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Vegetation and sand characteristics influencing nesting activity of *Caretta caretta* on Sekania beach

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Abstract

Despite its relatively small length (650 m), Sekania beach on Zakynthos island (Ionian sea) is the single most important *Caretta caretta* L. nesting beach in the Mediterranean Sea. The aim of this work was to tackle the possible relationships of sand and vegetation characteristics with the nesting activity of sea turtle *C. caretta*. The vegetation structure and distribution along the sandy beach was studied with the use of line transect method. Grouping of plant species was revealed through an ordination method. Plant groups were distinguished and mapped. Sand texture, pH, and organic matter were measured on the transects. Nesting activity was also mapped on the beach and hatching success was recorded. It was concluded that where sand salinity is high enough to prevent vegetation development, wet sand is located at a threshold depth for excavating an egg chamber. It seems that well-sorted sand grains favor nesting activity on the beach. The increase of fine sand – from east to west – is proportional with the reduction of nesting density. The data collected for this study are organized in a GIS database, which could be the basis for the establishment of an integrated monitoring system for Sekania beach.

Keywords: Sea turtle; Zakynthos; Nesting activity; Sandy beach; Coastal vegetation

1. Introduction

Coastal sandy ecosystems are littoral terrestrial habitats, which have strong and direct exchange with the sea. They are related to the marine environment through biotic and abiotic processes. The exchange of energy and material between sea and land not only defines the substrate but also the life on it (Packham and Willis, 1997). This fact lends a dynamic character to the ecosystem.

The Loggerhead Turtle, *Caretta caretta* L., has a wide distribution in warm, temperate and subtropical seas. It has established local populations in the Mediterranean Sea (Bowen et al., 1993; Laurent et al., 1998) where it is the only marine turtle species to nest in Greece (Margaritoulis, 1988). The Mediterranean loggerhead population seems to be enriched with a limited input from the Atlantic Ocean population (Groombridge, 1990). The nesting beaches of the species are distributed in the East Mediterranean basin, mainly in Greece and Turkey but also in Cyprus, Libya, Tunisia, (Groombridge, 1990) and in North Sinai (Clarke et al., 2000; Campbell et al., 2001).

The sandy beach of Sekania is located at the eastern part of Laganas Bay on the island of Zakynthos, in the Ionian Sea (Fig. 4). Laganas Bay hosts an extremely important nesting aggregation of the loggerhead turtle *Caretta caretta* in the Mediterranean (Margaritoulis, 2000; Margaritoulis and Rees, 2001). Despite recent discoveries for additional nesting areas (Baran and Kasparek, 1989; Broderick and Godley, 1996; Laurent

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et al., 1998; Clarke et al., 2000) Laganas Bay continues to host by far the largest single nesting colony known in the Mediterranean (Groombridge, 1990). In 2000 nesting season, 53.3% (726 nests) of all nests in Laganas Bay were made at Sekania beach (Margaritoulis et al., 2001). The average number of clutches deposited on Zakynthos over 16 years (1984–1999) is 1301 nests, which accounts for 25.9% of all loggerhead nests recorded in the Mediterranean (not including Libya) (Margaritoulis et al., in press).

Several factors influence nesting site selection by sea turtles. Among others sand texture has been reported (Mortimer, 1982, 1990) as important for the selection of the beach by sea turtles. Mortimer (1982) claims that "the substrate must facilitate gas diffusion, and the substrate must be moist and fine enough to prevent collapse of the egg chamber during construction". Mortimer's (1990) study on Ascension Island (South Atlantic Ocean) found lower hatching success to be associated with coarser grained nest sites. Mrosovsky (1983) and Eckert (1987) concluded that, in the case of Leatherback Turtles (*Dermochelys coriacea*) there was no pattern to nest placement on nesting beaches (Guianas and Virgin Islands) because the unpredictable environment prevented selection of sites for optimal hatching success. In contrast another study (Horrocks and Scott, 1991) found Hawksbills Turtles (*Eretmochelys imbricata*), nesting in Barbados to be clustered where hatching success was highest. Hays and Speakman (1993) concluded that nesting may be clumped in an area where hatching success was optimal if predictable environmental cues meant this was possible.

The vegetation of sandy beach habitats presents certain patterns according to its gradual stabilization from the sea to the mainland (Packham and Willis, 1997). High salinity, high pH values, low nutrient content and the porous, unstable substrate characterize the environment of coastal sandy habitats (Chapman, 1964; Evans and Hardy, 1970; Maun, 1994). It is a hostile environment for most of the plant species. Those plants capable of growing on these sites are adapted to the extreme environmental conditions and, in many cases, take advantage of these.

The role of vegetation in nesting site selection from the sea turtles has not been studied extensively. The Hawksbill Turtle, *E. imbricata*, preferred to nest amongst vegetation (Horrocks and Scott, 1991). Schofield (1996) has studied the nesting activity in a three 20 m sectors, two on east and one on west Sekania beach. She concluded that nesting peaked directly above the storm line and just below the vegetation line.

The aim of this research work is to describe Sekania beach, as an integrated ecosystem in order to reveal the possible influence that sand characteristics and vegetation structure might have on the successful nesting activity.

2. Methods

In order to evaluate the properties of this particular sandy ecosystem as a sea turtle nesting beach, the (a) sand characteristics, (b) vegetation structure and composition and (c) sea turtle nesting activity were all investigated in relation to each other. These investigations were carried out in the east sector of Sekania beach, which hosts the highest nesting concentrations.

2.1. Site description

Sekania beach is backed by hills covered with maquis vegetation (evergreen sclerophyllous tall shrubs). The shore east and west of the beach is rocky with steep non-vegetated slopes. Two streams, the Potamaki and the Kolokotsas, discharge into the sea and the beach is reached via an old water eroded, dirt road (Fig. 3).

The site is part of the National Marine Park of Laganas Bay designated in 1999 (Dimopoulos, 2001). So the nesting beaches are protected and human activities behind them are regulated. The area is proposed to be included in the panEuropaean Ecological Network NATURA 2000 (Directive 92/43/EEC). The area backing the beach (320 ha) has been acquired by WWF-Greece in 1994 with the support of the European Commission, the Ministry of Environment and the Sea Turtle Protection Society of Greece for conservation purposes.

2.2. Vegetation analysis

A transect-based method was selected as the most suitable for describing vegetation on the beach. This is an efficient way of sampling sparse vegetation along clear environmental gradients (Sutherland, 1996).

Seven couples of permanent markers were placed, by WWF scientific team, in the upper part of the beach. These were cement cylinders buried in the ground with an iron projection above the surface. The transect that connects the markers of each couple (Fig. 3), extended up to the sea line, was used for vegetation records. The transects were set along the environmental gradient which, in this case, was the distance from the sea. That means they were perpendicular to the coastline. Their length varies from 32 to 48 m. Along every transect, and every one meter, the intercept cover of each plant species presence was recorded. The distance from the sea and the slope of every transect unit were also recorded.

The plant species not possible to identified on the field, were brought to the laboratory where they were identified by using keys, the description of Flora Europaea and plant specimens from the Herbarium of University of Athens.

Gradient analysis and orientation techniques constitute a group of methods for data reduction and examination, which leads in hypothesis generation (Jongman et al., 1995). A method of direct gradient analysis was applied in this study. Canonical correspondence analysis (CCA) selects the linear combination of environmental variables that explains most of the variation in the species scores of each axis (Kent and Coker, 1992). Using the CANOCO program, CCA method was applied on transects data. Each meter of each transect was treated as a separate unit, where the cover value of each plant species served as variable. The plant species were placed in a scatter diagram and groups were defined. To avoid distortions, plants present only once and with less than 10 cm cover were omitted.

Plant allocation in each group was used for separating respective zones on the transects. Importance value was calculated for every plant species of each zone.

Brower et al. (1990) calculated importance value (IV_i) of a plant species by adding the relative cover index (RC_i), the relative frequency index (RF_i) and the relative density index (RD_i). For plant communities where individuals are hard to identify, as coastal sandy plant communities are, importance value does not employ density as a measure of abundance.

Instead importance value is calculated as:

$$\mathrm{IV}_i = \mathrm{RC}_i + \mathrm{RF}_i,$$

where relative coverage $\mathrm{RC}_i = l_i/\sum l$ (l_i is the sum of the intercept lengths for species i, $\sum l$ is the sum of the intercept lengths of all species). Relative frequency $\mathrm{RF}_i = f_i/\sum f$, ($\sum f$ is the sum of the frequencies of all species). Frequency $f_i = j_i/k$ (j_i is the number of the line-intercept intervals containing the species i, and k: total number of intervals on the transects).

To estimate species richness the Shannon diversity index was applied

$$\text{Diversity } H' = -\sum p_i \ln p_i p_i,$$

where p_i is the abundance of the species i expressed as a proportion of total cover $p_i = n_i/N$.

2.3. Sand characteristics

Along the transects and in every different zone, sand samples were collected from the surface down to a depth of 10 cm, using an extemporary soil tube. Before sampling the humus layer was removed since its placement on the unstable substrate depends on temporal wind conditions.

The samples brought to the laboratory, air dried at 72 °C for 72 h and then subjected to the following analyses:

Conductivity. Measured with portable conductivity meter (Consort K912).

Sand texture. Measured by sieving the sand through 1 mm, 500 μm, 250 μm, 100 μm and 50 μm diameter TAMISOR sieves (Van Reeuwijk, 1986). Sand grain size analysis was depicted transforming size classes in logarithmic scale (Phi (ϕ)). Using these diagrams, the following indices were computed (Bird, 1984):

Mean $M\o = \phi16 + \phi84/2$,
Sorting $\sigma\phi = \phi84 - \phi16/2$,
Skewness $\alpha\phi = M\phi - M\,\mathrm{d}\phi/\sigma\phi$,
where $M\,\mathrm{d}\phi = \phi50$.

Organic matter. Sand fraction of more than 1 mm diameter was removed so that the organic matter not directly available for the plants (stipels or sea wracks easily moved by the wind) was not included. Organic matter of the remaining fraction, was then measured (sand was put in a muffle furnace), with the loss ignition technique, at 500 °C for 5 h and the organic matter was burned.

2.4. Vegetation mapping

Plant groups were organized after processing the data from the transects as described and analyzed above. During this stage the spatial distribution of these groups in zones was mapped.

Each permanent couple of markers used for each transect was mapped and topographical coordinates were recorded. The contact points between plant groups were identified and mapped using triangulation of their distance from the permanent markers. The GIS program Arc-View and its extension Image Analysis were used to digitize this information. Polygons were digitized for each plant group area based on information collected in the field and a vegetation map was produced.

A colored digital aerial photo of the area (summer 2000) was aligned to the already digitized vegetation map using visible stable points. The map was properly corrected.

2.5. Nesting activity

One of the main goals of this work was to record spatially and with sufficient accuracy a representative number of nesting points. This step was necessary in order to correlate the spatial distribution of the nests with biotic or abiotic variables.

Location and excavation of hatched nests take place at the end of every nesting period (mid July to mid September). Trained for this purpose, researchers of the Sea Turtle Protection Society (STPS) were assigned with this task. When it is certain that hatching has been completed STPS follows the following protocol: (a) the nest is excavated and empty egg shells, unfertilized eggs, dead embryos, live embryos, dead hatchlings and live hatchlings are recorded. (b) Other comments, as the presence of roots or stones in the egg chamber, are also recorded. (c) STPS has placed 21 fixed stakes at the back of the beach in order to locate the nesting points through triangulation. Data collected from 180 nests, for the period from 25/7/2000 to 15/10/2000 were used.

The exact position of the 21 stakes of STPS was recorded through triangulation from the 7 permanent markers of the transects. As a result it was possible to depict them on a map with the coordinate system used for the transects and the vegetation cover. Using the distance between the nesting points from STPS stakes and the sea, these points were located on the map.

Overlaying the two maps, one is able to discover spatial relationships among vegetation, nesting activities and, since transects and sampling points are also mapped, sand characteristics (Fig. 3).

3. Results

3.1. Vegetation groups on the beach

CCA of the transects data results in a diagram (Fig. 1) where the plant species of Sekania beach are located in a two-axes space. Three groups of plants were distinguished:

The first group of plants can be distinguished at the right and central part of the diagram with *Elymus farctus*, and *Cakile maritima*, *Cyperus capitatus*, *Hedypnois cretica*, A subgroup can be distinguished here with *Pancratium maritimum*, *Silene colorata*, *Linum strictum.*

The second group is distinguished down left of the diagram with *Coridothymus capitatus*, and *Lagurus ov-*

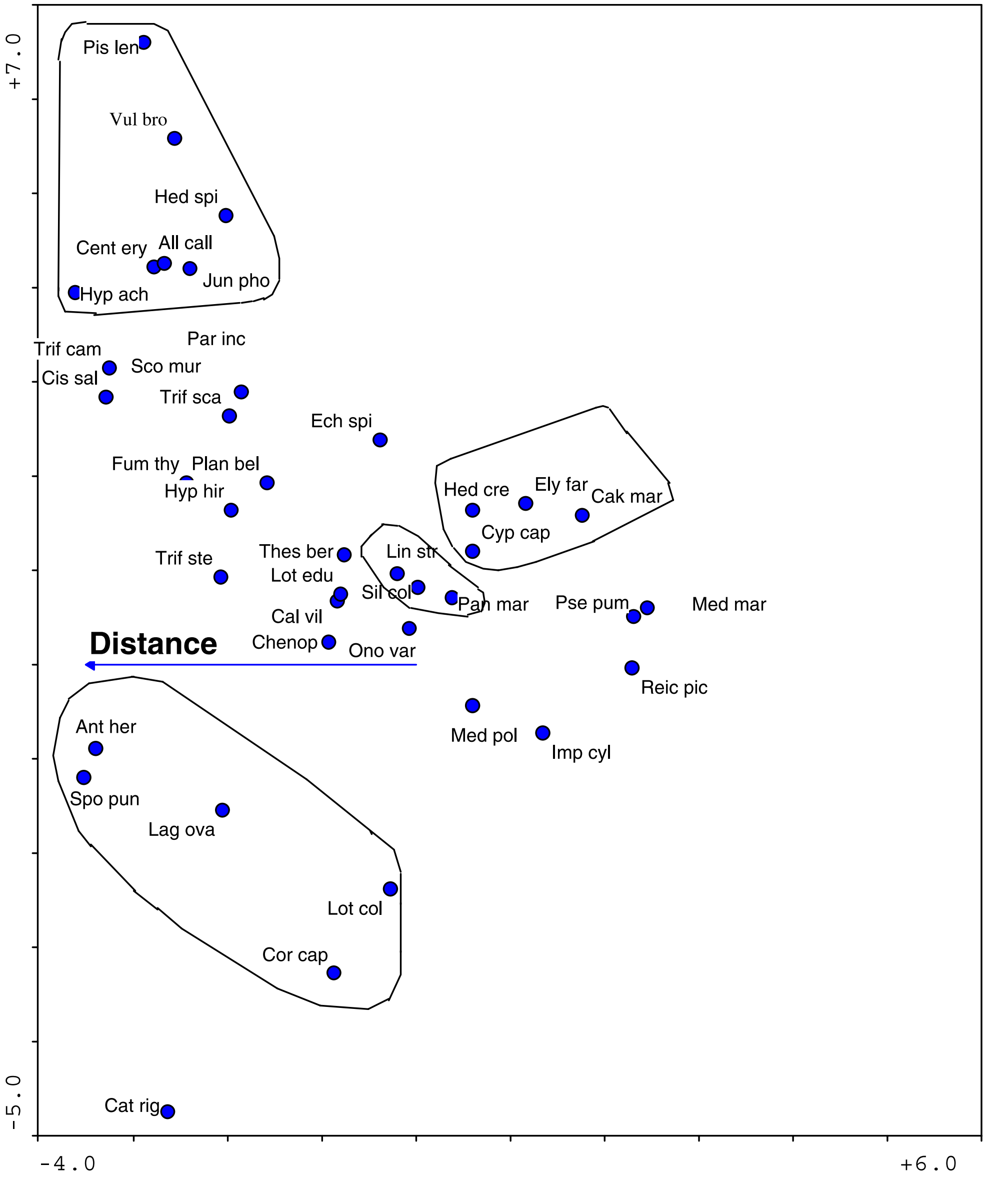

Fig. 1. CCA of the plant species recorded at Sekania beach.

Table 1
Importance value (index IV_i) of the plants in the three vegetation zones distinguished at Sekania beach (only values higher than 0,01 are recorded)

Group I		Group II		Group III	
Plant species	IV_i	Plant species	IV_i	Plant species	IV_i
Elymus farctus (Viv.) Runemark ex Melderis	0.592	*Coridothymus capitatus* (L.) Reichenb. fil.	0.745	*Pistacia lentiscus* L.	0.24
Medicago marina L.	0.253	*Hyparhenia hitra* (L.) Stapf	0.126	*Cistus salvifolius* L.	0.138
Pancratium maritimum L.	0.184	*Lotus collinus* (Boiss.) Heldr.	0.123	*Coridothymus capitatus* (L.) Reichenb. fil.	0.113
Cyperus capitatus Vandelli	0.144	*Pancratium maritimum* L.	0.108	*Hyparhenia hitra* (L.) Stapf	0.109
Hedypnois cretica (L.) Dum.-Courset	0.125	*Calicotome villosa* (Poiret) Link	0.093	*Juniperus phoenicea* L.	0.09
Pseudorlaya pumila (L.) Grande	0.112	*Trifolium scabrum* L.	0.085	*Sporobolus pungens* (Schreber) Kunth	0.072
Ononis variegata L.	0.089	*Silene colorata* Poiret	0.059	*Trifolium scabrum* L.	0.062
Imperata cylindrica (L.) Raeuschl	0.07	*Ononis variegata* L.	0.058	*Hypochoeris achyrophorus* L.	0.058
Echinophora spinosa L.	0.069	*Plantago bellardii* All.	0.051	*Plantago bellardii* All.	0.057
Cakile maritima Scop.	0.062	*Elymus farctus* (Viv.) Runemark ex Melderis	0.049	*Centaurium erythraea* Rafn	0.057
Reichardia picroides (L.) Roth	0.049	*Reichardia picroides* (L.) Roth	0.046	*Anthyllis hermanniae* L.	0.041
Silene colorata Poiret	0.046	*Hedypnois cretica* (L.) Dum.-Courset	0.041	*Fumana thymifolia* (L.) Spach ex Webb	0.035
Medicago polymorpha L.	0.041	*Medicago polymorpha* L.	0.041	*Scorpiurus muricatus* L.	0.03
Trifolium scabrum L.	0.04	*Trifolium stellatum* L.	0.034	*Hedypnois cretica* (L.) Dum.-Courset	0.03
Plantago bellardii All.	0.025	*Vulpia bromoides* (L.) S.F. Gray	0.033	*Medicago polymorpha* L.	0.029
Linum strictum L.	0.021	*Centaurium erythraea* Rafn	0.023	*Lagurus ovatus* L.	0.028
Lotus collinus (Boiss.) Heldr.	0.017	*Cyperus capitatus* Vandelli	0.020	*Ononis natrix* L.	0.028
Parapholis incurva (L.) C.E. Hubbard	0.01	*Juniperus phoenicea* L.	0.019	*Trifolium campestre* Schreber	0.028
		Thesium bergeri Zucc.	0.019		
		Lagurus ovatus L.	0.017		
		Catapodium rigidum (L.) C.E. Hubbard	0.016		
		Pseudorlaya pumila (L.) Grande	0.015		
		Linum strictum L.	0.015		
		Allium callimischon Link	0.015		
		Fumana thymifolia (L.) Spach ex Webb	0.013		
		Chenopodium sp.	0.012		

atus, *Anthyllis hermanniae*, *Sporobolus pungens*, and *Lotus collinus*.

Between the two groups *Medicago polymorpha*, *Imperata cylindrica* and *Reichardia picroides* are located.

The third group (up and left) includes *Pistacia lentiscus*, *Juniperus phoenicea*, *Centaurium erythraea*, *Hedysarum spinosissimus*, *Allium calimischon*, *Hypochoeris achyrophorus*, *Vulpia bromoides*.

The rest of the plant species are located somewhere between the three groups.

Within each group of plants, the dominant species was distinguished according to its Importance Value (Table 1).

The traits proposed by Garcia-Mora et al. (1999) for the classification of coastal fore dune plants in functional types, are recorded for the dominant (in each group) species on Table 2.

Shannon diversity indices (H') range between 2,123 for Group I to 1941 for Group II and 1073 for Group III. The zone covered by Group I plants has the highest diversity of all. This is expected since the plants forming this group are adapted to the coastal sandy environment, as it is indicated from the functional traits of its dominant plant (Table 2). Group II shows lowest diversity while Group III performs even lower.

Importance indices (IV_i), calculated on the transect data for the area of each group, indicate the importance of each plant in the group. The ‘‘important’’ plants of each group are clustered together also by CCA (Fig. 1). Nevertheless, some plants are presented as important in more than one group in Table 1 (*R. picroides*, *M. polymorpha*, *Hyparhenia hirta* and *P. maritimum*) while for others the importance value in a group does not strictly correspond to their orientation in Fig. 1 (in Table 1

Table 2
Fuctional types of plant species distinguished in the studied site. Dominant species of each type is shown

	Group I	Group II	Group III
Dominant species	*Elymus farctus*	*Coridothymus capitatus*	*Pistacia lentiscus*
Life span	Perennial	Perennial	Perennial
Vegetative growth on the beach	Up to 1 m	Up to 50 m	Up to 3 m
Underground structures	Spreading rhizome	Woody roots	Woody roots
Leaf adaptation to coastal environmental stress	Present	Present	Absent
Capability of withstanding deep sand burial	Present	Absent	Absent
Seawater dispersion capability	Present	Absent	Absent

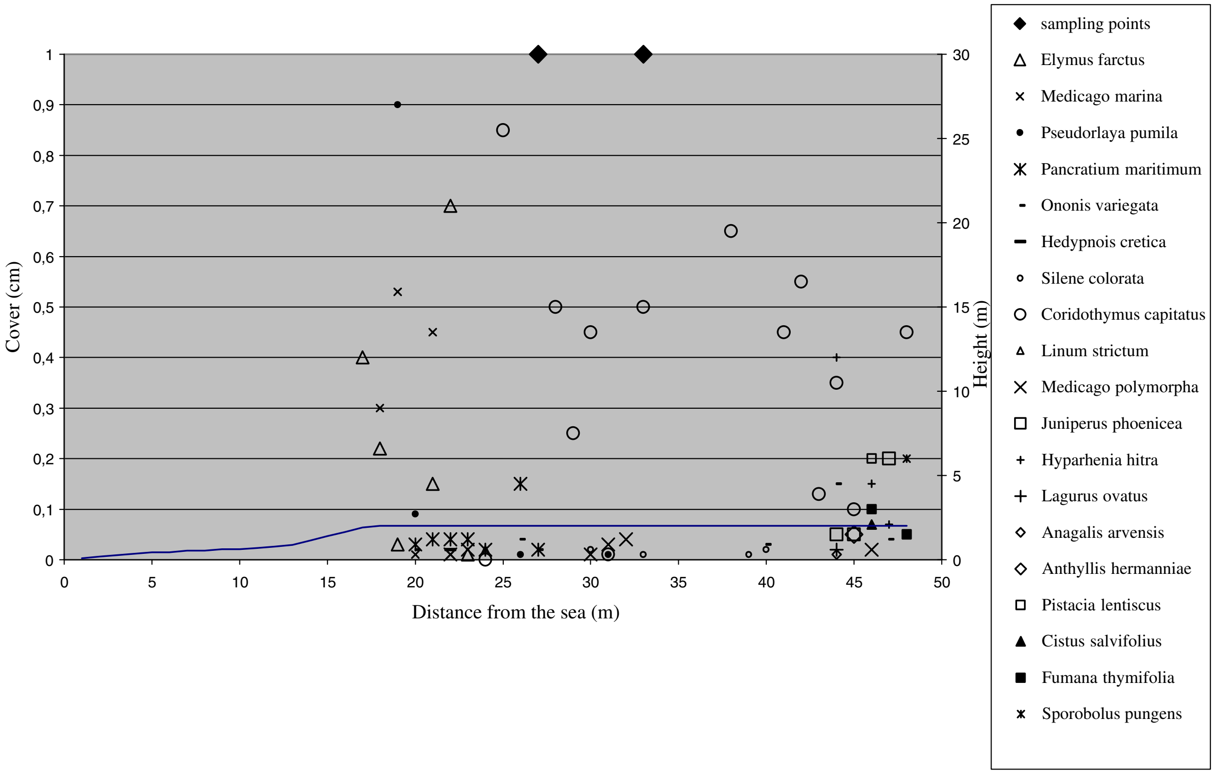

Fig. 2. Plant species distribution on transect 2.

Medicago marina and *Pseudorlaya pumila* are clearly allocated also in Group I). In these cases, one must have a look at the component indices of importance value or to refer to the transects diagrams (Fig. 2).

Pancratium maritimum is represented with a high importance value in Group I and Group II. The relative frequency index is higher for Group I. The transect diagrams (Fig. 2) show that this plant occupies an area extended from the upper zone of the first group up to the beginning of the second group. Sporadically it can be found elsewhere. Usually it appears in patches where it coexists with other sand plants (*Medicago marina*, *P. pumila*) but also with phryganic species (*S. colorata*, *L. strictum*, *Lotus edulis*, *Ononis variegata*).

3.2. Sand characteristics

Table 3 presents the data of the measurements on sand characteristics (conducted along transects), allocated in different vegetation zones (respective plant groups) as they have been separated previously according to CCA analysis.

Measurements points are stable, since they have been measured from the permanent markers.

Generally, there are not important differences between the values of sand characteristics variables in the different plant groups.

The sand of Sekania beach is medium to fine ($M\phi = 1.94$). In general it is medium to well sorted ($\sigma\phi = 0.41$–0.90). Consequently packing of sand grains is also medium. The value 0.65 indicates that the selective transport of sand grains from waves or the wind is medium. Positive skewness ($\alpha\phi$) (Table 3) indicates the addition of fine sand particles – from streams discharge – on the beach.

The relationship among wave energy, beach gradient and sediment size does exist (Pethick, 1984). In general, the smoother the slope of a beach is the finer the sand and the lower the wave energy are. The smooth slope of Sekania beach corresponds to its fine sand and medium wave energy recorded. The smoother slope (transects 5, 6, 7) and the finer sand (Table 3) of the western part indicate lower wave energy. Moving eastwards the slope gets steeper. On the central east side of the beach transects 2 and 4 present on their lower non-vegetated part (just before the vegetation line) the coarser sand and the best sorted one (the values $\sigma\phi = 0.41$ and $M\phi = 1.68$ are statistically significant different from the normal distributed values of sorting index and mean index, respectively, in Sekania beach). On the eastern side of the beach we recorded a steep change of the slope exactly on the vegetation line.

Well sorting (small $\sigma\phi$) that is found on this part of the beach shows the selective transport of sand grains. The two streams and the dirt road in the east part discharge fine sediment on the beach. The waves and the wind remove it from there. Water circulates within the bay in an anticlockwise direction (Laskaratos, 1987). So the sediment drifted from the east side of the beach is blocked by reefs (Fig. 3) and it is deposited on the west side. Fine material remains in the west side of the beach, transported from the sea or wind. As a result, the sediment of the west part is poorer sorted (higher $\sigma\phi$). Poorer sorted sediment are packed and compacted much better than well sorted ones (Pethick, 1984).

Table 3
Sekania beach sand characteristics

	Distance from the sea (m)	Salinity (μS/cm)	Organic matter (%)	$M\phi$	$\sum\phi$	$A\phi$	Plant groups
Tr 1	27	56.6	0.0579	1.71	0.48	0.2371	Group II
Tr 1	33	56.4	0.1117	1.65	0.75	0.0959	Group II
Tr 2	16	170.0	0.0634	1.68	0.41	0.2048	Beach
Tr 2	21	63.9	0.0395	1.87	0.58	0.2931	Group I
Tr 2	31	63.4	0.0923	2.05	0.75	0.2667	Group II
Tr 3	21	76.7	0.0529	1.91	0.61	0.2667	Group I
Tr 3	27	56.1	0.0917	1.80	0.55	0.3532	Group I
Tr 3	37	73.2	0.0859	2.16	0.84	0.2976	Group II
Tr 4	17	236.0	0.0770	1.68	0.41	0.2048	Beach
Tr 4	24	65.6	0.0404	1.95	0.65	0.3077	Group I
Tr 4	38	62.2	0.0695	1.95	0.65	0.2308	Group III
Tr 5	22	81.7	0.0410	1.78	0.50	0.3000	Group I
Tr 5	30	61.8	0.0947	1.91	0.61	0.2622	Group II
Tr 6	14	258.0	0.0867	2.00	0.70	0.2857	Beach
Tr 6	20	58.0	0.0501	2.10	0.70	0.2758	Group I
Tr 6	23	68.0	0.0482	2.10	0.70	0.0285	Group I
Tr 6	31	57.7	0.1111	2.17	0.75	−0.040	Group II
Tr 7	16	69.4	0.0457	2.05	0.71	0.0769	Group I
Tr 7	32	57.5	0.0994	2.28	0.90	0.0000	Group II
Mean		89.1	0.0715	1.94	0.65	0.2075	

Measurements have been taken along transects – from east (transect 1) to west (transect 7).

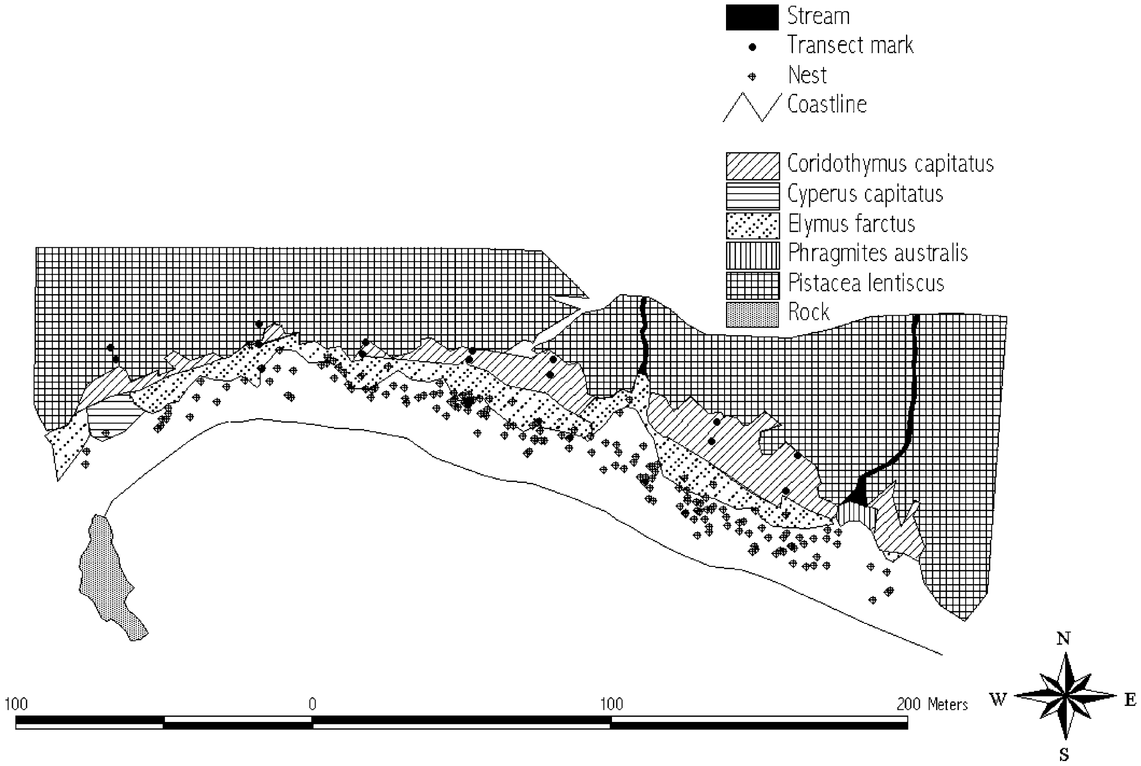

Fig. 3. Coastal vegetation and sea turtle nests on the beach of Sekania.

Organic matter is generally minimal, but this was expected for a sandy beach. However, a statistical significant increase is observed from Group I to Group II ($p < 0.05$, Marginal Homogeneity Test).

In a 2–3m zone just in front of the vegetation line, salinity is very high. At the vegetated area salinity fluctuates between 56 and 76 μS/cm, while at the zone in front of the vegetation line it is measured between 170 and 258 μS/cm. It seems that high salinity is the limiting factor for the expansion of vegetation towards the sea, at the zone between the storm line and the current vegetation line.

3.3. Nesting monitoring

Nests were separated in three categories (Table 4): (a) those located in front of the vegetation line (b) those located along the vegetation line and (c) those located evidently in the coastal vegetation zone (more than 1m inland from the vegetation line).

A fourth category was made for the nests where roots were found during excavation. These kind of nests are present in all three categories, but in a higher proportion in the two former. There are no significant differences, comparing the mean values of dead embryo or hatchlings of these categories, among the four categories.

3.4. Mapping

In the vegetation map of Sekania beach, (Fig. 3) five vegetation zones are presented. The three of them correspond to the three plant groups analyzed before (the dominant plant species of each group is referred in the legend). The subgroup of *P. maritimum* was not possible to be spatially distinguished on the map. Two more vegetation zones are presented. Both of them are

Table 4
Total number of nests and their hatching success in different zones on Sekania beach (for the year 2000)

	Nests No.	Mean depth (cm)	Empty shells	Unfertilized shells	Dead embryos	Live embryos	Dead hatchl.	Live hatchl.
Bare beach	164	53	87	19	7	0	4	1
Vegetated beach	18	51	79	22	5	0	5	1
Vegetation line	22	52	86	25	8	0	8	1
Roots	8	52	73	26	8	0	3	1

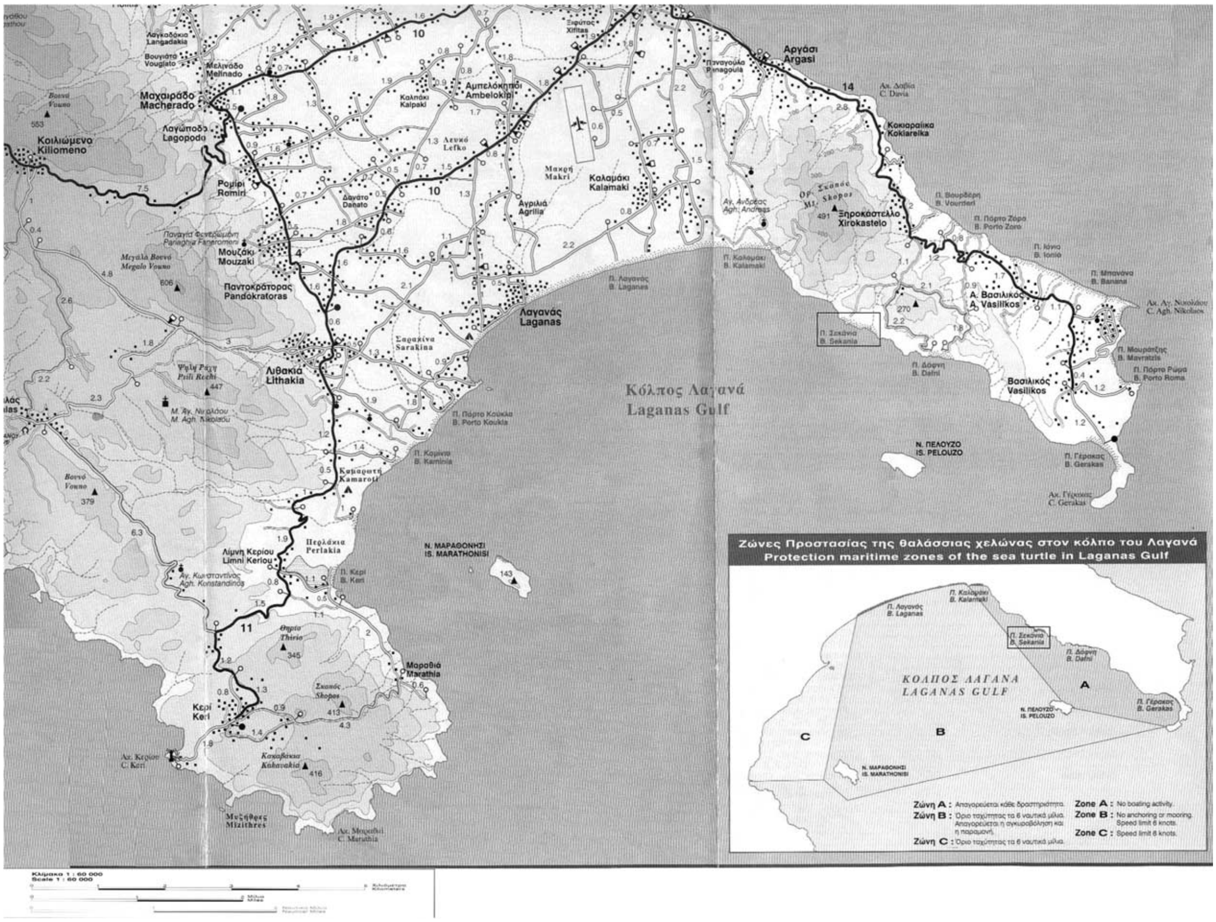

Fig. 4. Laganas Bay on the island of Zakynthos.

areas covered solely by one species. One polygon is covered by *C. capitatus* and the other one by *Phragmites australis.*

The first vegetation zone, after the bare beach, corresponds in plant Group I (*E. farctus*). It starts eastwards from the stream Potamaki mouth (covered by *P. australis*). The zone backslides along the mouth of the second stream (Kolokotsas). At the west edge of the beach that zone ends at local dominance of *C. capitatus.*

The following vegetation zone corresponds to plant Group II (*C. capitatus*). It succeeds the first zone along the beach except in some places, where Group III follows immediately after the Group I zone. At the east side of the beach, between the two streams the upper part of this zone is located on petrified dunes with few *C. capitatus* individuals on them.

The third zone (*P. lentiscus*) is covered with maquis vegetation. Maquis vegetation, covers the biggest part of the slopes around the beach. Although on the map this vegetation is presented as one entity for distinctness reasons, the part of maquis vegetation studied (plant Group III) was only the very narrow zone located on the sand. This narrow zone consists of some *P. lentiscus* and *J. phoenicea* shrubs, with limited understory, on sandy substrate.

On the same map the nesting points are depicted, on the basis of distances measured during STPS monitoring project in the summer of 2000.

In general the east part of the beach has fairly higher nesting density, than the west part.

It is obvious that the majority of nesting points is located on the bare beach, up to the point the vegetation cover starts. Considering the sparse character of sandy vegetation (especially that of the first group) the view of separation between nesting area and vegetated area on the beach is enforced. The upper nesting points are usually very close to the vegetation line. The higher nesting density is located in a 5m zone in front of the vegetation line. Where the vegetation line backslides the location is covered by nests but in the case of Kolokotsas stream this happens in a limited distance. Very few nests appear to be made in the inner part of Group I zone (less than 10 nests out of 180 that have been excavated). No nest was recorded in the zone of Group II, and of course, none within the zone of Group III, as well as in *P. australis* area.

4. Discussion

Vegetation, sand characteristics and nesting activity relationships are discussed in the light of general characteristics of the beach, concerning morphology and topography. These relations are examined in couples, but subsequently the complexity of relations is evaluated and important views and functions of the ecosystem are revealed.

4.1. Vegetation – sand characteristics

Plant groups distribution on the beach of Sekania cannot be justified either from the salinity levels or from the sand texture indices. Due to the small width of the beach differences between values are not obvious. The relatively low wave energy received from the beach smoothens any differences. Nevertheless, organic matter is correlated with vegetation distribution. Low values of Group I zone are followed by higher ones of the next, Group II, zone. In the case of Sekania beach, the source of organic matter is the interior terrestrial ecosystem and not the sea. The relatively low wave energy reaching the beach does not lead to deposits of enough litter on the beach (sea grass, sea organisms or terrestrial litter drifted by the sea). This is a possible reason for the absence of nitrophilous plants on strandline vegetation zone. The nesting activity contribution in organic content does not seem to be high (although sand samples were taken to 10 cm depth and nest chambers start at 30 cm, the sand is mixed from the continuous attempts for nesting, successful or not, and from excavations for monitoring).

Salinity does not seem to correlate with vegetation differentiation on the beach and the distribution of the plants. Nevertheless, it is the limiting factor for Group I plants expansion towards the sea.

4.2. Sand characteristics –nesting activity

Well-sorted sand grains favor nesting activity since sand is not coarse. *Caretta caretta* sea turtles prefer nesting in areas with uniform sand grain sorting (Livaditis and Alexouli-Livaditi, 1987). Almost the lowest Mϕ value (1.68 in logarithmic, Phi (ϕ), scale) and the lowest sorting value (0.41) on the beach are found exactly at sites where higher nesting density occurs (Fig. 3). These values denote that not a good packing of sand grains at these sites and a medium size sand something is missing in this sentence. This kind of sand allows the eggs to be aerated (gas exchange is facilitated), the water to be drained from the nests but also prevent egg chamber to collapse during construction.

The increase of fine sand on the beach from east to west is proportional with the reduction of nesting density. The deposition of fine grains at the west side of the beach leads in mixed sorting of sand grains and consequently in better packing. Good packing appears to deter nesting. Female turtles in Zakynthos have been observed testing the beach by thrusting their heads in the sand (Margaritoulis, 1985). This behavior is known as "sand smelling". The turtles may detect a difference in sand compaction. So this is a possible reason for the low nesting density on the west part.

The mouth of the Kolokotsas stream bed has high silt content (16.61% by Schofield, 1996). This results in a high mixed sorting that does not favor successful nesting. In areas with fine material, oxygen does not penetrate freely (Carthy, 1994) and water does not drain. This may explain why no nesting took place at this site.

4.3. Vegetation – nesting activity

Vegetation line on Sekania beach coincides more or less with the upper end of the nesting area.

Nevertheless, the data show no significant difference in hatching success for the few nests laid in the vegetation zone, the nests laid outside of it and the nests where roots were found. Therefore, the absence of nests in the vegetation zone cannot be correlated with the reduced hatching success observed at this site. Since nesting in the vegetation zone does not function as reproductive disadvantage, it is suggested that the development of an adaptive mechanism that rejects the vegetation zone for nesting is not justified, as far as the loggerhead is concerned.

The cause of the absence of nests in the vegetation zone of Group I is not the reduced reproductive success but the failure to nest there. "The majority of failed nesting attempts were initiated just before the vegetation line" (Schofield, 1996). The failure cannot be attributed to the rhizome of plants, since even the dominant and more robust plant there (*E. farctus*) has a soft rhizome, which can be broken easily by the strong back flippers of a sea turtle during egg-chamber digging (personal observations). Moreover it cannot be attributed to the volume of the plants since they are flexible and the vegetation is scarce. In general it cannot be attributed to the existence of vegetation itself. There must be an indirect relation between the vegetation development and failure of nesting.

STPS field researchers seem to agree that the factor restricts nesting activity, upwards, to a zone just before the vegetation line is the lack of enough wet sand at depth around 30 cm (this is the starting depth for digging the nest chamber) which prevents egg chamber support.

The measurements of sand characteristics on the beach of Sekania, point out that salinity is a limiting factor for the expansion of vegetation, downwards, on the zone between storm line and the present vegetation line.

Salinity and wet sand are strongly connected, since sand humidity - especially during summer – is the result of seawater that penetrates the sand horizontally or vertically through capillarity.

The fact is that where salinity is high enough to prevent sand vegetation development, wet sand is located at a threshold depth for excavating an egg chamber. Vegetation existence indicates the absence of wet sand in sufficient depth for nesting.

4.4. Future research

A monitoring program is no guarantee in itself of efficient and effective environmental management but – if set up properly – it will help to improve matters (Meulen et al., 1992). An aggregated monitoring system is essential for the conservation of high ecological importance and high vulnerability ecosystems as Sekania beach. The methodology followed for the purposes of this research provides common reference points for the spatial collaboration of different research fields and compatible monitoring, data storing and presentation procedures. The regular measurement of some of the variables presented, together with coastline morphological characteristics measurements (it has been conducted by WWF, on the transects used in this study for vegetation analysis), will provide an overall view of beach processes. All data can be recorded in a database connected with a G.I.S. program. In this way correlation of various sets of data is facilitated and management applications are possible. Moreover, there is always the ability to include vegetation and other thematic maps (topography, hydrology), of the hills around but also of seabed, so as to obtain an integrated supervision of the entire biotope.

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