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Effect of tagging marine turtles on nesting behaviour and reproductive success

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We studied green, *Chelonia mydas*, and loggerhead, *Caretta caretta*, turtles nesting on the island of Cyprus to determine the effects of flipper tagging on postovipositional behaviour and reproductive success. Tagging was undertaken immediately after oviposition (64 green turtles; 111 loggerheads). On 12 occasions, loggerheads immediately stopped covering the eggs and proceeded directly to the sea. No green turtles abandoned nesting. In all other cases, where sufficient data were collected, the duration of the two postovipositional phases of nesting behaviour (covering and camouflaging) and the speed of descent to the sea did not differ between tagged and untagged turtles. The durations of behaviours also did not differ between females not tagged, tagged once or tagged twice. There was no effect of tagging on the likelihood of hatching or on the hatching success of clutches in either species.

World-wide, many marine turtle research programmes involve the mark and recapture of nesting females and external flipper tags have been widely used as the method of choice in obtaining information on the life history of these species. Many different types of tags are used including plastic, monel and titanium, which can be attached to either the front or rear flipper(s) (see Balazs, in press for a review). Loss of tags is considered a major problem in the majority of species (Balazs 1982; Henwood 1986; Eckert & Eckert 1989; Limpus 1992; Alvarado et al., 1993; McDonald & Dutton 1994; Bjorndal et al. 1996). More recently, the use of passive integrated transponders (PITs) has been explored (Fontaine et al. 1987; Parmenter 1993; McDonald & Dutton 1996; Godley et al., in press). With PIT tagging, there is a lower rate of loss than with conventional methods, possibly leading to less retagging, and hence reduced interference as well as data of increased reliability and scientific value (Parmenter 1993; McDonald & Dutton 1996).

Few quantitative studies have examined the possible effect of human interference on nesting turtles. In a study of loggerhead turtles, *Caretta caretta*, in Florida, Johnson et al. (1996) recorded a shorter duration of camouflaging of nests by females observed by tour groups. Similarly, Campbell (1994) observed a shortening of the covering stage when green turtles, *Chelonia mydas*, were subjected to flash photography whilst nesting in Costa Rica.

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In this paper we examine the effects of tagging on the behaviour and nest success of green and loggerhead turtles. These species nest globally in the tropics and subtropics. In the Mediterranean the main nesting sites are Turkey and Cyprus (green) and Greece, Turkey, Cyprus and Libya (loggerhead; Baran & Kasparek 1989; Margaritoulis 1989; Broderick & Godley 1996; Laurent 1997).

METHODS

Study Site

We conducted this study on Alagadi Beach (35°33 N, 33°47 E), situated in northern Cyprus, in the eastern Mediterranean. This is one of the few sites in the region where both species are found nesting in considerable numbers (Broderick & Godley 1996). There is very little habitation or artificial lighting near this 2-km beach, which remains closed to the public from 2000 to 0800 hours (+3 h GMT) throughout the nesting season, ensuring minimal anthropogenic disturbance of nesting turtles. Any visitors wishing to observe nesting females are accompanied by a researcher and follow strict guidelines.

Data Collection

We collected data on patrols between 2100 and 0600 hours (local time) throughout the nesting seasons of 1993–1997. In northern Cyprus, most nesting occurs between late May and mid-August (Broderick & Godley 1996). We found turtles by walking at the water's edge without torchlight. Upon discovery of a female, the stage of nesting was ascertained and the time recorded. All subsequent behavioural stages were timed and classified as follows: ascent of beach; digging body pit; digging egg chamber; oviposition; covering; camouflaging; descent of beach (see Johnson et al. 1996). In addition, we collected data describing the position of the nest and hence the speed of descent could be calculated from the time taken for descent and the distance from the nest to the high water mark. Upon hatching, the nest contents were excavated and the shell fragments and unhatched eggs counted to ascertain the clutch size and hatching success.

We tagged both green and loggerhead females with plastic tags (Dalton Supplies Ltd, Henley-on-Thames, U.K.) on the trailing edge of the foreflippers, in the position recommended by Limpus (1992). Tags were self-piercing and pushed through the thin skin between the proximal second and third flipper scales. As this procedure is instantaneous we did not use a local anaesthetic, application of which is in itself painful. In some cases females reacted to tagging, withdrawing their limb or inhaling sharply. One incidence of biofouling at the tag site was recorded in this study.

Females were tagged only if they had nested successfully and only during the covering phase, immediately after the completion of oviposition. Where possible, females were tagged on both foreflippers. This was done to reduce the possible confounding effects of tag loss upon other ongoing research. If a female had lost one tag, or it had become unreadable, a new tag was attached. Owing to the short duration of the covering phase in loggerheads, it was not always possible to double tag, even when no other tags were present. If a female already had two readable tags in place, we just examined these tags. We measured the curved carapace length and width of all nesting turtles.

In 1997, all of the green turtles that nested at Alagadi were the subjects of two additional studies, which were thought to have a possible confounding influence. In these studies, females were tagged with PIT tags (Godley et al., in press) and had data-logging devices attached (Hochscheid et al., in press). None of these individuals was therefore included in our analyses. Data are therefore presented for loggerheads nesting in 1993–1997 and green turtles nesting in 1993–1996. Where appropriate, statistical analyses were two tailed.

RESULTS

The majority of data sets deviated significantly from normality (Anderson Darling: $P<0.05$), therefore non-parametric statistical tests were used throughout and medians (with interquartile limits) are presented. Individuals were considered as tagged once, tagged twice or not tagged. No significant differences were found between years for the duration of any of the postovipositional behaviours in either species (Kruskal–Wallis: green: covering: $H_3=0.27$, $P=0.966$; camouflaging: $H_3=3.47$, $P=0.325$; descent: $H_3=7.35$, $P=0.062$: loggerhead: covering: $H_4=4.1$, $P=0.394$; camouflaging: $H_4=4.41$, $P=0.354$; descent: $H_4=2.86$, $P=0.582$) or in the median hatching success of clutches for either species (Kruskal–Wallis: green: $H_3=0.24$, $P=0.97$; loggerhead: $H_3=9.32$, $P=0.053$). Data were thus pooled for each species.

Green Turtles

Table 1 gives the results. No significant differences were recorded between the three groups of green turtles in the duration of covering the egg chamber (Kruskal–Wallis: $H_2=0.73$, $P=0.695$) or camouflaging the nest (Kruskal–Wallis: $H_2=2.49$, $P=0.288$) or in the speed of descent of the beach (Kruskal–Wallis: $H_2=0.04$, $P=0.979$). In addition, the three groups did not differ in the total time spent covering and camouflaging the nest (Kruskal–Wallis: $H_2=2.38$, $P=0.305$). There were also no significant differences between tagged and untagged individuals (Mann–Whitney: covering: $Z=0.843$, $N_1=52$, $N_2=63$, NS; camouflaging: $Z=1.551$, $N_1=51$, $N_2=67$, NS; descent: $Z=0.113$, $N_1=51$, $N_2=64$, NS; total time covering and camouflaging: $Z=1.492$, $N_1=50$, $N_2=62$, NS).

The hatching success of clutches laid by the three groups did not differ significantly (Kruskal–Wallis: $H_2=1.83$, $P=0.401$), nor did the hatching success of clutches of tagged and untagged females (Mann–Whitney: $Z=1.233$, $N_1=43$, $N_2=50$, NS). In addition, there was no difference in the proportion of clutches that hatched between the three groups ($\chi^2_2=1.559$, $P=0.459$) or between tagged and untagged females ($\chi^2_1=0.286$, $P=0.593$).

Loggerhead Turtles

On 12 occasions (six out of 27 in 1994, three out of 18 in 1996, three out of 21 in 1997) loggerheads appeared to abandon nesting activity as a direct result of the tagging procedure and descended immediately to the sea. Of these individuals, three were not successfully tagged and we could not tell whether they revisited the site. Of the remaining nine individuals, five were subsequently recorded at the study site within the same season, with one individual emerging the following night and undertaking the full nesting process without laying eggs. Of the 12 clutches laid by these individuals, four failed to hatch, two clutches were transplanted (as they were laid too close to the sea) and subsequently hatched, and the remaining six clutches hatched naturally (median hatching success 87%; range 42–94%).

Table 1 shows the results. As was the case with green turtles, no significant differences were recorded in the duration of covering (Kruskal–Wallis: $H_2=2.93$, $P=0.231$) or camouflaging (Kruskal–Wallis: $H_2=3.7$, $P=0.158$) or speed of descent (Kruskal–Wallis: $H_2=0.45$, $P=0.801$) between the three groups of loggerheads. The total duration of covering and camouflaging the nest also did not differ between groups (Kruskal–Wallis: $H_2=2.47$, $P=0.291$). In addition there were no differences between tagged and untagged females (Mann–Whitney: covering: $Z=1.513$, $N_1=86$, $N_2=59$, NS; camouflaging: $Z=1.664$,

Table 1. Durations of two postovipositional behaviours, speed of descent down the beach and hatching success of clutches of green and loggerhead turtles

	Tagged once	Tagged twice	Not tagged	All Tagged
Green Turtles				
Covering nest (min)	9	8	6	8
	5–11	5–10	6–10	5–10
	N=14	*N*=38	*N*=63	*N*=52
Camouflaging nest (min)	50	55	55	55
	38–65	36–70	45–79	37–68
	N=14	*N*=37	*N*=67	*N*=51
Speed of descent (m/s)	0.06	0.05	0.06	0.05
	0.04–0.08	0.04–0.08	0.04–0.09	0.04–0.08
	N=14	*N*=37	*N*=64	*N*=51
Hatch success (%)	92	90	94	90
	80–97	84–95	83–96	84–95
	N=11	*N*=32	*N*=50	*N*=43
No. of clutches	14	41	71	55
No. hatched	11	32	50	43
Loggerhead turtles				
Covering nest (min)	4	5	6	5
	3–8	3–9	5–9	3–8
	N=20	*N*=66	*N*=59	*N*=86
Camouflaging nest (min)	10	11	10	11
	6–15	8–16	6–15	8–16
	N=23	*N*=66	*N*=60	*N*=89
Speed of descent (m/s)	0.06	0.06	0.06	0.06
	0.03–0.09	0.02–0.10	0.02–0.10	0.02–0.11
	N=24	*N*=66	*N*=60	*N*=90
Hatch success (%)	88	90	81	89
	76–94	69–94	61–92	74–94
	N=15	*N*=38	*N*=37	*N*=53
No. of clutches	25	70	64	95
No. hatched	15	38	37	53

Medians and interquartile ranges are given.

N_1=89, N_2=60, NS; descent: Z=0.460, N_1=90, N_2=60, NS; total time covering and camouflaging: Z=0.552, N_1=84, N_2=58, NS). There were no significant differences in hatching success between the three tagging categories (Kruskal–Wallis: H_2=3.16, P=0.207) or between tagged and untagged females (Mann–Whitney: Z=1.751, N_1=53, N_2=37, NS) or in the proportion of clutches that hatched between the three categories (χ^2_2=0.309, P=0.857) or between tagged and untagged females (χ^2_1=0.064, P=0.801).

DISCUSSION

Our observations suggest that turtles, especially loggerheads, sometimes react to the tagging procedure, by withdrawing a limb or sharply inhaling. It has been noted, although not quantified, that the reaction in both species to PIT tagging is less than to flipper tagging (Godley et al., in press). Evidence presented here shows that, certainly in a small sample of loggerhead turtles (12), there is a possible negative reaction to tagging, consistent with that expected from experiencing an unpleasant or noxious stimulus. A large proportion of identifiable individuals that abandoned the nest upon being tagged were recorded within the season as returning to the site (5/9) and a large proportion of these clutches (6/10) hatched with a comparable median success rate (87%) to those of untagged turtles (81%; Table 1) and those subjected to 'successful' tagging (89%; Table 1).

Our data on behaviour and reproductive success, of both green turtles and the remaining loggerheads, suggest no detrimental effect of tagging on the parameters measured. Tagging of turtles had no apparent effect on the duration of nesting behaviours or on the success of the clutch (as measured by the proportion of clutches that hatched or by median hatching success). Apart from the observation that a subsample of loggerheads abandoned their nesting activity, there would appear to be little effect of tagging female marine turtles on their behaviour.

The negative impact of a procedure such as tagging, however, should be compared with the benefits.

(1) Short-term effects. The stress response in marine turtles has been the subject of few studies and would appear to be difficult to measure. Valverde et al. (1996) reported significantly elevated corticosterone levels after several hours of capture in a wide range of species and age classes of marine turtles. No previous studies have encompassed the effects of tagging. Evidence presented here suggests that a small proportion of loggerhead turtles might have been disturbed by the tagging procedure. However, the benefits of knowledge gained from studying these endangered species would appear to merit the mild

to moderate disturbance caused. In addition, it is likely that in many cases flipper tagging may be the only tenable option in obtaining certain important parameters necessary for conservation and management of endangered populations.

(2) Long-term effects. Experiments in penguins have shown that flipper tagging causes significant drag effects (Culik et al. 1993). Since marine turtles are relatively large, slower-moving organisms than penguins, it might be expected that drag effects would be less significant. Although recorded on only one occasion in this study, several workers have noted that tags are often subject to biofouling (Schmid 1998; Balazs, in press) and fouling organisms, once established, are likely to increase drag. However, increased drag may cause the tag to be lost before tagged individuals are affected. Additionally, Witzell (1998) and Leong et al. (1989) have suggested that tagging wounds may themselves be a source of infection in captive-reared turtles. Possibly more importantly, two black turtles, *Chelonia mydas agassizii*, may have become entangled in fishing nets by their plastic flipper tags (Nichols et al. 1998). This view was supported by interviews with fishermen and an aquarium study where only tagged turtles were observed to become entangled in experimental nets. It was suggested that turtles without such tags are better able to escape nets (Nichols et al. 1998).

We have shown that tagging has some effect on the behaviour of at least a proportion of loggerhead turtles, whereas green turtles subjected to the same treatment at the same site appeared unaffected. Although this effect did not appear to harm reproductive success, studies such as ours should be considered as part of the rationale for justifying the use of similar procedures on endangered species.

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