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Hatching Success of Original and Hatchery Nests of the Green Turtle, *Chelonia mydas*, in Northern Cyprus

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Abstract: This paper provides information on the relation of abiotic factors (moisture content, nest depth, distance of nest from the sea and distance from vegetation) and a biotic factor (clutch size) with the hatching success of green sea turtles, *Chelonia mydas*, in original nests and hatcheries in Northern Cyprus. A hundred and twenty-nine randomly selected clutches (67 original and 62 hatchery) were examined. First, original and hatchery nests were tested separately and none of the factors were found to be associated with hatching success. Since no differences were detected between the original and hatchery nests in terms of hatching success, both were pooled and tested with general linear models (GLMs) by taking locality and nest type as categorical predictors. Accordingly, moisture was found to be associated with the hatching success ($F = 5.02$; $P < 0.05$) of green turtles in Northern Cyprus. However, R-squared statistics indicate that the model fitted explains 26% of the variability in hatching success. The correlation coefficient equals –0.30, indicating a relatively weak relationship between variables.

Key Words: *Chelonia mydas*, hatching success, nest, hatchery, Northern Cyprus

Kuzey Kıbrıs Yeşil Deniz Kaplumbağası, *Chelonia mydas*, Orijinal ve Taşıma Yuvalarında Yavru Çıkış Başarısı

Özet: Bu çalışmada Kuzey Kıbrıs'ta yeşil deniz kaplumbağalarına, *Chelonia mydas*, ait orijinal ve taşıma yuvalardaki bazı abiyotik (nem, yuva derinliği, yuvanın denize uzaklığı, yuvanın vejetasyona uzaklığı) ve bir biyotik faktörün (kuluçka büyüklüğü) yavru çıkış başarısıyla ilişkisi incelenmiştir. Çalışma rasgele seçilen 129 yuvada (67 orijinal ve 62 taşıma yuva) gerçekleştirilmiştir. Öncelikle orijinal ve taşıma yuvalar ayrı ayrı test edilmişler ve incelenen faktörlerin hiç birisi yavru çıkış başarısıyla ilişkili bulunmamıştır. Orijinal yuvalarla taşıma yuvalar arasında yavru çıkış başarısı açısından bir fark bulunmadığı için ($P > 0,05$) daha sonra her iki yuva tipi de genel lineer modelleme (GLM) tekniğiyle lokalite ve yuva tipi kategorik değişken olarak alınıp test edildiğinde yuva içindeki nemin yavru çıkış başarısıyla ilişkili olduğu saptanmıştır ($F = 5,02$; $P < 0,05$). Ancak R kare değeri uygun modelin yavru çıkış başarısındaki değişkenliğin ancak % 26 sını açıklamaktadır. Korelasyon katsayısının –0,30 olması değişkenler arasında nispeten zayıf bir ilişkinin olduğunu göstermektedir.

Anahtar Sözcükler: *Chelonia mydas*, yavru çıkış başarısı, yuva, taşıma yuva, Kuzey Kıbrıs

Introduction

The green turtle, *Chelonia mydas*, is globally endangered, and the Mediterranean population has been classed as critically endangered (IUCN, 2000). Nesting records in the Mediterranean appear to be confined to Turkey, Northern Cyprus, Israel, Lebanon and Egypt, with 99% of all recorded nesting occurring in Turkey and Northern Cyprus (Kasparek et al., 2001).

Previous reports of biotic influences on egg mortality have usually referred to predators. Successful incubation of eggs depends on the presence of suitable conditions in the beach sand. Among these conditions are temperature, humidity or water potential, salinity and levels of respiratory gases (Ackerman, 1997). In the laboratory, environmental factors such as temperature and moisture have been correlated with hatching success (Yntema and Mrosovsky, 1980; McGehee, 1990). All marine turtles lay white, spherical cleidoic eggs with flexible calcareous shells (Miller, 1997). Studies in both natural habitats and the laboratory have demonstrated that many species of

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turtles, including marine turtles, have flexible-shelled eggs which exchange water with the surrounding substrate and atmosphere (see the review by Packard and Packard, 1988). Bustard and Greenham (1968) reported that hatching success can be correlated with some physical characteristics of the sand environment. According to some researchers (Fowler, 1979; Mrosovsky, 1980; Miller, 1985), the hatching success depends upon the interaction of a number of factors such as salinity, humidity, temperature, gas flow, rainfall, tidal inundation, erosion and predation. Mortimer (1990) found that hatching success of Ascension Island *Chelonia mydas* was negatively correlated with sand grain size. Miller (1985) stated that higher levels of salinity in the sand reduce the ability of eggs to absorb water and reduce the humidity in the nest chamber. It was reported that the embryonic growth of *Caretta caretta* is independent of egg water exchange over a range of total egg water exchanges around –10% to +30% of initial egg mass (Ackerman, 1997). According to Miller (1999), in addition to biotic and environmental factors, emergence success is influenced by other factors, such as the number of eggs deposited that do not develop. Türkozan et al. (2003) tested the effects of abiotic factors on the hatching success of the loggerhead turtles at Fethiye beach, Turkey, and concluded that the factors examined had no effect on hatching success. Blamires and Guinea (2003) did not find any significant influence of mean nest temperature, clutch size or incubation period of emerged nests on emergence rates of the flatback turtle, *Natator depressus*.

The aim of this study was to evaluate the role of abiotic and biotic factors in the hatching success of *Chelonia mydas*. Therefore, we recorded moisture, nest depth, distance of nest from the sea and vegetation, total number of eggs, embryos and infertile eggs in a clutch in randomly selected nests at Dipkarpaz Peninsula, Northern Cyprus. The recording of these normative data will enable future monitoring of hatch rates and environmental parameters.

Materials and Methods

A total of 129 (67 original and 62 hatchery nests) randomly selected green turtle (*Chelonia mydas*) nests from 9 different beaches (Ayphilon, Dolphin, Laden, Beyza, K10, İkidere, Altınkum I, Altınkum II and Ronas) in Northern Cyprus (Figure 1) were examined from 2.8.2002 to 6.9.2002. Of the beaches investigated, 2 (Altınkum I and Ronas) were composed of artificial nests (hatcheries). For this study, 10-15 g sand samples were weighed and wrapped in plastic. At the end of the season, the sand samples were transferred to the laboratory and dried to a constant mass at 105-110 °C. The initial

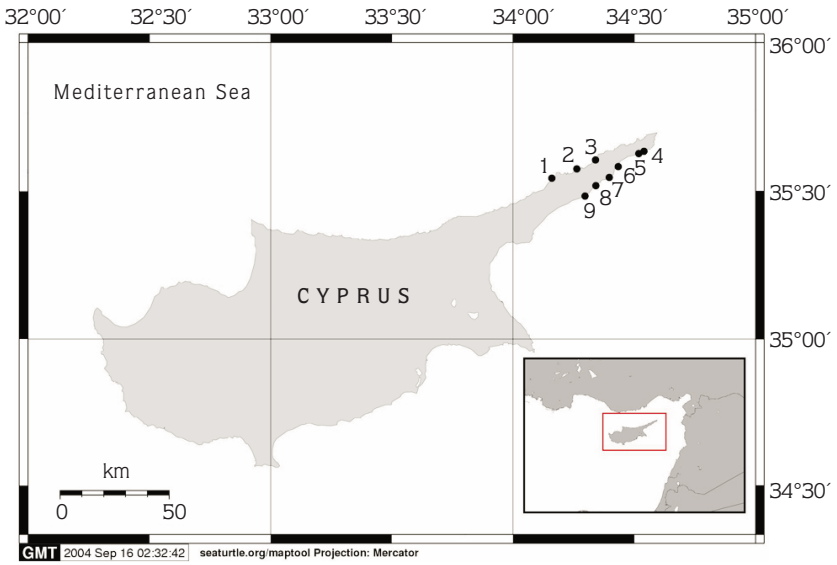

Figure 1. Map showing the study sites (1. Ronas, 2. Ayphilon, 3. K 10, 4. Altınkum I, 5. Altınkum II, 6. Dolphin, 7. Ikidere, 8. Beyza, 9. Laden).

moisture lost was not a problem since we recorded the initial weight of the sand samples as soon as we got them from the nests. Moisture content was calculated as the ratio of water loss to dry mass multiplied by 100 (Head, 1992). Hatching success was the percentage of total eggs in a clutch (determined by posthatching excavations) that hatched. Hatching success was ascertained by counting eggshells after hatching. When eggshells were fragmented, the pieces were grouped together to represent one egg. Unhatched eggs without visible embryos or blood formation were classified as infertile. Nest depths and distances were measured with a steel meter with an accuracy range of ±1 mm. All P values were compared to an alpha level of 0.05. STATISTICA version 6.0 was used for all descriptive statistics, the correlation coefficients and General Linear Model (GLM) analysis.

Original nests and hatcheries were compared by Mann-Whitney U test. Parameters of original nests were compared by ANOVA post-hoc test. The relationship between parameters (moisture content, nest depth, distance from the sea, distance from vegetation and clutch size) and hatching success was tested with GLM by taking locality and hatcheries as categorical predictors.

Results

The descriptive statistics were computed for the parameters examined separately for the original nests and hatcheries and are shown in Table 1. Accordingly, the mean number of dead hatchlings was higher in the hatcheries ($U = 1501$, $Z = 2.72$, $P < 0.01$), meaning a higher mortality rate in the hatcheries. The dead embryo percentage was higher in the hatcheries as well ($U = 1635$, $Z = 2.08$, $P > 0.05$). The hatching success did not differ between original and hatchery nests. The results of the ANOVA test revealed that nest depth ($F = 4.879$, $P < 0.001$), percentage of embryos ($F = 9.028$, $P < 0.0001$) and hatching success ($F = 6.637$, $P < 0.0001$) differed significantly among the original nests.

First the effects of biotic factor and abiotic factors were tested separately by GLM by taking locality as the categorical predictor. None of the factors were found to be related with hatching success in the hatcheries, while locality was associated with hatching success in the original nests ($F = 3.532$, $P < 0.01$). Since we found no difference between the hatching success of original and hatchery nests ($P > 0.05$) we pooled the data and evaluated accordingly.

Nest depth was positively correlated with clutch size ($r = 0.28$) and moisture content ($r = 0.21$). An increase in nest depth was accompanied by increases in clutch size and moisture in a clutch (Table 2A). A factor loading plot from PCA, which allows us to reduce the number of variables in a data set by finding linear combinations of those variables that explain most of the variability, showed how distance (from the sea and vegetation), nest depth, moisture and clutch size were related in a 2-dimensional space (Table 2B, Figure 2). The first 2 factors accounted for 50.2% of the variability in the original data.

Table 1. Summarized statistics of the variables taken for the nesting beach of the green turtle in Northern Cyprus (DFV: distance from vegetation, DFS: distance from sea, ND: nest depth, M: moisture, DH: dead hatchlings in the nests, CS: clutch size, EMB: embryo, UNFERT: unfertilized eggs, HS: hatching success).

	ORIGINAL NESTS				HATCHERY NESTS			
	N	Mean ± S.E	Range	S.D.	N	Mean ± S.E.	Range	S.D.
DFV (m)	57	5.92 ± 0.88	0.2-33.40	6.63	62	3.11 ± 0.17	2.6-8.8	1.32
DFS (m)	57	20.09 ± 1.81	0.3-68.30	13.66	62	17.13 ± 0.56	12.1-35.3	4.38
ND (cm)	56	68.57 ± 1.26	49-103	9.42	54	68.27 ± 1.02	52-85	7.50
DH	67	2.91 ± 0.74	0-43	6.06	62	4.19 ± 0.59	0-20	4.61
M (%)	59	3.81 ± 0.26	0.41-13.30	1.97	50	4.02 ± 0.22	1.71-10.53	1.56
CS	67	113.07 ± 3.46	37-194	28.29	62	107.40 ± 3.03	61-151	23.86
EMB (%)	67	11.38 ± 2.26	0-100	18.54	62	11.43 ± 1.23	0-42.28	9.69
UNFERT (%)	67	13.34 ± 1.85	0-100	15.13	62	17.65 ± 3.24	0-100	25.53
HS (%)	67	75.29 ± 2.81	0-98.11	22.98	62	70.96 ± 3.24	0-99.19	25.48

Table 2. (A) Correlations for physical factors determined in green turtle nests at Northern Karpaz beaches, Northern Cyprus (DFV: distance from vegetation, DFS: distance from sea, ND: nest depth, M: moisture, CS: clutch size)* Correlation is significant at the 0.05 levels. (B) The results of principal component analysis.

A

Parameters	DFV	DFS	ND	M	CS
DFV	1.00				
DFS	-0.08	1.00			
ND	0.02	-0.10	1.00		
M	0.00	-0.13	**0.21***	1.00	
CS	0.01	0.02	**0.28***	-0.08	1.00

B

Components considered	Eigen values	% Total variance	Cumulative eigenvalues	Cumulative %
DFV	1.350	27.001	1.350	27.001
DFS	1.158	23.150	2.508	50.151
ND	1.016	20.326	3.524	70.477
M	0.866	17.324	4.390	87.801
CS	0.610	12.199	5.000	100.000

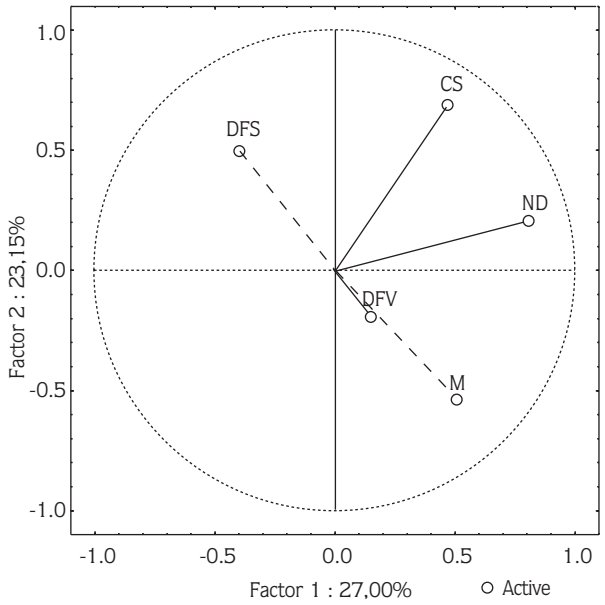

Figure 2. Factor loading plot from principal component analysis for distance from sea (DFS) and vegetation (DFV), nest depth (ND), moisture (M) and clutch size (CS).

Finally, the effect of parameters on hatching success was tested with GLM by taking nest type (original or hatchery) as the categorical predictor. This test verified that hatching success was negatively affected by the moisture content ($F = 5.02$; $df = 1$; $P < 0.05$) of the sand used for incubation (Figure 3). However, R-squared statistics indicate that the model fitted explains 26% of the variability in hatching success. The correlation coefficient ($r = -0.30$) indicates a relatively weak relationship between variables.

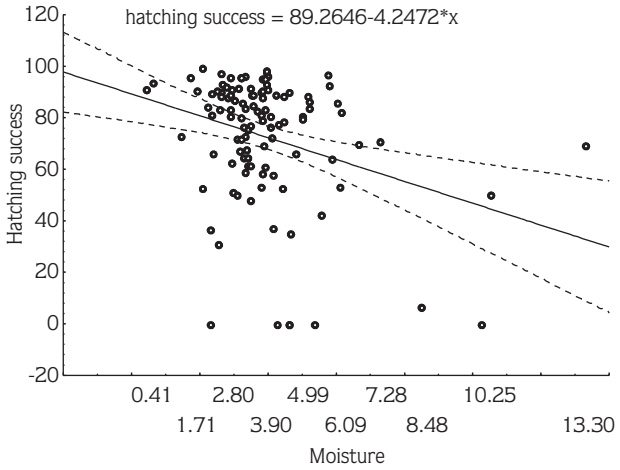

Figure 3. Relationship between hatching success and moisture in the nest.

Discussion

The higher mortality rates in hatcheries may result from fungal contamination. Limpus et al. (1983), on the island of the southern Great Barrier Reef and adjacent mainland, suggest that fungal presence within sea turtle nests may be contributing to egg failure. Thus, while relocating, nest sites should be chosen very carefully. McGehee (1990) reported that the hatching success of *Caretta* eggs was significantly affected by the moisture content of the sand used for incubation. He also noted that 25% moisture was the optimum level for maximum percent hatching and hatchling size. However, since McGehee (1990) carried out his study under laboratory conditions it is not useful to compare his results with ours. Mortimer (1990) stated that moisture may affect hatchling size and hatchling performance in oviparous reptiles. She found that the survival of green turtle clutches at Ascension Island is lowest in the driest substrata. Hall (1990) found a positive correlation between the hatching success and yolkless egg number in *Dermochelys* nests. He also reported a slight negative correlation between the nest depth and hatching success. In studies on *Lepidochelys olivacea*, at Escobilla, Oaxaca in

Mexico, Huerta (1995) found a positive correlation between moisture and hatching success. Wood and Bjorndal (2000) concluded that temperature, moisture and salinity did not affect the hatching success of loggerhead turtles near Melbourne beach. Hewavisenthi and Parmenter (2002) reported a significant positive relationship between hatching success and clutch size in flatback turtles. Türkozan et al. (2003) studied loggerhead turtle hatchlings in Turkey and concluded that none of the factors they examined was correlated with hatching success.

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