Effects of Organized Turtle Watches on Loggerhead (*Caretta caretta*) Nesting Behavior and Hatchling Production in Florida

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Abstract: *To evaluate the effects of organized turtle watches on female sea turtles and their eggs, we quantified nesting behavior and hatchling production of loggerhead turtles (*Caretta caretta*) in south Brevard Country, Florida, U.S.A. We compared the duration of five phases of nesting behavior, the directness of the turtle's return path, rate of travel during return crawl, hatching success, and hatchling emergence success between experimental and control turtles. Experimental turtles nested while observed by an organized turtle watch group consisting of at least 15 people; control turtles were not observed by a turtle watch group. Experimental turtles spent significantly less time camouflaging nest sites than did control turtles. The duration of the other four phases of nesting behavior were not significantly different between the two groups. Experimental turtles also traveled less-direct paths during return crawls, although their rates of travel were not significantly different from those of control turtles. Hatching success and hatchling emergence success were not significantly different between experimental and control turtle nests in either year. Although turtle watch groups influenced nesting behavior, they were not found to be detrimental to hatchling production. Florida's turtle watch program is a means for garnering public support for sea turtle conservation through education, and it should continue.*

El efecto de observaciones organizadas sobre el comportamiento de anidación y la producción de crías de la tortuga cahuama en Florida

Resumen: *Con el propósito de evaluar el efecto de las observaciones organizadas sobre las tortugas marinas hembras y sus huevos, cuantificamos el comportamiento de anidación y la producción de crías de la tortuga cahuama (*Caretta caretta*) en el Condado de Brevard, Florida, EEUU. Comparamos la duración de cinco fases del comportamiento de anidación, la rectitud del camino de regreso de la tortuga, la tasa de viaje durante el retorno, el éxito en la producción de crías y el éxito de la emergencia de las crías en tortugas experimentales y tortugas controles. Las tortugas experimentales anidaron mientras eran observadas por un grupo organizado de observación de tortugas que consistía en por lo menos 15 personas. Las tortugas control no fueron observadas por ningún grupo. Las tortugas experimentales emplearon una cantidad de tiempo significativamente menor camuflajeando sus sitios de anidación que las tortugas control. La duración de las otras cuatro fases del comportamiento de anidación no difirió significativamente entre los dos grupos. Las tortugas expe-*

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rimentales también siguieron caminos menos directos durante su viaje de retorno, pero las tasas de viaje no fueron significativamente diferentes de aquellas de las tortugas control. El éxito de la producción de crías y el éxito en la emergencia de las crías no fueron significativamente diferentes entre los nidos de las tortugas experimentales y aquellos de las tortugas control en ninguno de los dos años. Si bien los grupos de observación de tortugas influenciaron el comportamiento de anidación, no fueron perjudiciales para la producción de crías. El programa de observación de tortugas en Florida es un medio para conseguir apoyo público para la conservación de las tortuga marinas a través de la educación y debe permanecer en vigencia.

Introduction

The loggerhead (*Caretta caretta*) is a circumglobally distributed species of marine turtle occurring in tropical and temperate seas (Dodd 1988). Within the Atlantic, loggerhead nesting densities are greatest on the east coast of Florida, U.S.A., from Brevard to Broward County (National Research Council 1990). From May through August loggerheads annually deposit approximately 50,000 egg clutches in the state (Florida Department of Environmental Protection, unpublished data).

Loggerheads are an excellent target species for ecotourism because they are easily viewed when they come ashore to nest; they are therefore an important economic resource in Florida. Numerous organizations, operating under permits issued by the Florida Department of Environmental Protection (FDEP), conduct organized turtle watches to allow the public to view the nesting process. Thousands of tourists—both national and international—visit coastal areas each summer to attend organized turtle watches; approximately 10,000 tourists participated during the 1993 nesting season (FDEP, unpublished data).

Loggerheads exhibit stereotypic nesting behavior (Hailman & Elowson 1992) and take about 1.5 h to complete the nesting process. Sea turtles are susceptible to disturbance early in the nesting sequence and may be easily frightened prior to oviposition. Once a female begins to lay eggs, however, she becomes insensitive to external stimuli (Ehrenfeld 1989), and people may move to within 1 m of the turtle with no visible effect. To ensure as little disturbance as possible to nesting turtles, FDEP has established guidelines for organized turtle watches conducted in Florida. These guidelines define such parameters as group size, timing of approach and group position around the turtle, use of light and flash photography, as well as touching of eggs and the female. Previously, data were not available to evaluate the effectiveness of these guidelines. The objectives of our study were to evaluate FDEP turtle watch guidelines by testing two hypotheses: (1) organized turtle watches have no effect on the duration of various phases of loggerhead nesting behavior, and (2) organized turtle watches have no effect on loggerhead hatching success or hatchling emergence success.

Methods

Study Area

We conducted the study on a 16-km stretch of high-energy, barrier island beach along the east coast of central Florida in south Brevard County. The beach sand is biogenic and is composed mostly of crushed mollusk shell. Single-family homes, condominiums, and numerous hotels have been built behind the beach; few intact areas of undisturbed dune remain. Loggerhead turtles utilize the study area as nesting habitat from mid-May through August. In recent years, nesting densities have ranged from about 150 to 250 nests/km for an entire season (L. M. Ehrhart, unpublished data).

Nesting Behavior

Nesting behavior of loggerheads was studied from May through August in 1993 and 1994. Each year, data were recorded for experimental turtles, which nested while being observed by an organized turtle watch group of at least 15 people, and for control turtles, which were not observed by turtle watch groups.

We quantified behavior by timing the duration of seven phases of the nesting process (Table 1) with a digital chronograph capable of storing nine consecutive time intervals (Micronta brand, no. 63-5012). The transition cues between phases were obvious and consistent, which allowed for collection of repeatable data among turtles and investigators. We found turtles by walking at the water's edge and encountering either tracks or sighting females as they crawled from the surf. To avoid the effects of ambient light at dusk and dawn on the duration of turtle nesting behavior, we timed only those turtles initially encountered from 2100 h to 0100 h. Upon encounter, the chronograph was started, and the investigator approached the turtle by crawling along the same path taken by the turtle. Duration data for only those turtles initially sighted in emergence, body pit, or digging behavioral phases were used in analyses.

For control turtles a single investigator was the only human present during the nesting process. During the entire sequence, except when measuring carapace length (see below), the investigator remained 2–4 m behind the

Table 1. Start and end points and description of seven phases of loggerhead turtle nesting behavior.

Behavioral phase	*Description of phase and start and end points**
Emerge	Female ascends beach to suitable site for initiation of body pit excavation. Start: Turtle sighted stranded on the sand at surf's edge. End: First sand-sweeping motion of either a front or rear flipper, indicating initiation of body-pit preparation.
Body pit	Preparation of site by sand-sweeping movements of front and rear flippers. End: First anterior flick of a rear flipper, indicating initiation of egg chamber excavation.
Dig	Digging of egg chamber with rear flippers only. End: First egg drops from distended cloaca.
Oviposition	Deposition of clutch into egg chamber. End: Either rear flipper makes a sand-sweeping movement, indicating initiation of covering eggs.
Cover	Covering clutch by sand-sweeping and sand-packing movements of rear flippers only. End: Either front flipper makes a sand-sweeping movement, indicating initiation of camouflaging nest site.
Camouflage	Disguising nest site by sand-sweeping movements of front and rear flippers. End: Obvious movement of a front flipper (not a sand-sweeping movement), indicating female is about to return to the sea.
Return	Descent of beach by female from nest site to surf. End: Female 2 to 5 m from surf.

**Start point for each phase is the same as end point of preceding phase.*

turtle and out of the turtle's line of sight. The same procedure was practiced for experimental turtles, with the exception that organized turtle watch groups approached to within 1 m after oviposition was underway.

Organized turtle watches were conducted by a local, nonprofit organization, the Sea Turtle Preservation Society of Melbourne Beach. During all organized watches, turtle watch groups adhered to guidelines provided by FDEP (Table 2). The size of each turtle watch group was limited to 50 registered participants (Table 2). Group size occasionally exceeded 50, however, because group leaders, once on the beach, are supposed to invite individuals who are looking for turtles to join the organized group. During oviposition a single egg was removed from the nest, passed among the participants, and replaced before covering behavior began.

We attempted to gather data for at least one experimental and one control turtle during each night in which an organized turtle watch was conducted. Usually the experimental turtle was found first, and then a control turtle was located. On occasion, we recorded data for more than one control turtle, but only one experimental turtle was timed each night.

Additional data were also collected for each turtle. Curved carapace length (from nuchal notch to the longest projection of the pygal) was taken about halfway through oviposition by means of a flexible tape measure. To measure carapace length the investigator

Table 2. Partial list of Florida Department of Environmental Protection guidelines regulating organized turtle watches in Florida.

- Group size shall not exceed 25 participants per guide, with the total group size not to exceed 50 individuals.
- Use of flashlights by participants is not permitted. The use of low-intensity flashlights is limited to the walk leader and permitted scouts only. After approaching the turtle, the group leader or a scout may use one light to illuminate the nest cavity so that participants can observe egg deposition. The light may not be turned on the turtle until covering is underway.
- Turtle-watch leaders and scouts are encouraged to invite people out on their own looking for turtles to join the group.
- The leader or scout must exercise great caution when exposing the nest so as not to disturb the turtle. At no time should sand be allowed to fall into the nest chamber.
- Participants must be instructed to stay with the group and remain quiet at all times. During the entire watch the group must remain together. The group may not approach the turtle until egg deposition is well underway. Participants, scouts, and the leader must approach from the rear and remain behind the nesting turtle during egg deposition. At the principal permit holder's discretion, a single egg may be removed from the nest by the guide and passed around for the participants to touch. The egg must be returned to the nest before egg deposition is completed.
- Contact (light touching) with the nesting female is permitted only after all eggs have been deposited. Contact must not impede nest covering or the turtle's return to the ocean.
- The use of flash photography and lights for filming is not permitted.

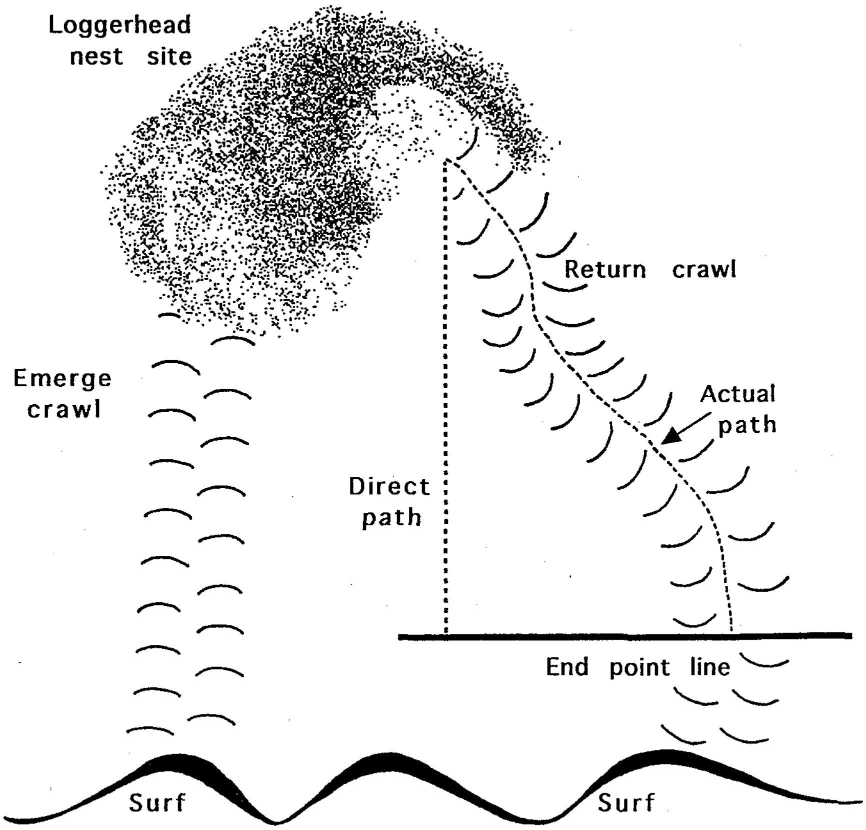

Figure 1. Schematic drawing of loggerhead nest site indicating how lengths of actual and direct paths were measured. Index of directness of return crawl was calculated by dividing length of the actual path by length of the direct path.

moved close to the turtle but stayed directly behind it. Each turtle was tagged after timing was terminated and just before she entered the surf. A single monel metal tag (National Band and Tag Co.) was attached to the trailing edge of one front flipper.

Length of travel from nest site to surf was measured after the turtle entered the ocean. Length of actual path (Fig. 1) was measured by placing a flexible surveyor's cord along the middle of the return crawl from the point where plastral drag was first apparent to the location of the posterior end of the turtle's shell at termination of timing. We drew a line in the sand at this point when we stopped the chronograph, usually 2–5 m above the surf.

Differences in beach width at various locations throughout the study area made absolute length of return path a poor indicator of disturbance to turtles during the return crawl. To evaluate disturbance during return, we also measured the most direct path the turtle could have traveled (Fig. 1). Direct path was measured from the initial point of the actual path directly to the surf, ending even with the end point line of the actual path. Each measurement was recorded to the nearest 5 cm. An index of directness of return crawl was calculated for each turtle (length of actual path divided by length of direct path; Fig. 1). The closer this value is to 1.0, the more direct the return crawl. Rate of travel (m/min) during return phase was calculated by dividing length of actual path by duration of return phase for each turtle.

Hatchling Production

To quantify hatchling production, we evaluated hatching success and hatchling emergence success of clutches deposited by experimental and control turtles. Hatching success is the percentage of yolked eggs in each clutch from which turtles hatched. Hatchling emergence success is the percentage of yolked eggs in each clutch that resulted in hatchlings that emerged from the nest. A nest produced hatchlings if at least one turtle emerged from that nest.

The location of each clutch was marked by placing two numbered, wooden stakes a measured distance from each clutch. One stake was placed conspicuously at the edge of dune vegetation, and the other was hidden within vegetation. A written site description was also recorded. This method proved effective for relocating clutches, except in a few cases in which stakes were removed by people.

During incubation, nests were periodically observed for signs of predation or disturbance. After all viable hatchlings had emerged from the sand, the contents of each nest were exhumed and examined. We recorded clutch size, number of hatched and unhatched eggs, number of pipped eggs containing dead turtles, and number of dead or moribund hatchlings unable to free themselves from the sand. All intact eggs were opened and examined with the unaided eye. The number of eggs apparently influenced by plant roots or predators was also quantified. All eggs were examined and clutch sizes estimated by S. A. Johnson.

Data Analysis and Statistics

Duration of behavioral phases, index of directness of return path, and rate of travel during return crawl were compared between experimental and control turtles to determine if organized turtle watches influenced loggerhead nesting behavior. Because the duration of all phases of nesting behavior did not differ significantly between years for control turtles, we combined both years of duration data for control turtles; the same was done for the duration data of experimental turtles. Statistical comparisons were conducted between the combined data sets.

To determine if organized turtle watches influenced hatchling production, we compared hatching success and hatchling emergence success between nests of experimental and control turtles. Because of numerous environmental factors, success of loggerhead nests within the study area may vary dramatically among nesting seasons (L. M. Ehrhart, unpublished data). For this reason nest success data from each year were analyzed separately.

Frequency distributions of duration data did not approximate a Gaussian distribution, and, as a result, assumptions of parametric statistical tests were not met (SAS Institute 1982; Zar 1984). Carapace length and clutch size data did not violate these same assumptions, however. Therefore, we analyzed duration data with nonparametric tests (Siegel & Castellan 1988) and body size and clutch size data with parametric tests (SAS Institute 1982; Zar 1984). The rejection level for all statistical tests was set a priori at $\alpha = 0.05$.

Results

Nesting Behavior

The duration of body pit, dig, oviposition, cover, and camouflage behavioral phases were not significantly different between control turtles in 1993 and 1994 (Mann-Whitney tests, $p > 0.1$). Spearman's correlation tests revealed no correlations between the curved carapace length of control turtles and the duration of emergence ($r_s = 0.02, p > 0.9$), body pit ($r_s = -0.16, p > 0.4$), dig ($r_s = -0.09, p > 0.6$), oviposition ($r_s = 0.24, p > 0.07$), cover ($r_s = -0.11, p > 0.4$), or camouflage phases ($r_s = -0.06, p > 0.6$). Curved carapace length and estimated clutch size of control turtles did not differ between years (t tests, $p > 0.3$).

The duration of body pit, dig, oviposition, and cover phases did not vary significantly between experimental and control turtles (Mann-Whitney tests, $p > 0.3$; Table 3). Duration of the camouflage phase, however, was significantly shorter for experimental turtles (Mann-Whitney test, $p = 0.015$). Experimental turtles also traveled significantly less-direct paths during their return crawls (Mann-Whitney test, $p < 0.0001$; Table 3). No significant differences were found between experimental and control turtles for rate of travel during return crawl (Mann-Whitney test, $p > 0.1$; Table 3) or curved carapace length (t test, $p > 0.2$; Table 3).

The number of people present during each organized turtle watch ranged from 16 to 65 and averaged 29.3 (SD = 9.06, $n = 63$ watches). No correlation (Spearman's correlation tests) was observed between duration of oviposition ($r_s = -0.03, p > 0.8$), cover ($r_s = 0.17, p > 0.1$), or camouflage phases ($r_s = 0.10, p > 0.4$) and the number

Table 3. Summary statistics for duration (min) of six phases of nesting behavior and four other parameters of experimental and control loggerhead turtles in 1993 and 1994.

	Experimental turtles					*Control turtles*				
Phase or parameter	*n*	*Mean*	*SD*	*Minimum*	*Maximum*	*n*	*Mean*	*SD*	*Minimum*	*Maximum*
Emerge	21	9.06	2.77	2.62	13.68	19	9.84	6.01	4.25	29.50
Body pit	30	3.93	1.59	1.67	7.47	22	4.09	1.76	1.57	7.17
Dig	42	18.26	4.64	12.37	37.40	33	18.11	3.55	12.38	28.13
Oviposition	63	17.83	4.15	6.42	29.30	60	17.16	3.53	10.75	24.40
Cover	63	13.21	4.53	2.95	29.45	60	13.34	3.77	6.53	22.55
Camouflage[a]	63	12.16	5.24	0.00	23.52	60	15.68	7.74	2.48	46.02
Total[b]	30	63.06	11.07	46.45	82.06	22	68.28	12.89	48.08	94.73
Index of directness[c]	61	1.29	0.58	1.02	4.67	57	1.06	0.08	1.00	1.35
Travel rate (m/min)	61	7.01	3.92	0.99	16.40	57	5.76	2.54	2.56	15.00
Carapace length (cm)	63	98.3	4.2	88.8	106.6	59	99.3	6.0	83.9	112.5

[a] *Significant difference observed (Mann-Whitney test,* p = *0.015).*
[b] *Includes duration of body pit through camouflage only.*
[c] *Significant difference observed (Mann-Whitney test,* p < *0.0001).*

of people around the turtle. The number of people around the turtle was also not correlated with the rate of travel by the turtle during the return crawl ($r_s = -0.07, p > 0.5$) or the directness of return crawl ($r_s = 0.05, p > 0.6$).

Clutch Size and Hatchling Production

Mean estimated clutch size was 116 eggs for both experimental nests (SD = 19.4, $n = 30$) and control nests (SD = 18.1, $n = 34$) in 1993. In 1994, mean estimated clutch size was 110 eggs for experimental nests (SD = 26.2, $n = 27$) and 119 eggs for control nests (SD = 25.4, $n = 25$). No significant differences in clutch size were found between experimental and control nests in 1993 or 1994 (t tests, $p > 0.2$). Furthermore, clutch size was not significantly different between years for either experimental or control turtles (t tests, $p > 0.3$). Clutch size was correlated with curved carapace length for both groups of turtles (Pearson's correlation tests, $p < 0.0001$).

The fate of experimental and control turtle nests, as well as the fate of individual eggs within those nests, were similar in 1993 and 1994 for both groups (Tables 4 and 5). Hatching success and hatchling emergence success of experimental nests were not significantly different from control nests during either year (Mann-Whitney tests, $p > 0.3$; Table 6). Although the values for both measures of success were lower for control turtle nests in 1994 than for control nests in 1993, these differences were not significant (Mann-Whitney tests, $p > 0.1$). Hatching success of experimental nests, although also lower in 1994 than in 1993, was not significantly different between years (Mann-Whitney test, $p > 0.06$). However, hatchling emergence success was significantly lower in 1994 than in 1993 for experimental nests (Mann-Whitney test, $p < 0.05$).

Relationships between hatching success and hatchling emergence success and duration of cover and camouflage phases were not significant (Spearman's correlation tests, $p > 0.05$) for either group in 1993 or 1994. Estimated clutch size was not correlated with hatchling emergence success (Spearman's correlation tests, $p > 0.1$).

Discussion

Our results indicate that organized turtle watches, conducted under FDEP guidelines, affect loggerhead nesting behavior. We found a significant difference between the amount of time experimental and control turtles spent camouflaging nest sites (Table 3). This suggests that nesting females were aware of and disturbed by the presence of people and, as a result, did not spend as much time camouflaging nests sites as they would have if the group had not been present. Furthermore, during their return to the surf, almost all experimental turtles were influenced by the group of people. Turtles usually moved in a path toward the surf but away from the group. This was obvious to the investigators present and can be seen in the fact that the mean index of directness value was significantly larger for experimental turtles than for controls (Table 3).

The effect of the disturbance caused by turtle watch groups on the subsequent behavior and reproduction of loggerhead females is unknown. Does the presence of the group influence nest-site fidelity or possibly clutch frequency? Moreover, did the group have any influence on other turtles attempting to nest within the area? These questions should be addressed in future studies. A more immediate concern, however, is the potential effect of the turtle watch group on loggerhead hatchling production. Does the reduction in the amount of time

Table 4. Fate of experimental and control loggerhead turtle nests evaluated in 1993 and 1994.

	1993		*1994*	
Fate	*Experimental ($n = 30$)*	*Control ($n = 34$)*	*Experimental ($n = 27$)*	*Control ($n = 25$)*
Undisturbed[a]				
Produced hatchlings	16	20	7	10
Did not produce hatchlings	1	1	2	2
Disturbed[b]				
Produced hatchlings				
Affected by crabs only	10	11	10	7
Affected by roots and crabs	0	0	2	0
Affected by tidal inundation	0	1	0	0
Did not produce hatchlings				
Affected by crabs only	2	1	4	2
Affected by tidal inundation only	0	0	2	2
Affected by crabs and inundation	1	0	0	0
Affected by raccoons	0	0	0	2

[a] *Undisturbed nests are those that were not apparently influenced by predation, inundation, or plant roots.*
[b] *Disturbed nests were influenced by either predation, inundation, or plant roots.*

Table 5. Fate of eggs within experimental and control loggerhead turtle nests evaluated in 1993 and 1994.

Year and condition of nests	*Number of nests*	*n (eggs)*	Number of eggs: *Hatched*	*Contents putrid*	*Contained embryo*	*Affected by inundation*	*Affected by plant roots*	*Pipped dead*	*Depredated by crabs*	*Depredated by racoons*
1993										
Experimental	30	3474	2341	831	221	0	0	31	50	0
Control	34	3929	2782	658	220	96	0	91	82	0
1994										
Experimental	27	2972	1502	813	254	116	10	70	207	0
Control	25	2971	1844	562	134	95	0	22	132	182

that experimental turtles spent camouflaging nest sites result in lower hatching success and hatchling emergence success?

During the 2-month incubation period, numerous biotic and abiotic factors influence the hatching success of sea turtle eggs. Included among the abiotic factors are tidal inundation, beach erosion and accretion, and rainfall (Ragotzkie 1959; Kraemer & Bell 1980; Witherington 1986; Peters et al. 1994). Predation may account for the loss of a large percentage of a season's eggs (Fowler 1979; Stancyk 1982; Cornelius 1986). Bacteria and fungi (Cornelius 1986; Wyneken et al. 1988), fertility of eggs (Miller 1985), and plant roots (Witherington 1986) have also been shown to influence hatching success.

Identified or suspected sources of egg mortality in our study were predation by crabs and raccoons, tidal inundation, and plant roots. Other unidentified biotic and abiotic factors undoubtedly influenced hatching success and hatchling emergence success in nests we evaluated. These biotic and abiotic influences dictated the success or failure of nests in our study. The presence of turtle watch groups around nesting loggerheads had no effect on hatchling production.

Even though no significant difference was found for hatching success between experimental and control nests, a note of caution is warranted. Because experimental turtles spent less time camouflaging nest sites than did control turtles, experimental turtles may have thrown less sand over their eggs. This may increase olfactory cues available to nest predators. Along our study area, predation by raccoons was insignificant. But because the intensity of predation on sea turtle nests differs throughout Florida and among different nesting rookeries, our results should be interpreted with the above caveat in mind.

Although viewing of nesting loggerheads by organized turtle watch groups following FDEP guidelines was found to influence nesting behavior, hatchling production was not compromised. Because turtle watch groups did not have a detrimental effect on hatchling production, we recommend that the program continue. Florida's organized turtle watch program is a mechanism for garnering support for sea turtle conservation through education and should be expanded to accommodate the high public demand for participation.

Recently, ecotourism on nesting beaches of sea turtles has been viewed as a means to boost local economies and promote sea turtle conservation. Some authors have expressed concern that such activities be conducted in a manner not detrimental to sea turtle reproduction (Arianoutsou 1988; Agardy 1992; Jacobson & Lopez 1994; Johnson et al. 1994; Whitmore 1994). Despite these concerns, few studies have investigated the possible effects of tourists on sea turtle behavior and hatchling production. Studies similar to ours and those of Campbell (1994) and Jacobson and Lopez (1994) should be con-

Table 6. Hatching success and hatchling emergence success for experimental and control loggerhead turtle nests in 1993 and 1994.

Year and condition of nests	Hatching success (%)					Hatchling emergence success (%)				
	n	Mean	SD	Minimum	Maximum	n	Mean	SD	Minimum	Maximum
1993										
Experimental	30	66.7	31.7	0.0	96.8	30	63.6	33.8	0.0	96.0
Control	34	70.3	30.0	0.0	99.0	34	69.1	29.7	0.0	99.0
1994										
Experimental	27	51.1	36.7	0.0	95.4	27	44.7	38.2	0.0	95.4
Control	25	59.5	40.2	0.0	97.5	25	53.1	40.6	0.0	96.7

ducted with other sea turtle species and at other nesting beaches before it is assumed that tourists are not jeopardizing the resource they have come to enjoy.

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