2e CONGRÈS INTERNATIONAL SUR LA ZOOGÉOGRAPHIE ET L' ÉCOLOGIE DE LA GRÈCE ET DES RÉGIONS AVOISINANTES - Athènes, Septembre 1981

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Abstract: Preliminary observations on the breeding behaviour and ecology of the loggerhead turtle (*Caretta caretta* L.) made during three nesting seasons (1978-80) at the recently discovered rookeries of Zakynthos are presented. These include behavioural aspects of nesting females and hatchlings. Predation and factors which may affect breeding are described with emphasis on human interference.

Introduction

Although sea turtles have been known in the Greek seas from ancient times, basic information on their ecology is particularly scarce. The conspicuous paucity of related works reflects probably the lack of data for nesting beaches where sea turtles (females and hatchlings) can be observed and investigated. The recent discovery of a loggerhead sea turtle (*Caretta caretta* L.) breeding area on the island of Zakynthos (Margaritoulis, 1982) presents an opportunity to study reproductive habits in Greek territory and to compare Mediterranean loggerheads with those from elsewhere.

Methods

The study was conducted in Zakynthos in the following periods:

28 Jul - 14 Aug. 1978,
5-25 Aug. 1979, and
3-13 Jul., 9-21 Aug., 20-22 Oct. 1980.

Observations on females were made at night during nesting activities. Emerged animals were located by patrolling the beach at intervals of about 30 minutes. Tracks of just emerged turtles were spotted and followed until the animal could be located and approached from behind. Some turtles were encountered at the water's edge in the beginning of their emergence. Although care was taken to avoid disturbing the animals, observations at the first stages of an emergence frequently interrupted the nesting procedure. Therefore the nesting sequence reported here represents a composite from different individuals.

Observations on hatchlings were done early in the mornings whenever they were encountered on the beach. As some hatchlings swam out to sea they were followed in the water with the aid of a face mask and flippers.

The movements of excavating females and swimming hatchlings were filmed and subsequently analysed in an editor viewer.

Observations on predators, abandoned nests etc. were made during early morning beach inspections.

Nest temperatures were measured with a mercury thermometer which could be lowered inside the nest through a 70 cm long, 1 cm in diameter plastic tube that had been placed during oviposition with the bottom at the center of the clutch. The other end of the tube extended above the beach surface and the opening was plugged with a cork. Temperature readings were taken as quickly as possible after pulling the thermometer out of the tube.

Results and Discussion

Nesting behaviour

As in other similar situations (e.g., Caldwell *et al.*, 1959; Bustard, 1972) nesting occurs in easily distinguishable steps; the most prominent of which are:

Emergence from the water and crawling to the nest site
Preparation of the nest
Oviposition
Covering and concealing the nest
Return to the water.

Nesting in Zakynthos takes place almost exclusively during the night hours. Of 63 turtles which have been observed in various stages of nesting, only 3 have been seen on the beach after daybreak, and all of these returned to the water within 30 min of dawn.

Loggerheads are shy animals. Disturbances during the first stages of nesting, especially during emergence and crawling to the nest site, usually cause immediate return to the sea. People moving on the nesting beach can scare the turtles away. Remaining motionless, however, does not apparently affect the emerging female which occasionally may even touch the observer on its way to the nest site. This can be explained by the fact that the loggerhead turtle was found by Beer to be highly myopic on land (Ehrenfeld and Koch, 1967). Nevertheless, as a turtle progresses into the nesting process, it becomes less sensitive to disturbances with the least sensitivity shown during oviposition and covering of the nest.

Of the 63 observed females only one exhibited an unusual behaviour which can be considered aggressive. This individual on her way to the sea rushed towards one of the observers thrusting her head forward and making a blowing noise. This lasted only a few seconds.

Emergence from the water does not necessarily end in oviposition. Most of unsuccessful nestings are due to obstructions which inhibit proper excavation of the nest. In these cases loggerheads abandon their nest sites and usually crawl further on the beach for a new try. Examination of the abandoned nest attempts often reveals stones and thick roots in the egg chambers but frequently the reason of nest desertion is not apparent. An unusual behaviour was noted once by a female which made a superficially perfect nest, remained above it for about 20 minutes without oviposition, then covered and packed laboriously the empty nest, and returned to the sea.

Apart from unsuccessful nestings, some emerged females return to the sea without any attempt at excavating. This has been seen either by inspecting the tracks or by observations made from a distance, presumably not affecting the animal's behaviour.

Female turtles in Zakynthos have been observed testing the beach on emerging from the sea by thrusting their heads in the sand. This behaviour known as «sand smelling» has also been recorded for loggerheads in other parts of the world with the exception of S.E. Africa (Hughes *et al.,* 1967).

Nest preparation starts with sweeping movements of the flippers which push away the dry sand. This makes the turtle lower herself several centimetres below the surface of the sand. Apparently, this behaviour brings the turtle in contact with the damp layers of sand which facilitates an effective excavation of the actual nest or egg chamber.

Excavation on the egg chamber is performed with alternate movements of the rear flippers. Digging behaviour, analysed through filming, shows that it combines actions of the body and the rear feet. In fig. 1 schematic drawings of the digging actions are presented. In A the turtle scoops up a small amount of sand with the left rear flipper, while the right flipper keeps in place sand collected from the previous cycle. In B she has dropped the collected sand to the left side and shifts her weight to the left. At the same time the right flipper throws away the sand collected from the previous cycle. In C the turtle scoops up sand with the right flipper to drop it to the right. In D, she shifts her weight to the right and kicks away the sand with the left flipper. Each cycle of movements is completed in 27-37 sec (N=6 cycles in 2 individuals) and it is repeated with occasional pauses, until the nest has acquired the maximum depth.

Observations of turtles that were unable to dig effectively corroborate the stereotyped nature of digging behaviour. One individual with an injured rear flipper continued the digging pattern even though it could not scoop up sand. Another, continued the kicking motion oblivious to an obstruction at her side

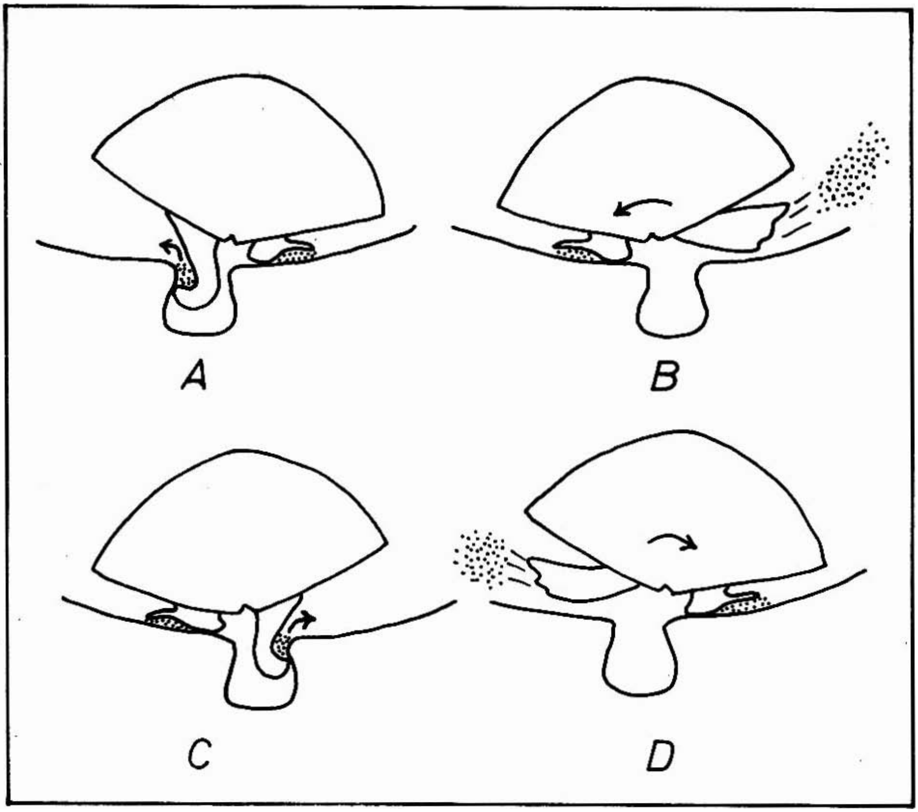

Fig. 1. Excavation movements of a nesting loggerhead sea turtle. D. Margaritoulis.

that prevented expelling the sand. In two other cases excavating turtles continued digging movements even though they couldn't pick up sand because of large stones at the bottom of the nest. Presence of stones was detected by the scratching of the turtle's nails on the stones. After about 3-5 cycles, respectively, of fruitless digging movements the observer removed the stones, without touching the animal, by reaching into the nest in the pause between alternation of rear flippers in the digging cycle. In both instances when the next flipper was inserted into the nest the turtles remained motionless for some time, as if surprised by the disappearance of the stone but they resumed excavation until oviposition.

Finishing the excavation, the turtle spreads her hind flippers beside the mouth of the egg chamber and oviposition starts. The white eggs are almost spherical, with a diameter of 3.5-4.0 cm (N=12 in 2 individuals). They are laid singly or in doubles at a mean rate of 8.5 eggs per min (5 one-minute observations in 2 individuals).

Covering of the nest starts immediately after egg laying. The rear flippers are used in drawing sand to the egg chamber. The rear flippers are used in drawing sand to the egg chamber. As soon as a portion of sand is dragged into the egg chamber the distal half of the flipper turns upside down so that its upper surface touches very gently the sand above the eggs. This continues with alternate movements until the egg chamber has been filled. Then the behaviour changes and the turtle starts to press hard the loose sand above the eggs with «kneading» movements of its rear flippers. At this point the front flippers join in the process and throw back sand which is drawn to the nest and pressed firmly by the rear flippers.

Concealing of the nest site is performed with sweeping movements of the front flippers which throw back a considerable amount of sand. This results in «sand-spraying» of the turtle's carapace and of the area around the nest. Thrown sand reaches more than 1m behind the posterior edge of the turtle's carapace.

Zakynthos female loggerheads returning to the water were attracted by flashlights which made them change course temporarily, heading towards the light source. This is comparable with the results of experiments with green turtles (Ehrenfeld, 1968) which have shown that turtles with neutral density filters of 1% transmittance over one eye were able to find the sea, after some time, presumably when dark adaptation in the filter covered eye had proceeded to equalization of light inputs from both eyes. Although unilaterally blindfolded turtles, in the same experiments, exhibit continuous (for a testing period of 10 min) turning movements towards the side of the uncovered eye, a one-eyed turtle encountered in Zakynthos returned to the water without difficulty after nesting. However, brief flashes of light as from camera flashbulbs did not cause changes in the course of turtles returning to the water. This is explained by Mrosovsky (1978) as an ability of turtles to integrate brightness cues over wide spans of time and therefore not responding to short-lived changes of illumination.

Nesting periodicity

It is known from studies in other turtle populations (e.g., Hughes *et al.*, 1967; Worth and Smith, 1976) that loggerheads nest more than once in the same season. Evidence of multiple nesting in Zakynthos was groups on unlaid eggs of distinct sizes seen in the dissection of a turtle found dead on the beach in 1978. Dissection revealed 93 shelled eggs of mature size which would probably have been laid the previous night. In addition to this they were found 102 enlarged follicles ranging from 15 to 25 mm in diameter and about 150 smaller follicles ranging from 4 to 8 mm in diameter.

Epizoa

Barnacles and algae were present on many turtles. The most prominent epizoan was *Chelonibia testudinaria* L. which occured mainly on the carapace and plastron but it was also observed on the lower jaw (1 case) and on the hind flippers (1 case). The largest *Chelonibia* collected had a diameter of about 6.5 cm. Cracks on the turtles' shells due to old injuries usually harboured large colonies of barnacles. To a lesser extent *Lepas* sp. was also present. Annelids (*Serpula sp.*) were found on two individuals. Samples of algae taken from one turtle were identified as *Cladophora* sp. and *Sphacelaria* sp.

Incubation of the eggs

Three nests monitored in 1980 gave a mean incubation period of 50.7 days. Temperatures, measured in the center of one nest, increased gradually from 26.5° C at oviposition (5 July) to a mean of 30.39° C in the period 11 August to 18 August (9 measurements). During the same period (11-18 August) control temperatures measured at the same depth about one meter away from the monitored nest gave a mean of 29.34° C (Table 1). The temperature difference

TABLE 1

RECORDED TEMPERATURES AT THE CENTER OF A LOGGERHEAD CLUTCH AND ONE METER AWAY FROM THE NEST AT THE SAME DEPTH IN ZAKYNTHOS, 1980.

Date	Time	Days after oviposition	Temperature °C Nest	Temperature °C Control
11.8	17 30	37	30.0	29.5
12.8	09 00	38	29.5	29.5
12.8	17 00		30.0	31.0
14.8	13 00	40	30.5	29.0
15.8	19 00	41	30.0	28.5
16.8	07 30	42	30.0	29.0
17.8	07 30	43	30.0	28.5
17.8	20 00		31.5	29.0
18.8	15 00	44	32.0	30.0
	Mean		30.39	29.34

of 1.05^{0} C is attributed to metabolic heating. The first hatchlings from this nest emerged on 27 August, 53 days after oviposition.

Behaviour of hatchlings

Early morning inspections showed that most hatchlings emerge during the night. Hatchling emergence from the nest was uncommon between 10.00 and one hour before sunset. Occasionally the uppermost hatchlings of a nest were found protruding from the surface of the sand during the day. Their inactivity was evidently stimulated by warm ambient temperatures at the surface, a response which prevents diurnal emergence and the concomitant exposure to heat prostration and diurnal predators (Bustard, 1967). Unfortunately, no observation was carried out to determine the fate of these individuals.

Hatchlings scurry towards the water, moving synchronously their diagonal limbs. When approached from the side they change course but quickly resume their initial orientation. In rare cases the tracks of hatchlings followed a course parallel to the water's edge with much circling. This uncommon behaviour was attributed to the simultaneous presence of other animals which hatchlings were trying apparently to avoid. Inspection of tracks suggested the presence of *Rattus rattus* and *Martes foina*, which are locally abundant.

Entering the water, hatchlings change their walking pattern to swimming movements. These are performed with the front flippers moving synchronously up and down within an angle of about a 160^{0}. Films taken of 2 hatchlings swimming out to sea showed that the frequency of swimming movements is 1.8-2.4 sec^{-1}. In the water, hatchlings follow a course almost perpendicular to the beach, swimming 15-25 cm under the surface and coming out to breathe every 7-12 sec ($N=12$). Approached from under or above the water they become immobile holding their front limbs close to the body and floating to the surface, they remain motionless until the intruder leaves.

Predation

Mutilated hatchlings found on the beaches were thought to have been killed by predatory birds. Herring gulls (*Larus argentatus* Pontopp.) and ravens (*Corvus corax* L.) patrol Zakynthos rookeries in the morning. These avian predators do not dig into the nests but take only the hatchlings that are on their way to the water or are immobile and visible on the sand. Inspection of tracks on the beaches have shown that ravens search for hatchlings in a systematic way. They walk along the splash zone, and when they come across hatchling tracks follow them up to the nest where they wait for possible new emergences. A few pairs of falcons (*Falco* sp.) and about 25 shags (*Phalacrocorax aristotelis* L.) have been seen flying or perching close to the nesting beaches but they have not been observed taking hatchlings.

Nest predation is not common in Zakynthos. Only one nest was found destroyed, possibly by a dog. Examination of the opened nest revealed eggs with almost fully developed embryos that were subsequently eaten by rats.

Each year, a number of fully developed hatchlings have been found dead around hatched nests, and these are thought to have died from desiccation. Bustard (1967), investigating the mechanism of emergence from the nest, stated that occasionally during the day topmost hatchlings are pushed out of the sand by the activity of those below. These hatchlings often perished before they were able to reach the sea showing signs of heat torpor.

Human perturbations

Reliable information from local residents, albeit lacking in quantitative data, gives evidence of a serious reduction in the number of nesting females. It seems that Zakynthos loggerheads are mainly threatened by degradation of their nesting habitat through beach development and tourism. All nesting beaches in Zakynthos are affected in one way or another by those factors. The effects of beach development have been investigated in other loggerhead rookeries. Dean and Talbert (1975) observed that loggerhead nesting activity in South Carolina was lowest in areas where beach homes were present even if the beach appeared ideal for nesting. Declines in nesting populations of loggerheads in Florida are attributed by Worth and Smith (1972) to urban development, artificial lights and human activities. Bustard (1972) considered coastal development and construction in nesting areas the greatest threat to sea turtles in Queensland, Australia.

Since sea turtles depend strongly on optical cues for finding the sea (Ehrenfeld, 1968; Mrosovsky, 1978), artificial lights in the vicinity of the nesting beaches disorient both nesting females and hatchlings. Responding positively to brightness hatchlings may be attracted by lights even at the sea (Frazier, 1971). Artificial lights, common on all Zakynthos beaches, apparently disturb nesting turtles, for they tend to emerge at the darker sectors of the beaches. Tracks of females, presumably seeking a place to nest away from lights, have been observed in places unsuitable for nesting like in very narrow strips of sand and even inside a sandy-bottom cave. The coincidence of the nesting season with the peak in tourism, manifested in Zakynthos by brightly lit hotels, makes the problem of lights critical.

The recent increase of motor boats in Zakynthos evidently has a negative effect on turtles in the marine area. Each season fewer turtles are encountered at sea and nesting females have been observed with injuries on their heads and carapaces which are attributed to collisions with fast moving craft.

Tar and oil on the nesting beaches also present a serious problem. All Zakynthos rookeries have on the high beach a conspicuous strip of oil and tar, carried there by storms. In most cases, hatchlings on their way to the water have to cross this polluted zone. The situation was worsened after February 1980 when Zakynthos southern coast was fouled by a large oil slick spilled from a tanker at the Gulf of Pylos. Tar balls are also present under the surface of the sand. Oil and tar apparently affect nest excavation, incubation and hatching. Some hatchlings (N=5) and adult femals (N=2) fouled with tar have been observed on Zakynthos beaches.

Fishing nets and lines cause trouble to adult turtles in the sea as they may become entangled and drown. Although only two dead turtles have been observed washed up on Zakynthos beaches, mortality caused by this factor is probably higher than the data indicates because the prevailing north winds, during the nesting season, may push carcasses offshore.

Illegal use of underwater explosives for «fishing», observed frequently close to Zakynthos nesting beaches, has a catastrophic effect on the benthos ecology of the area and can also directly damage turtles and hatchlings.

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