

# Assessing the Impacts of Human Activities on Nesting of Loggerhead Sea-turtles (*Caretta caretta* L.) on Zákynthos Island, Western Greece

by

MARGARITA ARIANOUTSOU, Ph.D.(Thessaloniki)  
Assistant Professor of Ecology, Division of Ecology,  
Department of Biology, University of Thessaloniki,  
540 06 Thessaloniki, Greece.

## INTRODUCTION

Of the seven existing species of sea-turtles, three are known to occur in the Mediterranean Sea: *Caretta caretta* (Loggerhead Sea-turtle), *Chelonia mydas*, and *Dermochelys coriacea*. Of these species, *Caretta caretta* and *Chelonia mydas* breed in the Mediterranean and have evolved local populations, while *Dermochelys coriacea* seems to be a regular visitor from the Atlantic ocean (Margaritoulis, 1986).

Only *Caretta caretta* is known to nest in Greece, where its main nesting locality is the large Zákynthos Island, off the south western mainland of our country, and where it has been reported since 1977 (Margaritoulis, 1982) as nesting. Every summer, at night-time, female Loggerheads come ashore on the sandy beaches of Zákynthos to lay their eggs. After their emergence from the sea they slowly crawl landwards up to a distance of usually 10–15 m from the water's edge. Provided they find a suitable place to dig (without stones or roots or other impediments), they start preparing their egg-chamber by taking out the sand until they have made a hole 50–60 cm deep. Oviposition then commences and usually lasts for some 30 minutes (Fig. 1).

The Loggerhead Sea-turtle lays about 100–150 eggs at a time. After covering the nest, the Loggerhead moves back to the sea. Any bright light or noise can interrupt this procedure. The hatchlings appear 50–60 days later. The young Loggerheads emerge from the egg-chamber during the night, although some of them have frequently been encountered on their way to the water during early-morning hours.

Zákynthos is the most important Loggerheads' nesting habitat within Europe. However, its sandy beaches attract

not only the Sea-turtles but also human tourists, and are therefore subjected to the trends of economic development.

*Caretta caretta* is considered an endangered species within the European Community (Groombridge, 1982). It is also included in Appendix I of CITES (Convention on International Trade in Endangered Species), and in Appendix II (Strictly Protected Species) of the Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention).

The impacts of human activities on the nesting beaches have been investigated in several Loggerhead 'rookeries'. Dean & Talbert (1975) observed that Loggerhead nesting activity in South Carolina was lowest in areas where beach houses were present, even if the beach appeared ideal for nesting. Declines in nesting population of Loggerheads in Florida were attributed to urban development (Worth & Smith, 1976), artificial lights, and human activities. Bustard (1972) considers coastal development and construction in nesting areas to be the greatest threat to the Loggerheads in Queensland, Australia.

This paper, being part of a wider study on the Loggerhead's nesting activity and on parameters affecting its nesting in Greece, reports on the significance of each of the nesting beaches, and on the impact of human interference with those habitats, on Zákynthos Island.

## THE OVERALL STUDY-SITE

Zákynthos is a large island situated in the Ionian Sea, and is characterized by a mild climate and abundant sunshine (Fig. 2). Nesting of Loggerheads on Zákynthos occurs mainly on the beaches of Laganas Bay on the southern coast. The nesting beaches, starting from the western part of the Bay, are: Marathonissi, East Laganas, Kalamaki, Vrontonero, Bakania, Daphni, and Gerakas—comprising a total length of about 3,700 m (Fig. 3). Of their characteristics we mention only those which make them preferred by people, whereas parameters that may affect their preference by Loggerheads—such as physico-chemical properties of the sand or water depth and temperature—may be very different (Laskaratos, 1987; Livaditis & Alexouli-Livaditi, 1987). Details of the nesting activity in the area for 1985 are given by Margaritoulis (1987).

The components of the overall Zákynthos study-site will now be characterized as follows, the number of Loggerheads' nests per 100 m of each beach during the 1985 nesting season being indicated in Fig. 4:

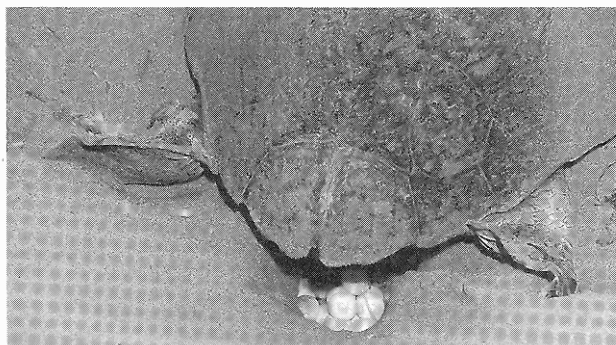


FIG. 1. Female Loggerhead Sea-turtle laying her eggs (each c. 3 cm wide, giving scale). Photo: D. Margaritoulis.

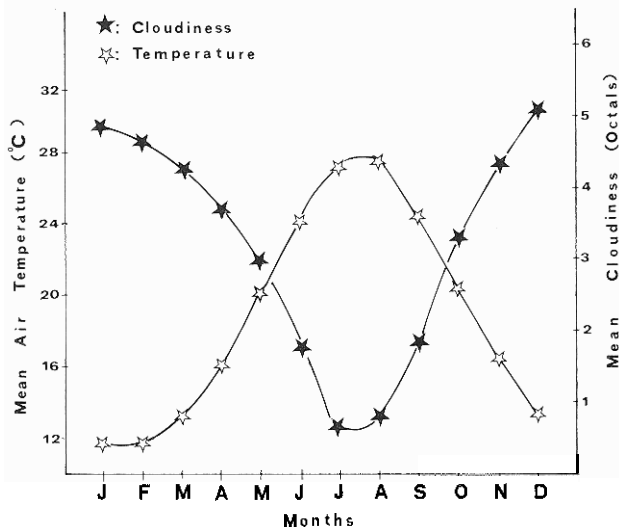


FIG. 2. Mean monthly air temperature and cloudiness at Zákynthos for the period 1930-75 (data from the Greek National Meteorological Service).

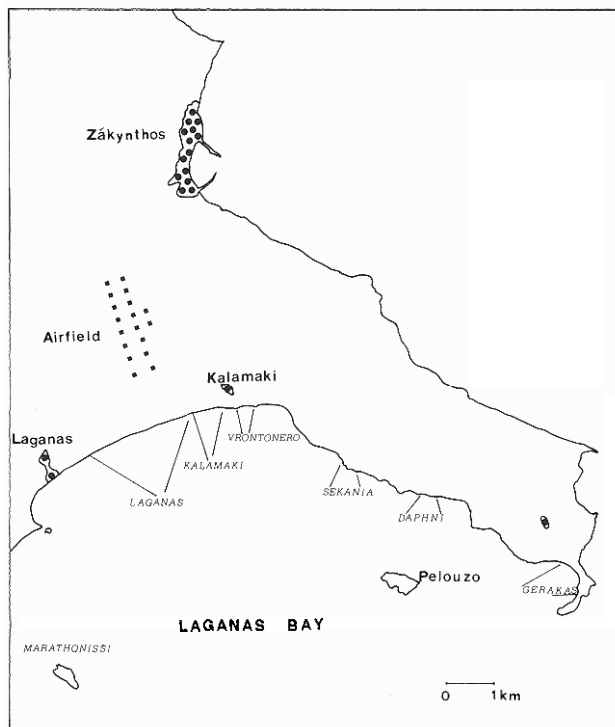


FIG. 3. Sketch-map of Laganas Bay in Zákynthos, showing the nesting areas of the Loggerhead Sea-turtle.

a) *East Laganas-Kalamaki*:—These beaches together comprise the eastern half of a 6-km-long beach of which the western part is almost fully developed and hosts the major portion of all touristic activity in Laganas Bay (Fig. 3).

In contrast to the other beaches in the Bay, East Laganas beach is characterized by an inland-extending dune-field which used to be larger in the past. For large quantities of sand have been taken from it to be used for construction activities, and as a result of this abstraction the sand remaining by the sea has become 'soggy' and solid, so that it is easily crossed by cars and motorcycles—despite the Pre-

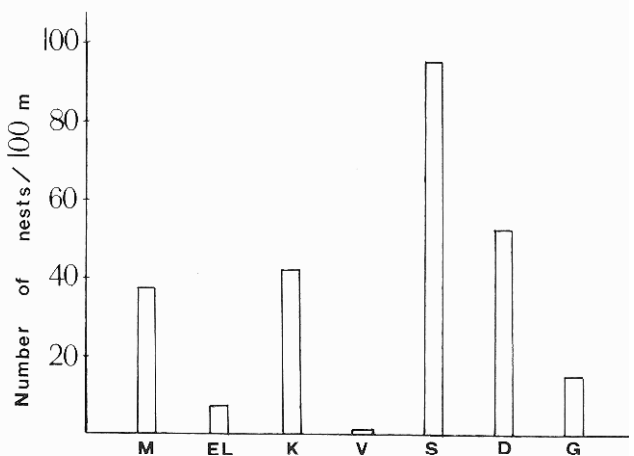


FIG. 4. Number of Loggerheads' nests laid per 100 m of beach length during 1985 nesting season on the Loggerhead Sea-turtle's nesting beaches in Zákynthos (M-Marathonissi, EL=East Laganas, K=Kalamaki, V=Vrontonero, S-Sekania, D-Daphni, G-Gerakas). Data from Margaritoulis (1987).

fecture's prohibition. Daytime activities, such as water-skiing and sailing, take place only along the western, 'developed', shore of Laganas Bay, while beach-umbrellas, sun-beds, sea-paddles, and wind-surfs, are concentrated in the same part.

Residence on the beach after sunset is prohibited, at least theoretically, by the Prefecture of Zákynthos. At nighttime, lights from the hotels along the developed part of (West) Laganas Beach, as well as lights from the nearby villages of Laganas, can be seen from the beaches, while the airport, though not directly visible from the beaches, diffuses its lights from behind the dunes.

At East Laganas and Kalamaki, the hotel owners have planted Tamarisk (*Tamarix* sp. or spp.) trees 10-25 m from the water's edge in order to give shade.

b) *Vrontonero*:—This is a beach about 150 m long that is separated from Kalamaki by a small rocky promontory. Its characteristic feature is the high percentage of stones and pebbles in the sand. The beach is relatively isolated and very few people visit it. The water is shallow near the coast, and the sea-bed is mostly sandy, although rocky in several places.

c) *Sekania*:—This site is the most important Loggerhead Sea-turtle nesting area in Zákynthos (Margaritoulis, 1987). It is a rather remote beach, about 3 km from the nearest paved road, divided into two sectors by a rocky outcrop. The available nesting area extends for about 350 m, the greater part of it belonging to the eastern sector. It is covered by deep sand, and reaches 30-40 m inland. The only access from the hinterland is an unpaved road which is in very bad condition, with a surface soil into which even the lightest footstep is apt to sink, although efforts to improve it have been reported quite recently. Approaching the beach from the sea is not easy, because there are many reefs and rocks.

Behind Sekania there is a natural light barrier—a mountainous mass with a 50-60% slope covered with dense Mediterranean vegetation and devoid of buildings. On the beach there is no shade, and in order to find drinking-water one must walk for about 45 minutes.

d) *Daphni*:—This is a small beach, about 250 m long and 3 km away from the nearest asphalt road, though an unpaved road in very bad condition leads to it. The available nesting area is less than the actual beach, because the sand on part of the beach is interrupted by large pebbles. Behind the beach there are in places tall Carob-trees (*Ceratonia siliqua*) and Lentiscs (*Pistacia lentiscus*), offering plenty of shade and camping space (Fig. 5). The beach is protected landwards by a mountainous mass, which is covered by dense Mediterranean vegetation that is interrupted only by the unpaved road, on both sides of which cypress (*Cupressus* sp. or spp.) trees are growing.

The local human inhabitants, trying to confront the restrictions in beach use set by the Prefecture and/or the Ministry of the Environment, have illegally transferred, to a place not far from the nesting beach, two trailers, probably aiming to instal more of them, in order to organize a camping site. The access to Daphni beach from the sea is precarious, because there are a series of reefs that leave but one opening between them. The reefs are most picturesque, however, and offer shelter to fish, which attract sub-aqua fishermen. East of Daphni there is a narrow strip of sand, 1–4 m wide, at the base of a rocky cliff.

e) *Gerakas*:—This Loggerhead nesting beach is situated at the eastern end of Laganas Bay (cf. Fig. 3). It is a beautiful beach about 500 m long and 10–25 m wide (Fig. 6), that ends abruptly in a 10–15 m-high hill with steep slopes. On the top of the hill there is a flat area with row-crops, Olive Trees (*Olea europaea*), a small tavern, and a few houses.

The beach is relatively remote but is connected with Zákynthos town by a fairly good road. Many visitors arrive here during the day, to swim and sunbathe. On the beach there are sea-paddles, canoes, and windsurfs for rent, all concentrated in a place approximately 5 m from the water's edge. Sun-umbrellas have recently been set up along the beach. The water is fairly shallow, and the sea-bed is covered with fine sand. No lights are visible from the beach during the night as the physiography of the area covers the inland buildings. The vegetation, while patchy, is dense in places (Fig. 7), and typical of many coasts of the eastern Mediterranean (cf. Polunin, 1980; Polunin & Walters, 1985).



FIG. 5. *Daphni* beach, one of the main nesting habitats of *Caretta caretta* in the region. Photo: D. Margaritoulis.

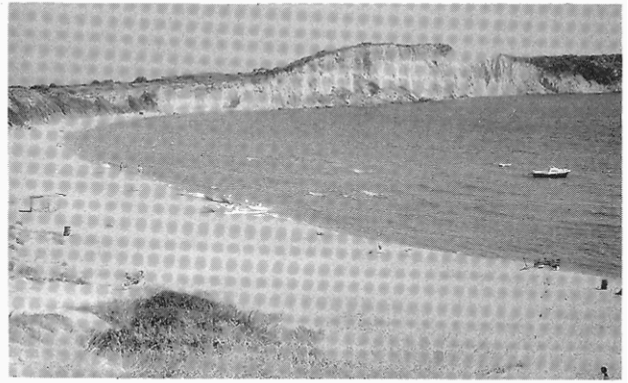


FIG. 6. *Gerakas* beach, another of the Loggerhead Sea-turtle's nesting habitats on Zákynthos. Photo: M. Arianoutsou.



FIG. 7. Another view of *Gerakas* beach, showing the rather drastic topography and patchy 'garigue' vegetation. Photo: D. Margaritoulis.

f) *Marathonissi*:—This is a small island lying well offshore in the western part of Laganas Bay (cf. Fig. 3). The only sandy beach of the island is about 200 m long and is situated on its northern side, forming a right-angle with half of its length facing NE and the other half NW. In contrast to the other beaches in Laganas Bay, the sea-bottom slopes abruptly off most of the NE-facing part of the beach. The beach is, on the average, some 15 m wide, and has its landward side covered with dunes that reach as far back as 50 m. On the dunes there are sparsely-distributed wild plants such as thyme (*Thymus* sp. or spp.), various spurges (*Euphorbia* spp.), Agave (*Agave americana*), and Sea-daffodil (*Pancratium maritimum*).

The island is reached daily by boats which bring people to stay for several hours. Upon departure they usually leave a considerable amount of trash.

#### METHODS

Our observations were made during the summer of 1985, when all the nesting beaches were surveyed as follows: the working-group, consisting of 2–3 persons, stayed on a beach for two consecutive days and then moved to the next beach. Under this schedule each nesting beach was surveyed for a minimum of 6 days per month.

All surveyed beaches were divided longitudinally into five zones of 5 m width each, starting from the water's edge

and moving landwards (0–5 m, 5–10 m, 10–15 m, 15–20 m, 20–25 m), to determine the number of people present at right-angles to the length of each beach (namely the water's edge) and therefore the possible pressure on the Loggerheads' nests.

Observations made on each beach consisted of the following:

a) The number of persons present on the beach, and in the sea in front of the beach, counted every 2 hours, from 08:00 until 20:00 h.

b) During the survey at 14:00 h, an estimation of the distribution of people present at right-angles to the water's edge was made in the assigned zones parallel to the seashore.

It is obvious that full information on activities such as traffic of vehicles on the beaches, or planting of trees on them, cannot be obtained except by means of some kind of qualitative-semiquantitative method, which was necessarily adopted.

## RESULTS

All nesting beaches in Zákynthos are affected in one way or another by perturbations caused by people. The main perturbation affecting Sea-turtles are summarized in Table I. Sekania nesting beach is not referred to in this table because none of those activities occurs there. The beaches are listed at a decreasing degree of activity intensity.

It is apparent that East Laganas and Kalamaki are the beaches which are most affected by human activities, whereas Daphni's nesting habitat (also not indicated in Table I) is threatened only by daytime visits. It seems reasonable, then, to say that the Sea-turtles which come ashore to lay their eggs on Laganas and Kalamaki nesting beaches will have to face more interference than on the other beaches. On the other hand, we cannot definitely claim that any single factor is the critical one, as in many cases data of the census on nesting activity are contradictory. For example, nesting activity is less on Marathonissi than on Kalamaki (Fig. 4), although human influence on the latter beach is much heavier than on the former. Clearly more information is needed.

Looking at the data on the daily distribution of human presence on the nesting beaches, we see that it is strongly temporal (Fig. 8). The number of persons per beach rises, rather abruptly during the day, to a maximum value

TABLE I

### Main Perturbations Affecting Sea-turtles per Nesting Beach in Zákynthos

(M = Marathonissi EL = East Laganas  
K = Kalamaki G = Gerakas)

Perturbation	Nesting beach
Lights seen from the beach	EL, K, M,
Beach used by people during the day	EL, K, G, M
Beach used by people during the night	EL, K
Traffic of vehicles along the beach	EL
Motorboats close to the beach	EL, K, M
Noise on the beach during the night	EL, K, M
Planting of trees on the beach	EL, K

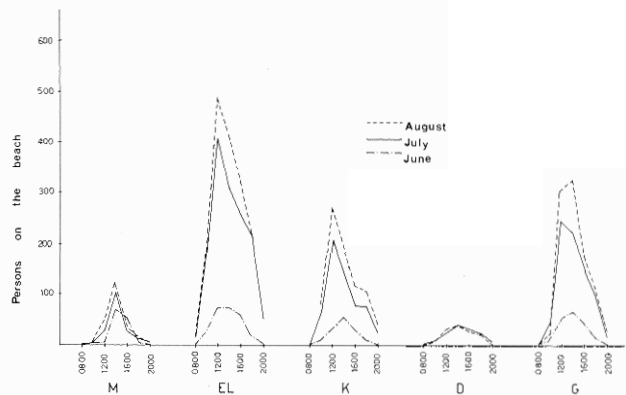


FIG. 8. Mean daily distribution of people on Zákynthos nesting beaches in June, July, and August, of 1985 (M=Marathonissi, EL=East Laganas, K=Kalamaki, D=Daphni, G=Gerakas).

around midday or soon thereafter and then falls off progressively on most of the beaches. This tendency is quite prominent during July and August, whereas the numbers are usually smaller in June.

Generally, the human presence per beach increases as the tourist season progresses, with maximum values attained in August. This is obviously a result of mass tourism which shows a maximum in Greece in July and August. The greatest increases in numbers of visitors occur on the East Laganas beach (almost 7 times as high in August as in June) and on Kalamaki and Gerakas beaches (almost 5 times as high in August as in June). This high increase is largely attributed to the easy access to those beaches as well as to the existence of nearby facilities. It is reasonable to note that the limited capacity of scheduled boats transporting people to Marathonissi does not allow the number of its visitors to increase in line with those to most of the other beaches. The 'flat' curve of Daphni can be explained by the fact that some people, visiting the beach, camp nearby and therefore spend more time on the beach.

The human presence on each surveyed beach, expressed as the daily average number of persons present at 14:00 h per 100 m of beach-length in August, is shown in Fig. 9 for five of the beaches. Of these the most frequented beach is Kalamaki, where more than 100 people on the average are present per 100 m of beach length, and the least frequented is Daphni.

Average distribution of people on each of those same five beaches, at right-angles to the shoreline, is shown in Fig. 10. Maximum concentration (>55%) of people on the beach occurs in the first 5 m from the water's edge. The percentage of people falls off rapidly in the next zone (5–10 m) and becomes even lower in the 10–15 m zone. On East Laganas beach the shade of the planted Tamarisk trees attracts a higher percentage of people (c. 16%) in the 10–15 m zone than in the 1–10 m zone. In Daphni, the existence of many trees and shrubs offering shade in the 20–25 m zone also attracts many people.

During the early hours of the night, the human presence on the nesting beaches is still fairly high on Kalamaki and on East Laganas. This is due to the easy access to them and to the neighbouring tourist facilities. Among the other beaches, Gerakas is visited occasionally during the night by groups of 'curious' people, mainly Greeks. Marathonissi beach has a minimum of night visitors, mainly owing to its

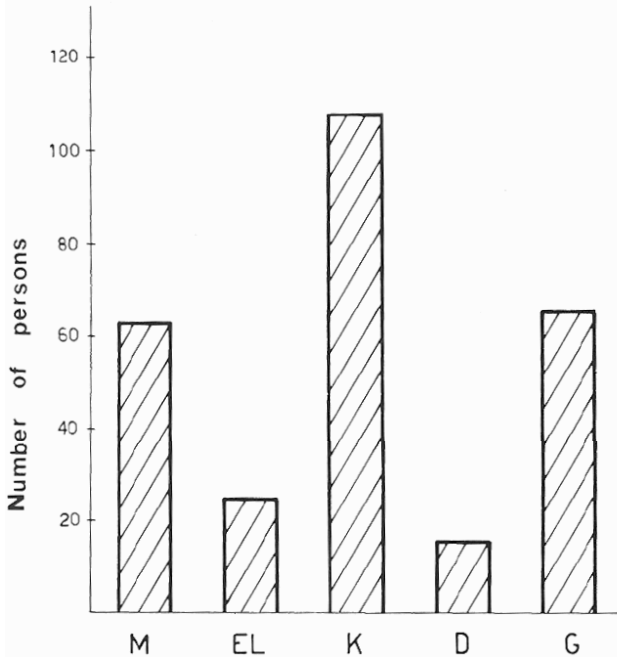


FIG. 9. Human presence on Zákynthos nesting beaches expressed as the daily average number of persons present at 14:00 h per 100 m of beach length during August 1985 (M=Marathonissi, EL=East Laganas, K=Kalamaki, D=Daphni, G=Gerakas).

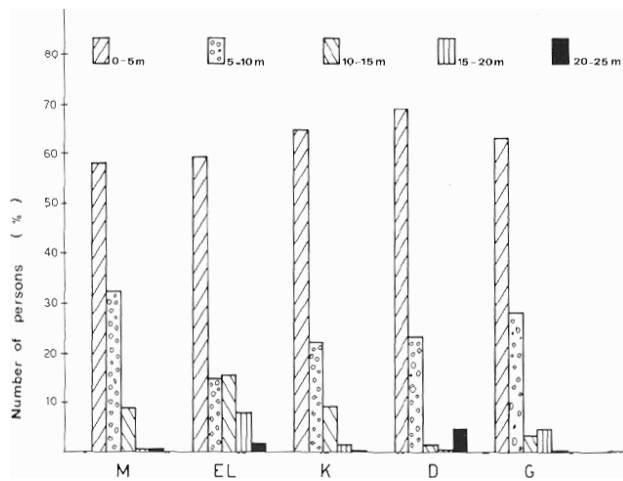


FIG. 10. Average percentage (%) distribution of people in zones parallel to the water's edge on Zákynthos nesting beaches during the 1985 nesting season (M=Marathonissi, EL=East Laganas, K=Kalamaki, D=Daphni, G=Gerakas).

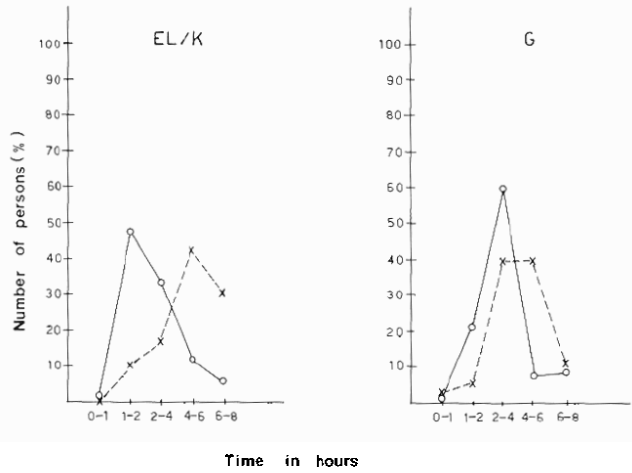


FIG. 11. Time spent on the beach by Greek (—o—) and foreign (---x---) visitors to Zákynthos nesting beaches during the 1985 nesting season (EL=East Laganas, K=Kalamaki, G=Gerakas).

dence that the main nesting biotope\* used to be the Laganas-Kalamaki area. The onset of tourism in the late 'sixties apparently led to the nesting concentration observed today on the as-yet undeveloped beaches (Margaritoulis, 1987). The main anthropogenic factors affecting the breeding of the Loggerhead Sea-turtle on Zákynthos will now be discussed:

1. Lights

'Photoc pollution', in this case referring to lights seen from the nesting beaches, causes disorientation of hatchlings when they move towards the sea. This is because hatchlings display a directional response towards areas of most light, which on a beach is—normally—the sea and the reflection of the moon and the stars on it (Ehrenfeld, 1968; Mrosovsky, 1978).

Disorientation of hatchlings has been observed on the East Laganas and Kalamaki beaches, which are the most 'illuminated' nesting areas. Lights on those beaches come mainly from nearby hotels, taverns, and other touristic facilities. East Laganas beach is also affected by lights of cars driving along the western Laganas beach. The lights of Zákynthos airport, in the interior of the Laganas Bay area, are also seen as a glow in the sky in the landward horizon of the East Laganas and Kalamaki beaches. Artificial lights discourage adult females to emerge onto the beach. This is perhaps the reason why tracks of females, attempting unsuccessfully to nest, are regularly observed in very narrow strips of sand east of Daphni and on Vrontonero beach (pers. obs.; D. Margaritoulis, pers. comm.).

2. Beach Use by People

The Loggerheads' nesting activity is generally inversely related to the intensity of disturbances on a particular beach. The number of nests laid per 100 m of beach-length during the 1985 nesting season (Fig. 4) is clear evidence for this. The influence on nesting of beach-use by people, provided that other factors are excluded, might be a direct result of the human presence on the beach, as female Loggerheads tend to concentrate during the day in the shallows

\* To the extent of being characterized by apparent uniformity of environmental conditions.—Ed.

DISCUSSION

In Zákynthos, the morphology of the Laganas Bay area as well as information from the local population provide evi-

difficult access and the unfavourable camping conditions.

The time spent on the beach by Greek and foreign visitors is shown in Fig. 11. Although most of the people stay on a beach for 2-4 hours, with slight differences observed between the different beaches, the foreigners tend to stay longer (up to 6 hrs) and so may be considered as potentially higher threats to the nesting Loggerhead Sea-turtles.

in front of the beaches. These day-time assemblages, probably stimulated by the higher water-temperatures in the shallows than in the deeper sea, seem to be affected by the distribution of the human presence on the beach; Loggerheads tend to concentrate in the sea in front of beach sectors which have little or no human presence. However, the effect of this concentration on their emergences during the night has not been corroborated, at least on East Laganas—probably due to the influence of other factors (pers. obs.; D. Margaritoulis, pers. comm.). On the other hand Gerakas beach, with no lights and only minimal disturbances during the night, supports relatively low nesting activity, which can be attributed to its heavy beach-use by people during the day (cf. Figs 4, 8, and 9).

Besides that, heavy trampling might affect nesting success to the extent that it compacts the sand and makes it difficult to dig.

Apart from the above-mentioned direct influence of any human presence on nesting, extensive beach-use by people results in heavy trampling of the sand, especially close to the sea where most people concentrate (Fig. 10). The effect of sand-trampling on the female Sea-turtles' emergences may be negligible, as no emergences were observed to be interrupted—apart from immediately apparent reasons such as the passing of a motorcycle (pers. obs.; D. Margaritoulis, pers. comm.). On the other hand it is known (Bustard, 1972) that hatchlings, after hatching, move upwards in the nest. As they reach the layers just under the surface of the sand-covering of the nest and the temperature near the open air is high, they become torpid, waiting for the temperature to drop before they emerge. This is a protective mechanism of hatchlings to avoid exposure to scorching sand-temperatures during the day. If at this stage trampling occurs close to the nest, hatchlings might get activated and attempt emergence during daytime, which can be lethal if the temperature at the surface of the sand is high.

Premature emergence of hatchlings from a nest can be caused by accidental or deliberate excavation of the nest by people. Predation of such premature hatchlings by birds is heavier than of those emerging normally.

Sun-umbrellas, sea-paddles, and various sun-bathing paraphernalia that are commonly set on beaches, actually minimize the area available for nesting, disturb the incubation by shading the nests and thus altering the temperature in the egg-chamber, while physically destroying some nests and obstructing female turtles and hatchlings. And as if all this and the above were not enough, night-time disturbances may be caused by people who come to the beach in groups to watch the nesting animals.

### 3. Traffic of Vehicles on Beaches

Vehicular traffic is concentrated mostly at the water's edge and mainly on East Laganas beach. It is known that Sea-turtles which have been disturbed in the early stages of their nesting procedure may return to the sea immediately. Besides that, there is another effect on the nests themselves, the severity of which is dependent on the weight of the vehicle and the phase of the incubation during which this disturbance occurs. A nest becomes more vulnerable to pressure as the hatching period approaches, owing to the formation normally of an air-space between the eggs and

the ceiling of the egg-chamber. This air-space begins to develop about 21 days prior to the emergence of hatchlings (Kraemer & Richardson, 1974), and in this period the nest's ceiling can easily collapse.

Vehicular tracks on the beach also affect the hatchlings on their way to the sea. It has been observed (D. Margaritoulis, pers. comm.) that hatchlings, on entering ruts, will commonly move for relatively long distances in the direction of the rut which normally runs parallel to the shoreline. Although in the end the majority of these 'trapped' hatchlings find their way to the sea, it is apparent that they have lost a lot of energy and are then more susceptible to predation. Hosier *et al.* (1981) showed that vehicular tracks on a nesting beach increase by 35% the time taken by hatchlings to reach the sea.

### 4. Noise

The most persistent noise on any nesting beach is that of the 'discos' in the Laganas settlement. The ear of the Sea-turtle is a low-frequency receptor with a useful span of perception of perhaps 60–100 Hz (Ridgway *et al.*, 1969). Low-frequency noises from sources in Laganas Bay are transmitted over wider distances than are high frequencies, and are therefore received by Sea-turtles over a wider area. Although the effect of noise on Sea-turtles is not known, the anthropogenic sounds which are received by them may interact with natural ones, for example from the sea, that are used by them as behavioural signals—with unknown effects which could, however, be serious.

### 5. Planting of Trees on the Nesting Beaches

Although plants cannot be considered directly as an anthropogenic factor, those that do not occur naturally on the beaches but have been planted there by people to offer shade to beach users and exploiters, can indeed be so considered.

As already indicated, Tamarisk trees have been planted on the beaches of East Laganas and Kalamaki to provide shade. As the trees grow, their roots will cause a problem both to the sea-turtles which will try to dig their egg-chamber and to the hatchlings which will hatch from the eggs and try to find their way to the open sea. Furthermore, the roots of the trees will absorb water and nutrients from the sand, and this in consequence will alter the microenvironment of the substrate in and around the rhizosphere. The roots will also consume oxygen for their respiration, while their fast summer growth may directly destroy incubating eggs by mechanical pressure (Caldwell, 1959; Lazell & Auger, 1981). Finally, the shade of the trees will affect the incubation of the eggs and the sex-ratio of hatchlings (Yntema & Mrosovsky, 1979).

### 6. Motorboats at Sea

The immediate effects of motorboats on turtles has not been investigated, but a small number of Loggerheads (2–3 per season) have been found either dead or wounded, with injuries which could be attributed to collisions with fast-moving craft (pers. observ.; D. Margaritoulis, pers. comm.).

### 7. Fishing Activities

There are many fishing activities in and plying out of Laganas Bay during the nesting season. Both amateur and

professional fishermen use gillnets, and the professionals also employ long lines. Fishing nets and lines cause trouble to adult Sea-turtles in the sea, as they may become entangled and drown. Although only 3 dead turtles were found to have been washed up on Zákynthos beaches during 1985, the mortality caused by this factor is probably higher than this figure suggests, because the prevailing winds during the nesting season may push the carcasses offshore (Margaritoulis, 1987).

Illegal use of underwater explosives for 'fishing', frequently observed close to Zákynthos beaches, has a catastrophic effect on the benthic communities of the Bay and can also directly and indirectly affect Sea-turtles and hatchlings.

#### MANAGEMENT PROPOSALS

Any management plan of the Zákynthos Sea-turtles must be based on two facts. *First*, economic development is bound to continue in any case on that island. *Second*, the Sea-turtles must be protected, and species protection in this case means first of all due conservation of its nesting biotope. Naturally, the kind of economic development to be encouraged by society is an open question, as some development activities are clearly in conflict with fundamental conservation principles and measures whereas others are not.

The proposals discussed herewith have been formulated with difficulty, because one has so to minimize the conflict between development and conservation as to make all these proposals both realistic and feasible. Several factors have been taken into consideration: the trends of development, the vulnerability of the nesting biotopes, and the ways in which they can be threatened by people as described above.

The data on the biological parameters of the Loggerhead Sea-turtles' nesting behaviour (Margaritoulis, 1982, 1987), as well as the human influence on the nesting beaches and the trends in development, indicate that the nesting sites can be separated into two groups. The first group consists of East Laganas and Kalamaki beaches, and the second group of Sekania, Daphni, and Gerakas, beaches, and Marathonissi and Pelouzo islets (cf. Fig. 3).

As was indicated before, the reproductive activity of *Caretta caretta* is inversely related to the touristic development of the nesting sites. Laganas and Kalamaki villages are located in the western part of Laganas Bay, only 5 km away from the town of Zákynthos, in a flat region that is easily accessible (Fig. 3). Kalamaki is less developed than Laganas, but Laganas has deteriorated strongly because of its uncontrolled and unplanned manner of development.

There was a Presidential Decree, issued in 1984, which imposed building and land-use restrictions, but which was met with strong opposition by the landowners and the local communities. However, this Decree did not include any explicit measure for the protection of the nesting beaches themselves.

We think that some direct measures must be taken and applied to the nesting beaches of East Laganas and Kalamaki (first group), and suggest the following:

- a) Beach-cleaning before the beginning of the season, especially if it is to be done by grading machines.
- b) Overnight and day patrolling of the beaches.

- c) No motorized traffic of any kind should be allowed on the beaches.
- d) Planting of trees should be forbidden within a 50-m zone above the summer sea-waves' upper limit. Planting of low and dense vegetation, acting as a light-screen, should be encouraged above 50 m from the summer sea-waves' limit.
- e) Walking freely on the dunes of East Laganas and the higher levels of the nesting beaches should be avoided; wooden pathways for this purpose could be constructed where it is necessary to cross the dunes.
- f) No sun-umbrellas, deck-chairs, sea-paddles, boats, etc., should be allowed on the nesting beaches, except on specific sites on East Laganas and Kalamaki where there is a strong demand—and there only in designated areas.
- g) All lights of the hotels and other buildings, as well as public lighting, should be so screened as not to be visible from the nesting beaches and from the sea. Planting of dense vegetation at the back of the beaches could further eliminate lighting.
- h) All noise should be kept as low as possible.
- i) No speedboats should be allowed in the whole Laganas Bay area. The marine area defined by Kalamaki, Pelouzo, and Gerakas (Fig. 3), should be closed to all vessels and all fishing activities.

The second group of nesting beaches—consisting, as already indicated, of Sekania, Daphni, Gerakas, and the islets of the Bay, namely Marathonissi and Pelouzo—can be considered under a long-term management plan which is analysed below.

It is known that the Greek economy, in order to succeed and balance, must be based substantially upon tourist income. It is also evident, from the studies described above, that the major threat to the nesting biotopes of *Caretta caretta* is tourist development and the activities which this development implies.

A good example of tourist development in the way it is currently considered is presented by Laganas settlement and its massive tourism. In opposition to that model, we propose the small-scale development of 'ecotourism' as an alternative (Margaris *et al.*, 1982). Ecotourism can be considered as a means of 'ecodevelopment' of the Loggerheads' nesting biotopes.

Under the frame of ecodevelopment through ecotourism, the proposal is formulated as follows: Sekania, Daphni, and Gerakas, nesting beaches could form the broader area of a *Marine Park*, whose 'nucleus' must be Sekania beach. The acquisition of this beach up to a distance of 500–600 m from the sea would be necessary, so that the Sea-turtles would continue their reproductive activity relatively undisturbed. The landowners who would not be indemnified, because their lands located at Sekania, Daphni, and Gerakas, are practically outside the immediate nesting area, should form a Community Company. This Company would undertake the exploitation of an *Interpretation Center*, with various activities aimed at raising the environmental awareness of both the local population and all visitors.

The physiography of Gerakas Beach, on the other hand, supports the idea of daytime guided tours along the top of the cliff which separates the beach from the interior. Tou-

rists, after visiting the *Interpretation Centre*, would be guided to Gerakas early in the morning—to look from above at this marvellous beach and observe the Sea-turtles' tracks imprinted in the sand. This, of course, implies that during the day the beach, or at least part of it, would be closed to the public.

The islets of Marathonissi and Pelouzo must be expropriated and declared as sites of Special Natural Beauty or Wildlife Reserves.

### CONCLUSIONS

The evaluation of the consequences of local anthropogenic activities revealed that the *Caretta caretta* breeding habitats on Zákynthos are running out of time. It is recognized that the above-mentioned suggestions are simple conservation measures but that they are nevertheless vital for the sea turtles. The philosophy of the management proposal for the 'nucleus' of the nesting biotopes (Sekania) and its satellite nesting beaches (Daphni, Gerakas, and Marathonissi) is imposed by the urge to have environmental conservation and economic development combined in an equitable scheme.

Greece is a small country and it does not have the privilege of being able to create numerous National Parks in which no human activity is permitted. Therefore its development must be carefully planned, and on a small scale. Sea-turtles' nesting biotopes must be protected because they are unique, and can be protected through ecologically sound tourist development. It is essential for Greece to keep its human population active and productive, if not actually wealthy, but it is also essential that the Greek environment will not become just a 'product for sale' to the summer-time influx of tourists.

### ACKNOWLEDGEMENTS

I am gratefully indebted to all students who helped to carry out the monotonous beach surveys. Editorial assistance was generously provided by Professor P.A. Gerakis, and I am thankful also to Mr D. Margaritoulis for his valuable comments and discussions; the work would not have been possible without the encouragement and patience of my companion.

This study was financed by the Greek Ministry of the Environment, Physical Planning, and Public Works, in the context of a contract between the Ministry and the Commission of the European Economic Community.

### SUMMARY

The island of Zákynthos, in western Greece, supports the most important nesting biotope of the endangered Loggerhead Sea-turtle (*Caretta caretta*) within Europe. The evaluation of the impacts of human activities, such as beach-use by people, lights, noise, and traffic, on its nesting habitats revealed that they are running out of time under the pressure of rapid and massive tourist development. It is therefore essential for the protection of this unique species to conserve its nesting biotope. This implies adequate, ecologically sound management, which might well be ensured through the establishment of a Marine Park.

### REFERENCES

- BUSTARD, R. (1972). *Sea turtles, Natural History and Conservation*. Collins, London, England, UK: 220 pp., illustr.
- CALDWELL, D.K. (1959). The Loggerhead turtles of Cape Romain, South Carolina. Pp. 319-48 in 'The Atlantic Loggerhead Sea Turtle *Caretta caretta* (L.) in America' (Eds D.K. CALDWELL & A. CARR). Bulletin of Florida State Museum, Biological Science 4, illustr. [not available for checking].
- DEAN, J.M. & TALBERT, O.R. (1975). *The Loggerhead Turtles of Kiawah Island*. Environmental Research Center, Inc., Columbia, South Carolina, USA: T-1-T-19 pp.
- EHRENFELD, D.W. (1968). The role of vision in the sea finding orientation of the green turtle, 2: Orientation mechanism and range of spectral sensitivity. *Animal Behaviour*, 16, pp. 281-7.
- GROOMBRIDGE, B. (1982). *Conservation of Species of Wild Flora and Vertebrate Fauna Threatened in the Community, Part IV: Reptiles and Amphibians*. IUCN Species Conservation Monitoring Unit, Cambridge, England, UK: pp. 295-385 [not available for checking].
- HOSIER, P.E., KOCHHAR, M. & THAYER, V. (1981). Off-road vehicle and pedestrian track effects on the sea-approach of hatching Loggerhead Turtles. *Environmental Conservation*, 8, pp. 158-61, 3 figs.
- KRAEMER, J.E. & RICHARDSON, J.I. (1979). Volumetric reduction in nest contents of Loggerhead Sea Turtles *Caretta caretta* on the Georgia coast. *Journal of Herpetology*, 13, pp. 255-60.
- LASKARATOS, A. (1987). Physical oceanography of Laganas Bay in Zákynthos. Pp. 7-38 in *Nesting Activity and Factors Affecting Breeding of the Loggerhead Sea Turtle *Caretta caretta* (L.) in Greece*. Final Report on Contract No ENV-790-GR to EEC, Ministry of the Environment, Physical Planning and Public Works, Athens, Greece: [not available for checking].
- LAZELL, J.D. & AUGER, P.J. (1981). Predation on diamondback terrapin (*Malaclemys terrapin*) eggs by dunegrass (*Ammophila breviligulata*). *Copeia*, pp. 723-24.
- LIVADITIS, G. & ALEXOULI-LIVADITI, A. (1987). Geomorphology of the coasts of Zákynthos and sedimentology of the nesting beaches. Pp. 39-65 following LASKARATOS, q.v.
- MARGARIS, N.S., ARIANOUTSOU, M. & ZAFIROPOULOU, S. (1982). [Possibilities of Ecotouristic Development in Greece—in Greek.] Report to Ministry of National Economy for the Five-year (1983-1987) Program of Economic and Social Development, Athens, Greece: 171 pp., illustr.
- MARGARITOULIS, D. (1982). Observations on Loggerhead Sea-turtle *Caretta caretta* activity during three nesting seasons (1977-1979) in Zákynthos, Greece. *Biological Conservation*, 24(3), pp. 193-204, 3 figs.
- MARGARITOULIS, D. (1986). Captures and strandings of the Leatherback Sea Turtle, *Dermochelys coriacea*, in Greece (1982-1984). *Journal of Herpetologia*, 20(3), pp. 471-4.
- MARGARITOULIS, D. (1987) Nesting activity of the Loggerhead Sea Turtle. Pp. 56-85 following LASKARATOS, q.v.
- MROSOVSKY, N. (1978). Effects of flashing lights on sea finding behaviour of green turtles. *Behavioural Biology*, 22(1), pp. 85-91.
- POLUNIN, O. (1980). *Flowers of Greece and the Balkans: A Field Guide*. Oxford University Press, Oxford-New York-Toronto-Melbourne: xv + 592 pp., + numerous coloured photos.
- POLUNIN, O. & WALTERS, M. (1985). *A Guide to the Vegetation of Britain and Europe*. Oxford University Press, Oxford-New York-Toronto: ix + 238 pp., numerous coloured photographs.
- RIDGWAY, S.H., WEVER, E.G., MCCORMICK, J.G., PALIN, J. & ANDERSON, J.H. (1969). Hearing in the giant sea turtle, *Chelonia mydas*. *Proceedings of the National Academy of Sciences (US)*, 64, pp. 884-90.
- WORTH, D.F. & SMITH, J.B. (1976). Marine turtles nesting on Hutchinson Island, Florida, in 1973. (Department of Natural Resources.) *Florida Marine Research Publication*, 18, 17 pp.
- YNTEMA, C.L. & MROSOVSKY, N. (1979). Incubation temperature and sex ratio in hatching loggerhead turtles: a preliminary report. *Marine Turtle Newsletter*, 11, pp. 9-10.