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Vegetation Zonation Patterns on the Göksu Delta (Southern Turkey)

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Abstract: Vegetation zonation within temperate coastal ecosystems is commonly controlled by tidal regimes with the degree of emersion and immersion of tidal waters affecting the distribution of plant communities. However, vegetation zonation in Mediterranean coastal ecosystems experiencing microtidal regimes will not be controlled by the tide. The Göksu Delta is a wetland ecosystem located in southern Turkey in the Eastern Mediterranean. The Göksu region experiences extremely low tidal regimes. The vegetation zonation of the ecosystem is distributed in a patchy mosaic and is controlled by local factors including ground water levels, topography and the salinity of lentic water bodies. Aim of this paper to determine the vegetation patterns for the Göksu delta and to propose a zonation model for an ecosystem subjected to microtidal influences.

Key words: Göksu delta, vegetation zonation patterns, patchy mosaic zonation, Jaccard's coefficient of similarity

INTRODUCTION

The Göksu delta is one of the five Turkish wetlands under the protection of Ramsar convention. It has been noted in other studies that the saline marshes on deltas of the Mediterranean are amongst the most biologically diverse in Europe (Mitsch *et al*., 1994; Efe, 2004; Efe and Tagil, 2007) and support large numbers of migratory birds. They are not without problems however and the loss of Mediterranean wetlands is continuing, even those under RAMSAR protection (Hollis, 1993). The Göksu delta is no exception to degradation pressures and it is therefore essential that monitoring of ecological change be carried out. Vegetation zonation in coastal areas that experience microtidal regimes will not be controlled by emersion and immersion of coastal waters. The Mediterranean Sea experiences microtidal regimes, with spring tidal ranges of less than 2 m (Orme, 1990). Subsequently, the tidal regimes of the Göksu Delta are extremely low and vegetation zonation within the delta ecosystem is not controlled by the tide.

The Göksu delta of southern Turkey is located in the levantine basin of the eastern Mediterranean at the mouth of the River Göksu (Fig. 1). A regular supply of nutrient enriched sediment has been deposited on the delta, establishing one of the most biologically productive areas within the Mediterranean region. The delta is one of the largest intact wetland complexes in Europe and the Middle East with a range of habitats including dunes, salt marsh and lakes (Anonymous, 1995). Limited research has been undertaken on the vegetation of the delta by such bodies as the Authority for the Protection of Special Areas (APSA) and the society for the protection of nature (DHKD). This study continues this development by investigating the patterns of distribution of plant species and discusses associated environmental factors.

MATERIALS AND METHODS

Two belt transects approximately 100 m apart and measuring 720 m in length, were established perpendicular to the beach foreshore, until they reached the edge of Lake Akgöl (Fig. 1). Twenty four sites were studied along each transect, located at 30 m intervals. At each site a 25 m^2 quadrat was used to record (a) the number of plant species (b) the % cover of each species (c) the % cover of total vegetation (d) The dominant species and the number of individual plants of this species (e) conductivity of any surface water.

Table 2 and 3 were used to show the data and Jaccard's coefficient of similarity used to compare all sites along transect 1 with those of equal distance from the sea, along transect 2.

Jaccard's coefficient = C/A+B−C×100 (= % similarity between the two transect communities)

where:

A = No. of species from transect 1;
B = No. of species from transect 2;
C = No. of species common to both transects).

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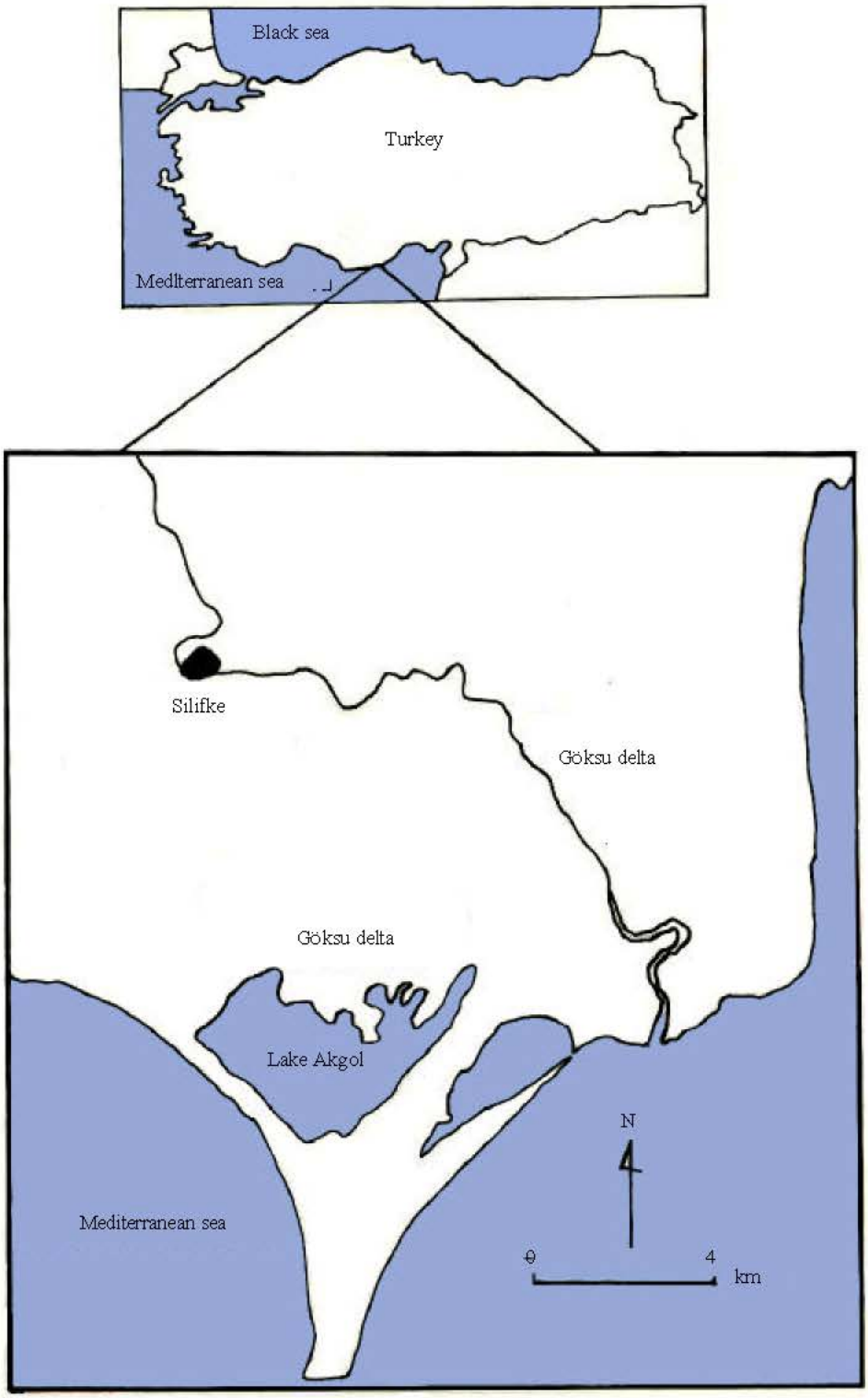

Fig. 1: Location map

RESULTS

A total of seventy one plant species were identified 38 from transect 1 and 33 from transect 2. The names of each plant species are shown in Table 1. The distribution of species along each transect is shown in Table 2 and 3, the number of species at each site along each transect, shown in Fig. 2. Sites of highest diversity are found at 690 m (transect 1) and at 660 m (transect 2).

A comparison of the percentage cover of vegetation at each site along the two transects is shown in Fig. 3. Marked differences exist, especially in the mid section of each transect, until, at >480 m, high values are found suggesting, along with an increase number of species (Fig. 2.), there is greater ecological stability. This may represent a broad ecotone between a sand dune and more marshland ecosystem.

The pattern of conductivity readings is shown in Fig. 4. The foreshore (0-180 m) has no areas of surface water. In the mid section of the profile (180-330 m), surface water is prevalent with conductivity value fluctuating between <1.0 to >13.0 mS cm^{-1}. At distal sites (>330 m) conductivity values did not exceed 2.0 mS cm^{-1} and were noticeably lower than the brackish Lake Akgöl (3.6 mS cm^{-1}).

There are 57 species in transect 1 and 52 species in transect 2, of which 33 are different and 38 are same. Using Jaccard similarity index, there are a 53.5% similarity in species between transect 1 and 2. Examining this further, Jaccard similarity index was used between the transects at each distance from the sea (Table 5). Transect 1 mean number of species per quadrat is 5.58 and transect 2 is 5.42.

The similarity between the plant communities at the twenty four sites of equal distance along the two transects (T1, T2), is shown in Table 5 and sites along transect 1 with similarity values >50%, in Table 4. The percentage similarity between adjacent sites along the two transects is very low suggesting any form of recognised zonation pattern. Site comparisons generating high percentage similarity values (>50%; Table 4), are also few in number, are in the mid section of the transect but again show little evidence of two adjacent sites being similar.

Table 1: Plant species found along the transect 1 and 2

Site No.	Plant species	Site No.	Plant species
1	*Zygophyllum album*	37	*Sporobolus virginicus*
2	*Schhoenus nigricans*	38	*Centaurea spinosa*
3	*Salsola kali*	39	*Sporobolus virginicus*
4	*Eryngium maritimum*	40	*Ephedra distachya*
5	*Paronychia argentea*	41	*Silene frivaldskyana*
6	*Cakile maritima*	42	*Juncus gerardii*
7	*Arthrocnemum fruticosum*	43	*Limonium vulgare*
8	*Polygonum mesembricum*	44	*Verbascum levantinum*
9	*Salsola ruthenica*	45	*Vitex agnus castus*
10	*Inula viscosa*	46	*Ammphilia arenaria*
11	*Inula graveolans*	47	*Bromus tectorum*
12	*Inula crihtmodies*	48	*Corrigiola litoralis*
13	*Limonium virgotum*	49	*Molluga cerviana*
14	*Ammophila arenaria*	50	*Agrostis stolonifera*
15	*Limonium gmelini*	51	*Lagurus ovatus*
16	*Alhagi mannifera*	52	*Halimione portulacoides*
17	*Aurinia uechtritziana*	53	*Juncus maritimus*
18	*Eryngium pusillum*	54	*Juncus acutus*
19	*Cressa cretica*	55	*Erenthus ravennea*
20	*Halocnemum strobilaceum*	56	*Phragmites frutescens*
21	*Piptatherum milicæum*	57	*Verbascum pinnatifidum*
22	*Salicornia europaea*	58	*Dianthus ingoldbyi*
23	*Elymus farctus*	59	*Medico marina*
24	*Cynodon dactylon*	60	*Artemica salina*
25	*Ononis natrix*	61	*Tamarix smyrnensis*
26	*Myrtus communis*	62	*Corrigiola litoralis*
27	*Centaurea plyclada*	63	*Euphorbia paralis*
28	*Rhamnus oleides*	64	*Euphorbia pithyusa*
29	*Osyris alba*	65	*Molluga verticillata*
30	*Nerium oleander*	66	*Sarcopoterium spinosum*
31	*Chondrilla juncea*	67	*Agrostis stolonifera*
32	*Holoschoenus vulgaris*	68	*Halimione portulacoides*
33	*Jasione heldreichii*	69	*Verbascum levantinum*
34	*Inula ammophula*	70	*Xanthium gmelini*
35	*Phragmites australis*	71	*Lagurus virgatum*
36	*Paliurus spina cristii*		

Table 2 : Number of plants in sites along the transect 1

	Site No.																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
	Distance from sea (m)																							
	30	60	90	120	150	180	210	240	270	300	330	360	390	420	450	480	510	540	570	600	630	660	690	720
Species	No. of plants																							
Zygophyllum album	3		1	1		1		1	1															
Schoenus nigricans		2	2	2	2	4	3	2	2		2	2	3		1			4	4	4			1	
Salsola kali						1			2															
Eryngium maritimum			1			2	1																	
Paronychia argentea		1	1			2																		
Cakile maritima							1			1	1	2			1									
Arthrocnemum fruticosum											1		2											
Polygonum mesembricum										1	1	1			1	1								
Salsola ruthenica											3			2	3	4					1			
Inula viscosa										1	1	1	1			2	4							
Inula graveolans											1			2	4	2	1				2		1	
Inula crihtmodies																2								
Limonium virgotum																2								
Ammophila arenaria																2					2		1	
Limonium gmelini																					1			
Alhagi mannifera															2						2		1	
Aurinia uechtritziana																					2		4	
Eryngium pusillum																					2		2	2
Cressa cretica																					2			
Halocnemum strobilaceum															1						3		1	
Piptatherum milicaeum																					1			
Salicornia europaea														2							3	5		
Elymus farctus							1					2							2					
Cynodon dactylon		1																				2		
Ononis natrix																								
Centaurea diffusa																	1							
Centaurea plyclada																	2							
Rhamnus oleides																						4		
Osyris alba																						2		
Nerium oleander																								
Chondrilla juncea																			3	5			2	4
Holoschoenus vulgaris																				2				
Jasione heldreichii			3																					
Inula ammophula								2	4															
Phragmites australis													2					3					1	
Paliurus spina cristii																		1	2					
Sporobolus virginicus																		3						
Centaurea spinosa																		2					2	
Sporobolus arenarius																		1						1
Myrtus communis																		1					2	
Ephedra distachya																							2	
Silene frivaldskyana																							2	
Juncus gerardii														3										
Limonium vulgare																							1	
Verbascum levantinum																							1	
Vitex agnus castus																							1	
Ammphilia arenaria														1										
Bromus tectorum																							2	
Corrigiola litoralis																							2	
Molluga cerviana																			3					
Agrostis stolonifera																			2		3			
Lagurus ovatus																			6					
Halimione portulacoides																								2
Juncus maritimus																							2	
Juncus acutus																							2	
Erenthus ravennea																							4	
Phragmites frutescens																							5	

Table 3 : Number of plants in sites along the transect 2

	Site No.																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
	Distance from sea (m)																							
	30	60	90	120	150	180	210	240	270	300	330	360	390	420	450	480	510	540	570	600	630	660	690	720
Species	No. of plants																							
Zygophyllum album	3	3	3		2	2				3														
Schoenus nigricans		3										2	3								6			
Salsola kali			2		1														2					
Paronychia argentea		2	2	2	2	2	1	2																
Cakile maritima										5				2			2							
Arthrocnemum fruticosum								3	3															
Salsola ruthenica										1	1		1	1	2	4	1							
Inula viscosa							2	2	5	2		2												
Inula graveolans							5			4	3			3	2	1	2	2		5				
Inula crithtmodies					3					3				5						4		3		
Limonium virgotum							2		2			2												
Limonium gmelini		2	2	2																3				
Alhagi mannifera																	4					4		
Aurinia uechtritziana									3													3		
Eryngium campestre																							2	
Halocnemum strobilaceum															2			2	2		2			
Salicornia europaea							5		5			5	2				2							
Elymus farctus								3																
Cynodon dactylon		3													3					3				
Centaurea plyclada																	2							
Rhamnus oleides															3									
Nerium oleander																2	4							
Chondrilla juncea																1		2						
Jasione heldreichii			2	1													3				1	4		
Phragmites australis									2															
Paliurus spina cristii																		1	4	1			1	
Sporobolus virginicus																					2			
Centaurea spinosa																							1	
Sporobolus arenarius																					2			
Myrtus communis																		1		1	4			
Juncus gerardii										2											1		1	
Phragmites frutescens												3												
Vitex agnus castus																				2				
Corrigiola litoralis																		2		2		2		
Lagurus ovatus						2				2								4				2	4	
Halimione portulacoides												2												
Phragmites australis																							2	
Verbascum pinnatifidum																							2	
Dianthus ingoldbyi												2												
Medico marina							2																	
Artemia salina																						2		
Tamarix smyrnensis																						2		
Corrigiola litoralis				2					2															
Euphorbia paralias									2															
Euphorbia pithyusa																		2						
Molluga verticillata			2																					
Agrostis stolonifera																							2	
Sarcopoterium spinosum																		2	2					
Halimione portulacoides																		3						
Verbascum levantinum															4									

Table 6, gives the Jaccard coefficient of similarity at sites with similar conductivity values. The wide-ranging values in both data sets support the notion of a varied and changing ecosystem with little evidence of similarity between the two adjacent transects.

The water salinity measurements at submerged sites (Fig. 4) show that extreme fluctuations occur throughout both transects. The highest salinities on both transects are seen between 180 and 270 m from the sea. However, salinity as a controlling factor on the vegetation patterns

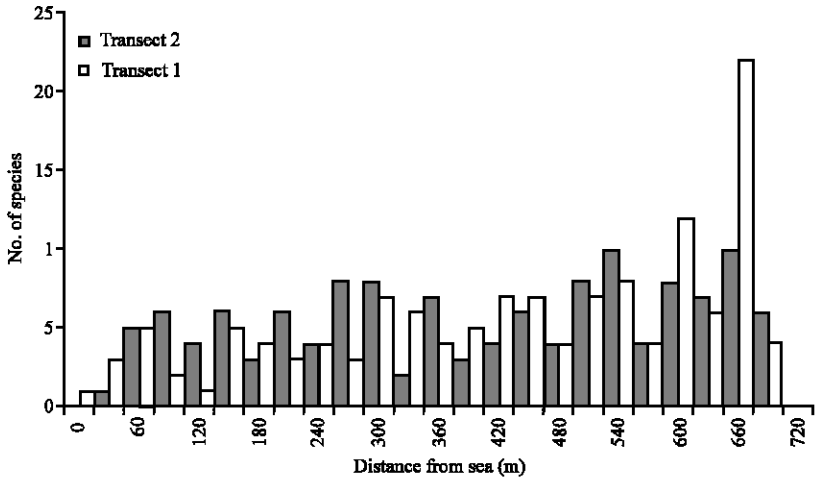

Fig. 2: The number of plant species at each site along the two transects

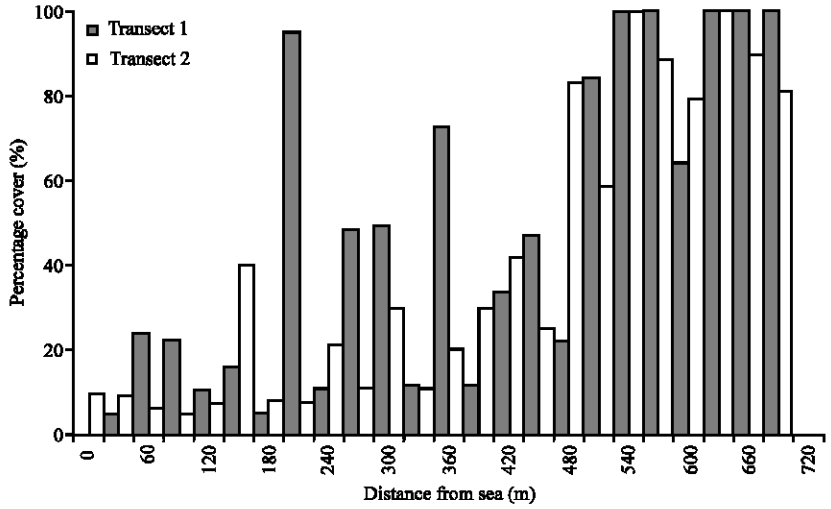

Fig. 3: The percentage cover of vegetation at each site along the two transects

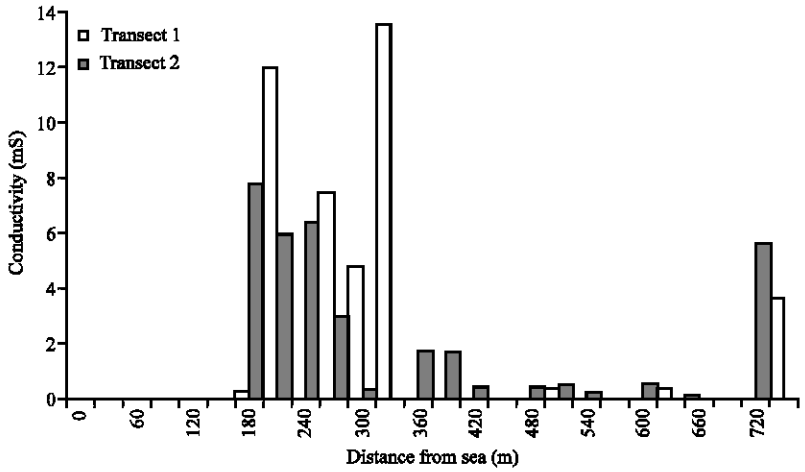

Fig. 4: The conductivity in (mS cm^{-1}) at submerged sites along the two transects

Table 4: Sites along transect 1 and 2 with the similarity values >50%

Site No. along transect 1				
Distance from sea (m)	Site A	Distance from sea (m)	Site B	Jaccard similarity result (%)
30	1	120	4	50
90	3	180	6	66
120	4	150	5	50
120	4	240	8	66
180	6	270	9	50
210	7	360	12	50
240	8	270	9	75
300	10	360	12	60
330	11	360	12	50
330	11	440	15	56
360	12	440	15	50
Site No. along transect 2				
300	10	410	14	57
330	11	470	16	50

Table 5: Jaccard's coefficient of similarity along transects 1 and 2

Distance from sea (m)	Site No. transect 1 and 2	No. of species along transect 1	No. of species along transect 2	No. of shared species	Jaccard's similarity results (%)
30	1	1	1	1	100.0
60	2	3	5	3	60.0
90	3	5	6	3	37.5
120	4	2	4	0	0.0
150	5	1	6	0	0.0
180	6	5	3	2	33.3
210	7	4	6	0	0.0
240	8	4	3	0	0.0
270	9	4	8	0	0.0
300	10	3	7	2	25.0
330	11	7	2	2	28.5
360	12	5	7	2	20.0
390	13	4	3	1	16.6
420	14	5	4	2	28.5
450	15	7	6	3	30.0
480	16	7	4	2	22.2
510	17	4	8	2	20.0
540	18	7	10	2	13.3
570	19	8	4	1	9.1
600	20	3	8	0	0.0
630	21	12	7	1	5.5
660	22	6	8	1	7.7
690	23	22	8	2	7.1
720	24	4	0	0	0.0

Table 6: The similarity between plant communities at sites with similar salinity levels

Transect No. and site No.		Jaccard similarity result (%)
Site A	Site B	
Site 7-Transect 1	Site 8-Transect 1	16.6
Site 6-Transect 2	Site 9-Transect 2	0.0
Site 11-Transect 1	Site 12-Transect 1	50.0
Site 7-Transect 1	Site 8-Transect 2	14.3
Site 13-Transect 1	Site 15-Transect 1	10.0
Site 16-Transect 1	Site 19-Transect 2	0.0
Site 15-Transect 1	Site 15-Transect 2	18.2

of the two transects is controversial. There is similarity between plant communities at sites with similar salinity levels and in all but one case (sites 11 and 12 on transect 1, 50%) the similarity between plant communities is insignificant. Therefore it is possible to suggest that other factors, such as soil characteristics, site exposure and wind action, are important in determining the patchy mosaic vegetation zonation within the Göksu delta.

DISCUSSION

Pioneering studies of rocky foreshores have identified the importance of both wave action and fluctuations in tidal height, as establishing vegetation zonation patterns (Lewis, 1964). In coastal areas experiencing macrotidal regimes (4-20 m), wetlands are often extensive and the periods of tidal immersion and emersion are again key factors in the establishment of the vegetation zones (Orme, 1990; Williams, 1990).

However, in coastal areas experiencing microtidal regimes e.g., the Mediterranean, with a spring tidal range of <2 m, the vegetation patterns that are established must be controlled by other environmental factors (Orme, 1990).

The distribution of plant species common to both transects supports a patchy mosaic zonation model. Phragmites australis was recorded at 690 m (T1) but at only 360 m from the sea along T2. Limonium gmelini was present near the ends of both transects but also identified closer to the sea along T2 between 60-120 m.

If the typical model of distinct zonation is based upon decreasing salinity values, then zones of halophytic, psammophytic and freshwater loving plants, will be seen along transects perpendicular to the shoreline. Some evidence of this does occur as illustrated by Zygophyllum album is most prevalent at 30 m and then in smaller quantities up to 270 m along transect 1. In transect 2 it is most common between 30-90 m, absent at 120 m, to reappear at 150-180 m and again at 300 m. This is a halophytic species and seems to be spread in isolated sites and not tightly bound to the lower shoreline as would be expected in areas under greater tidal influence. Decreasing conductivity values towards Lake Akgöl might account for its absence further inland giving some indication that a weak zonation for this species, may exist on the delta.

Salsola kali is present in small isolated numbers at 180 and 270 m in transect 1 and in three isolated quadrats in transect 2 (90, 150 and 570 m). This species is also halophytic with sharp, narrow, fleshy leaves, tiny green flowers and is considered a dune initiating plant (Archibald, 1995; Williams, 1987).

Salicornia europaea is distributed at sites 21, 22 in 630-660 m along transect 1, with a small amount occurring at 420 m. Along transect 2 it is plentiful at 210, 270 and 360 m but declines at 390 m and again at 510 m. Another typical halophytic plant with fleshy leaves, S. europaea is also found in saltier parts of the delta (Anonymous, 1995). However, its main distribution is some distance from the sea and appears not to follow the normal zonation pattern.

Ammophila arenaria is a psammophytic species and sparsely distributed, being only recorded at 420 m along transect 1. Commonly known as Marram grass, it is essential for continued dune development (Archibald, 1995). The psammophytic adaptations include tough rhizomes, enabling individual genets of Ammophila to survive in a depauperate form for many years and its vigorous growth maintains its position upwards as sand accumulates (Carter, 1988). Brown and McLachan (1990) position the distribution of this plant as close to the sea but in this study it only retains a foothold in the middle section of the transect. A similar pattern is found with another psammophyte, *Elymus farctus* which appears in three isolated quadrats in transect 1 (210, 360 and 570 m) and once at 240 m in transect 2.

Juncus acutus, a freshwater-loving plant appears once at 690 m in transect 1. This hygroseries plant (Salman, 1992) is common in inland marshy areas (Archibald, 1995; Tiner, 1987), which suits its position at 690 m, next to Lake Akgöl. At this particular site, this may not reflect the natural pattern, as the freshwater environment is a consequence of human manipulation of the regions hydrology.

CONCLUSIONS

A comparison of the plant communities at equal distances from the sea along the two adjacent transects, supports the concept of a patchy mosaic zonation model. Regular immersion and emersion by macrotidal movements would result in coherent community zones in horizontal bands across the shore. With the exception of the first two sites, none of the sites of equal distance are significantly similar (>50%).

This study proposes that the interconnection of three major factors is responsible for the observed vegetation patterns; topography, groundwater levels and conductivity of any surface water. Strong winds are also responsible for changing the surface topography at a microscale and rainfall will accumulate in the lowlying regions of the delta.

The Göksu delta is an unique area of ecological importance as a habitat for many endemic plants and essential for migratory birds. Conflicts as to land use arise and although much of the area is a specially protected area and designated a class A wetland site, under the Ramsar convention, the rich fertile plains are required for agriculture and tourism.

Although legislation has been passed to limit the construction of holiday homes on the delta, building still continues with 25% of the coastline currently affected.

The impact of agricultural practices has already been realised and changes in pesticide and fertiliser applications is being considered. Some concerned is being expressed as to agricultural runoff increasing levels of eutrophication in the lakes and lagoons of the delta.

Mediterranean coastal ecosystems such as the Göksu delta, are important resources. They have a high diversity of fauna and flora and their nutrient-rich soils encourage agriculture. Such pressure requires careful control if sustainable development is to be achieved and changes, both natural cycles and those applied, should be carefully monitored.

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