factor 1	Factor 2	Factor 3	Factor 1	Factor 2	Factor 3	Factor 4
Wet nest depth	**0.70**	–0.14	–0.36	**–0.72**	0.63	–0.04	0.17
Dry nest depth	0.21	0.04	**0.78**	**0.94**	0.28	–0.02	–0.02
Total nest depth	**0.81**	0.07	0.15	0.17	**0.87**	–0.05	0.18
Diameter	0.69	0.07	0.04	0.14	**0.73**	0.06	–0.21
Distance to sea	–0.26	**0.73**	0.04	–0.05	0.04	**0.76**	0.19
Moisture	–0.18	**–0.75**	0.01	0.04	–0.07	**0.77**	–0.12
Clutch size	0.34	0.51	–0.48	–0.01	0.42	0.03	**0.72**
Incubation duration	0.23	0.07	–0.66	0.11	0.07	–0.03	**–0.87**
Eigenvalue	2.10	1.43	1.22	2.16	1.63	1.21	1.05
% of variance	26.21	17.86	15.25	26.98	20.43	15.09	13.15

Table III. Multiple regression summaries among the nest site parameters and embryonic mortality rates in natural and relocated nests.

Parameters	Early				Middle				Late			
	Natural		Relocated		Natural		Relocated		Natural		Relocated	
	Beta	*P*	Beta	*P*	Beta	*P*	Beta	*P*	Beta	*P*	Beta	*P*
Wet nest depth	–0.12	0.41	–0.25	0.47	0.13	0.14	–0.14	0.81	**0.28**	**0.03**	0.78	0.16
Dry nest depth	–0.10	0.41	–0.35	0.30	–0.05	0.50	–0.30	0.60	–0.18	0.12	0.48	0.37
Total nest depth	0.02	0.89	0.26	0.45	**–0.19**	**0.03**	0.14	0.81	**–0.35**	**0.01**	–0.55	0.32
Diameter	0.23	0.08	0.11	0.24	**0.84**	**0.00**	–0.08	0.62	0.18	0.13	–0.08	0.59
Distance to sea	–0.08	0.54	0.09	0.32	–0.15	0.05	0.02	0.89	–0.19	0.11	–0.04	0.80
Moisture	0.08	0.51	0.11	0.18	0.03	0.72	0.09	0.54	0.19	0.11	0.25	0.07
Clutch size	**–0.33**	**0.02**	0.08	0.44	–0.06	0.43	–0.06	0.70	0.10	0.44	–0.14	0.37
Incubation duration	0.00	0.98	**0.83**	**0.00**	0.13	0.08	0.02	0.88	–0.01	0.94	–0.02	0.88
F	1.7721		**12.789**		**18.553**		0.395		**3.330**		1.125	
P	0.100		**0.000**		**0.000**		0.918		**0.003**		0.363	
R^2	0.19		**0.67**		**0.71**		0.06		**0.30**		0.15	

Clutches in natural and relocated nests were calculated to have a mean incubation duration of 52.51 and 50.26 days, respectively. We estimated sex ratio from incubation duration. Firstly, a regression line was produced to estimate the middle third of incubation temperature. Secondly, another regression line was produced to estimate percent female middle third of incubation temperature (MTIT), and female ratios were estimated using the equations. The results of these calculations are summarized in Table I. Natural nest and relocated nests were compared by *t*-tests. A higher female ratio was found in relocated nests based on estimated MTIT. Accordingly, clutches in natural and relocated nests had a mean of female ratio of 80% and 88%, respectively.

The total number of eggs was 5346 in natural nests while the total number of eggs transferred to relocated nests was 4225. Hatching success in relocated nests (84.4%) was significantly higher than in natural nests (72.7%).

Discussion

This study evaluates the significance of nest site factors on mortality and sex ratio. The results of the nest site factor analysis reveals three components in natural nests and four components in relocated nests. Nests under the natural regime had a significantly higher embryonic mortality ratio and lower estimated female ratio than relocated nests. Nest site selection by a female is a complex system that produces hot spots on a nesting beach, which can have dramatic effects on the embryonic mortality and sex ratio.

Early stages of sea turtle life span including embryonic development and hatchling life are the critical period because of the high level of mortality (Richardson & Richardson 1982; Stancyk 1982; Cıtak 1998; Taşkın 1998; Özdemir et al. 2008). This study demonstrated that the mortality rate was higher in both early and late embryonic stages (Figure 2), as reported in the studies of Çıtak (1998), Taşkın (1998) and Özdemir et al. (2008). Moreover, the total mortality rate including all of the stages was higher in natural versus relocated nests at Dalyan beach.

Loggerhead turtle eggs usually increase in weight by 5–10% by absorbing water from the surrounding sand after oviposition (Miller et al. 2003). For normal embryonic development, the water contents of an egg are not reduced 40% of its initial mass (Miller et al. 2003). According to Miller (1985), higher levels of salinity in the sand reduce the ability of eggs to absorb water and reduce the humidity in the nest chamber. Wood and Bjorndal (2000) indicated that moisture was inversely related to temperature at nest sites in the Archie Carr National Wildlife Refuge in Florida. McGehee (1990) reported that the incubation duration for eggs of *Caretta caretta* was influenced significantly by the percentage of moisture of the substrate. Türkozan et al. (2003a) concluded that the above factor had no effect on hatching success. However, Özdemir and Türkozan (2006) stated that moisture was associated with the hatching success of green turtles in Northern Cyprus. Reduction of sand gas conductance decreases embryonic growth rate in green turtle (*Chelonia mydas*) and loggerhead turtle clutches (Ackerman 1981). Gas diffusion is affected by water content (e.g. heavy rainfall) and particle size of the sand (Prange & Ackerman 1974; Kraemer & Bell 1980; Ackerman 1991). Clutch oxygen consumption rates are related to clutch metabolic mass and developmental stage (Ackerman 1980). However, neither PO_2 nor temperature was correlated with hatching success of Leatherback Turtles, *Dermochelys coriacea* (Wallace et al. 2004). In this study, important parameters affecting late-stage embryonic mortality in natural nests are the wet sand depth and total depth of the nests. The mean value wet nest depth is greater (deeper) in natural nests.

The PCA generated three significant factors in natural nests. The factor structures in terms of natural nests reveal as follows: "wet sand depth of nest", "total nest depth" and "nest diameter" have high loadings in Factor 1. Therefore, this factor can be named "Clutch Volume". Hays and Speakman (1993) predicted that there were a positive relationship between clutch size and body size. According to Hays (2001), clutch size effects clutch volume and both adult size and morphology influence on clutch volume in marine turtles. Factor 2 comprises the variables of "moisture" and "distance to sea". This factor can be entitled "Sea Effect". Türkozan et al. (2003a) indicated that moisture was an inversely related to distance from sea. Moisture content was found to be a potential cue for nest site selection (Wood & Bjorndal 2000). It is suggested that Factor 3 represents the "Temperature Effect" as shown by the relationships of "dry sand depth of nest" and "incubation duration". Incubation duration is inversely correlated with incubation temperature (Mrosovsky et al. 1999; Matsuzawa et al. 2002) and metabolic heating is significantly correlated to clutch size (Zbinden et al. 2006).

The PCA generated four significant factors in relocated nests. Especially the ratio between dry and wet sand depth in relocated nests varied from the natural nests (wet/dry of the natural nests: 1.55; wet/dry of the relocated nests: 1.07). The factor structures could be differentiated due to the ratio wet/dry

sand depth of nests not being considered by us when the nests were relocated. In relocated nests installed for the Factor 1 are the variable depths of dry and wet sand of nests. Clutch size had no effect on Factor 1 as shown. Therefore, it is different from the Factor 1 (Clutch Volume) in the natural nest and the Factor 1 for relocated nest can be named "Relative Depth". Factor 2 and Factor 3 in the relocated nests are very similar to Factor 1 (Clutch Volume) and Factor 2 (Sea Effect) in natural nests, respectively. Incubation duration and clutch size have high factor loadings in Factor 4. Zbinden et al. (2006) indicated that the number of eggs and metabolic heating has a positive relation and incubation duration and nest temperature has a negative relation. Therefore, clutch size and the incubation duration may have been located in Factor 4 as a marker of nest temperature.

Considering the high load values obtained from factor analysis and the factor structures in natural nests, we guess that loggerhead turtles take three main factors into consideration when selecting a nest location: clutch volume, sea effect and temperature effect. However, this structure has partially changed in relocated nests. The main reason for this difference may be the ratio of dry sand to wet sand not being taken into consideration during the relocation.

Eggs that incubate at temperatures below 22°C for the last third of incubation and those held at temperatures exceeding 33°C for extended periods seldom hatch (Miller et al. 2003). Mrosovsky (1980) stated that survival of the offspring may be strongly related to the distance that the nest is from the sea. Inundation of nests by sea water leads to egg mortality from suffocation (Whitmore & Dutton 1985) and/or chloride toxicity (Bustard & Greenham 1968). For example, hatching success significantly increased for loggerhead nests laid further from the sea at Cephalonia, Greece (Hays & Speakman 1993). In our study, no relationship was found between embryonic mortality and distance to the sea.

Sexual differentiation of sea turtle hatchlings depends on the temperature during incubation, especially during the middle third of development (Yntema & Mrosovsky 1980; Mrosovsky 1994). Studies have indicated that nests produce a larger ratio of females at higher temperatures (>29.0°C), while the cooler nests (<29.0°C) produce more males (Mrosovsky 1994; Ackerman 1997). One technique to estimate the sex ratio of sea turtle hatchlings is to draw inferences from incubation durations (Marcovaldi et al. 1997; Godfrey & Mrosovky 1999; Godley et al. 2001b). Godley et al. (2001b) used this technique at Alagadi, Northern Cyprus over six seasons (1993–1998) and estimated that nests produce mainly females (89–99%). The pivotal temperature above which mainly females are produced is just below 29.0°C for *C. caretta* (Kaska et al. 1998). Incubation durations are significantly correlated to both mean temperatures during the incubation duration and the middle third of incubation (Kaska et al. 1998; Godley et al. 2001b). In this study, the mean incubation durations of natural and relocated nests were 52.51 and 50.26 days, respectively. The estimated female ratios based on incubation durations were 80% and 88%, respectively, at Dalyan beach. However, Godley et al. (2001a) stated that the mean temperatures may be just below 29.0°C and that the hatchling sex ratio is even slightly male-biased at Dalyan beach.

Relocation of eggs is a common strategy for conservation of declining reptilian populations around the world, including marine turtles (see Pfaller et al. 2008). However, there is no consensus among scientists whether relocation is an effective conservation tool for sea turtles. Başkale and Kaska (2005) stated that relocation, screening, and fencing clearly increased the hatching success rate of loggerhead turtle and provided effective protection of nests against inundation and predation. Ilgaz and Baran (2001) demonstrated the hatching success of transplanted nests to be higher (72.8%) than under natural conditions (55%) for loggerhead turtles in Dalyan. Dutton et al. (2005) stated that nest protection and/or nest relocation can have positive effects on hatching success. According to Mortimer (1999), hatcheries should be used as a last option. Godfrey and Mrosovky (1999) stated that hatchery practice potentially has negative effects on sex-ratio alternation. Mrosovsky (2006) suggested that nest relocation over the long term may distort gene pools. Türkozan and Yılmaz (2007) demonstrated that hatchlings emerging from relocated nests are heavier and have more abnormal scutes than those from natural ones. Recently, the validity of egg relocation of the sea turtles as a conservation strategy was one of the most questionable issues among the marine turtle researchers (Mrosovsky 2006, 2008; Pike 2008). Related to doomed eggs, three suggestions were proposed by Mrosovsky (2006): do not relocate any eggs; relocate eggs for boosting population numbers and accept the potential genetic results; or sell or eat relocated eggs. According to Pfaller et al. (2008), doomed-egg relocation is a strategy for the conservation of sea turtle populations. Their results also show that doomed-egg relocation does not substantially distort the gene pool in the eastern Australian loggerhead stock.

In conservation projects, to relocate numerous nests to saving them from predators can lead to

many changes in the natural balance. Relocation can be increasingly utilized for hatching success in future conservation projects. It can considerably boost hatching success. However, it may also be argued, based on our results, that hatching success may not be enough if the natural sex ratio balance is altered. If looking for characteristic features during nest site selection is hereditary and beneficial to the natural balance, then nest relocation may well alter this natural balance. Based on these considerations, we can only partially support nest relocation. Moreover, it remains to be seen how effective the conservation measures will be in curbing predation on nests. Although relocation is a conservation tool, one should be cautious using it because of the sensitive parameters of incubation and hatching procedure. Thus, on the condition that predation is prevented by screening, screening could be preferred rather than relocation. Ultimately, however, researchers are called upon to make use of the full range of conservation tools to protect endangered species.

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