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Phenological observations on *Posidonia oceanica* (L.) Delile medows along the coast of Akkum (Sıgacık Bay, Aegean Sea, Turkey)

Akkum Kıyısı boyunca *Posidonia oceanica* (L.) Delile çayırlarında fenolojik gözlemler (Sığacık Körfezi, Ege Denizi, Türkiye)

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Abstract

Phenological observations were carried out on *Posidonia oceanica* meadows between December 1994 and April 1995 along the coast of Akkum (Sıgacık Bay, Aegean Sea, Turkey) from two shallow depths (1-3 m; 4-7 m). The highest flowering density of 136 inflorescence / m^2 was observed in the 4-7 m depth during January 1995. Inflorescences more often occured on the orthotropic rhizomes in the dense beds. Inflorescence mostly bore 2 rarely 1 or 3 spikes, distichous with 2-3 flowers with a male flower and a sterile extension at the apex. Fruits started maturing in February and got mature during April. Plants at the 4-7 m depth produced 15 mature fruits from a total of 19 flowers in seven inflorescences. Shoot density was found to be maximum (880 shoots / m^2) during December, with 7420 leaves / m^2), at the 4-7 m depth. The leaf lengths of the plants at the 4-7 m depth gradually increased from December to April. Phenological differences between the two depths were mainly due to the fact that the plants in the sparse and isolated meadows in the shallower areas had short and even falciform leaves, compared to the ones in the deeper and central areas.

Key words: Seagrass, *Posidonia oceanica*, phenology, the Aegean Sea, Turkey.

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Introduction

Posidonia oceanica, endemic to the Mediterranean Sea, forms homogenous and dense meadows from shallower up to the 40 m deep (Hartog 1970). The hypothesis that flowering was scarce in the data published previously stems from insufficient observations rather than the scarcity of flowers (Giraud 1977 b). Despite the fact that there were few studies on flowering in the past (Giraud 1976, Giraud 1977a), flowers have been observed in many localities in the. Mediterranean recently, speeding up studies on sexual reproduction (Pergent et al. 1989, Caye and Meinesz 1984) as well as on vegetative production (Boudouresque et al. 1983, Buia et al. 1992, Pergent et al. 1994).

Phenological records for *P. oceanica* have been reported in 41 localities from Spain to Morocco, 17 of which are located in southern France and only 3 in Turkey (Ceşme, Candarlı, Urla) (Thelin and Boudouresque 1985). As the number of phenological records started to increase, studies in the Mediterranean were considered to be based on a standard protocol (Boudouresque and Thelin 1985). In Turkey since the first study performed on this respect (Pergent and Pergent 1984), this is the second work that shows the flowering and fruiting of *P. oceanica* by the researching of Sıgacık Bay (Akkum).

Material and Methods

The study area, located in Sıgacık Bay (Akkum Coast: 38^{o}11'N and 26^{o}46'E), cowers two different depths (1-3 m; 4-7 m) (Figure1). The bottom formation is sandy at 1-3 m depth and contains muddy sediments with very fine granules at the 4-7 m depth. The bed deepens to the west and the population exhibits a high degree of stability and continiuty. Eastward, especially towards the Esek Island, the bottom is rather rocky and the population is patchy among the rocks.

Water temperature was measured for each sampling period. Four replicates from each *P. oceanica* beds located at two different depths were taken by means of *in situ* SCUBA DIVING from December 1994 to April 1995 monthly. Plants were collected and morphometric measurements were obtained from the sample plants were then converted to square meters. The vegetative parameters, such as shoot density, the number and the length of the leaves were determined according to Giraud's (1977 b, 1977 c) measurement and classification methods. Reproductive phenological parameters, such as the number of inflorescences and flowers, the spike condition and fruiting for the areas 25x25 cm quadrats were determined. The effects of depth on density, inflorescence number, leaf length and leaf number as well as the effects of density, leaf number and leaf length on flowering were tested by means of regression analyses. ANOVA analysis were used to test the significance of the differences found among the replicates in the two stations over months.

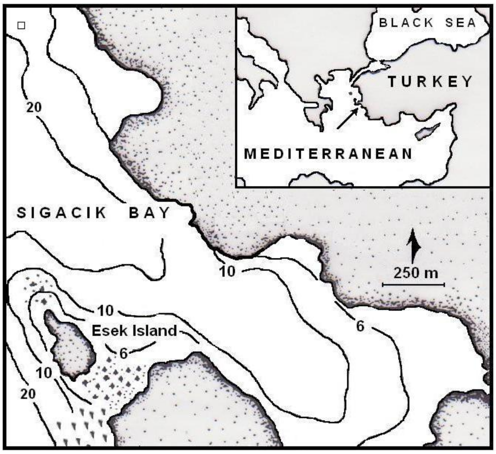

Figure 1. Map of the study area

Result and Discussion

Vegetative parameters

Upper limits of the beds ranged between 1 and 3 meters along the study area. Two types of rhizomes were found in the area and flower presence in orthotropic and plagiotropic rhizomes and structural variations between the depth and the stations were compared. Caye (1980), explained two types of rhizom. Plants at the 1-3 m depths often formed plagiotropic rhizomes, and these plants were usually short, but had broad leaves. All the other sampling localities were older beds with central plants bearing orthotropic rhizomes. The density of shoots were lower in beds at 1-3 m depths than 4-7 m depths. Also, it appeared that the depth had a statistically significant effect on the shoot density ($p<0.05$). Shoot density decreases by depth according to Pergent et al. (1995). In our study, the beds at 1-3 m were heterogenous and younger than the beds at 4-7 m. Shoot density and leaf numbers decreased from December to April. Mean values of shoot density and leaf numbers were found to be the highest in December at 4-7 m depths (880 shoots/m^2) (Figure 2).

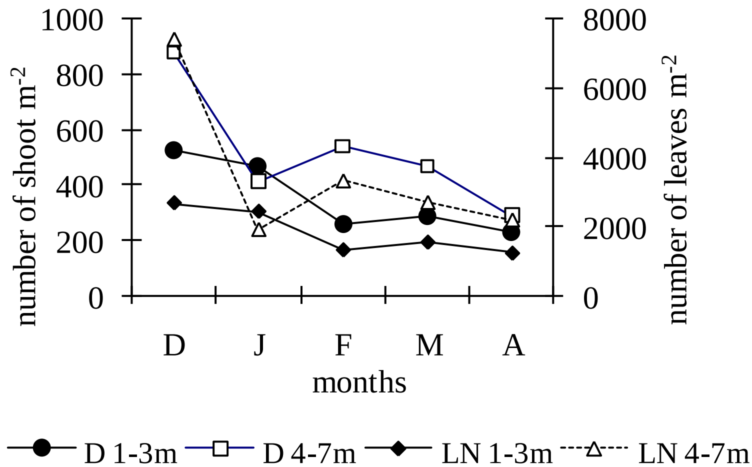

Figure 2. Monthly change in density (shoot number/m^2) and in leaf number at two different depths

For *P. oceanica*, it is possible to analyse the density of the fascicles according to depth and condition of the meadow. For a given depth, four classes of density could explained and the shoot density at 4-7 m varies between 806-663 shoots/m^2 for supra-normal class of exceptional situations of meadows Pergent et al. (1995). The maximum shoot density value belong to our study area was higher than the values determined in supra-normal class. This showed that there is an exceptional *P. oceanica* vitality in the bed.

When a two-way variance analysis was performed, an interaction was determined between the variables for the months and the depth (P-value=0,04<0,05). In brief, it could be concluded that the number of leaves changed with time depending on the depth. This change can be clearly obseved at the 4-7 m depth, whereas it is rather unclear at the 1-3 m depth (P-value=0,03<0,05) (Figure 3, 4).

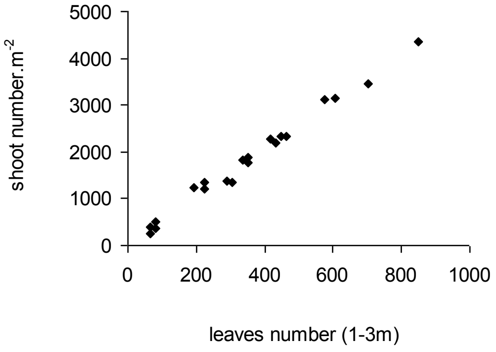

Figure 3. Linear regression between leaf number and shoot density at 1-3 m depth.

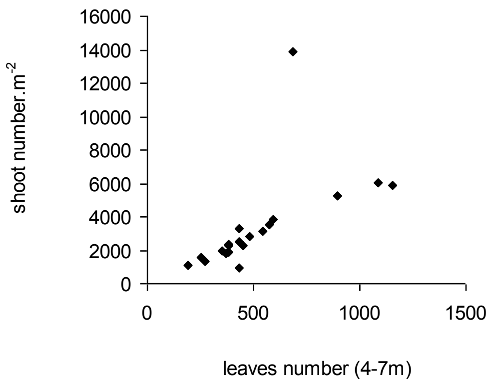

Figure 4. Linear regression between leaf number and shoot density at 4-7 m depth.

The mean values for leaf length, there was no relation between the time and depth factors (P-value=0,84>0,05); however, time and depth seemed to have a certain effect on mean length values (P<0,05) (Figure 5).

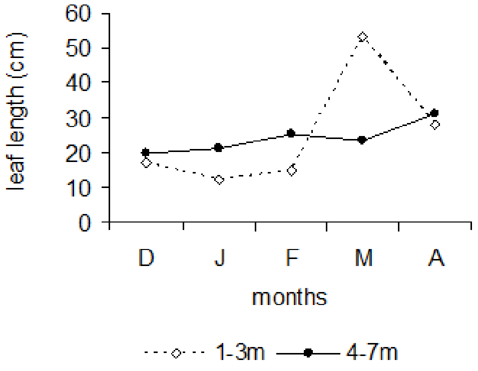

Figure 5. Monthly change in mean leaf length

As suggested by Giraud (1977 b), this result clearly reiterates that plants start growing in length as of February and especially in the spring. No meaningful relationss between leaf length and flowering; leaf length and shoot density; and the number of leaves and flowering were obseved in the populations of both 1-3 m and 4-7 m dephs (Table 1).

Table 1. The values of water temperature, shoot density, number of flower bundles, inflorescence and percentage of flowering at two depths according to months.

Months	Temperature (°C)	Shoot density/m^2		Number of flower bundles/m^2		Percentage of flowering (%)		Number of inflorecence/m^2)	
		1-3 m	4-7 m	1-3 m	4-7 m	1-3 m	4-7 m	1-3 m	4-7 m
December	15.8	524	880	26.2	9.1	3.8	10.9	20	96
January	15.8	464	412	0	3	0	33	0	136
February	16	260	540	10.8	8.4	9.2	11.8	24	64
March	15.5	284	468	0	5.8	0	17	0	80
April	16.5	232	288	19.3	10.2	5.1	9.7	12	28

Reproductive Parameters

a) Flowering

The samples collected over a period of 5 months had a total of 400 flowers, 360 of which were fertile. Most of the flowers were borne on the inflorescences were arranged in a two-spike order.

Flowering percentages were computed for the inflorescences only, but the spike orders were determined taking into consideration all the flowers. The total number of inflorescences for all the replicas at both depths was 115, of which 91 were in a 2-spike order, 18 in a 1-spike order and 6 in a 3-spike order. Although hermaphrodite flowers accounted for the majority in both quantity and percentage, none was strong enough to form a mature fruit (Table 2). Of all the inflorescences, the percentage of 2 spiked ones was greater than those with 1 or 3 spikes (79 %).

Table 2. Number of spikes with orders of 1, 2, 3 per inflorescence (1-7 m depths). H: hermaphrodite; M: male flowers.

Order of species	Spike n° 1		Spike n° 2		Spike n° 3		Fertile flowers number	Total flowers number
Number of spikes	1	8	9	1	6	-	-	-
Sexuality	H	M	H	M	H	M	-	-
Number of flowers	24	7	306	28	30	5	360	400
%	6	1.7	76.5	7	7.5	1.2	-	-

Flowering values for the 4-7 m samples were found to be greater than the ones at the 1-3 m depth (maximum, 136 inflorescences /m^2 in Januar; minumum, 28 inflorescences /m^2 in April). The first value belongs to the II. group in Giraud's flowering classification in the Mediterranean (dense flowering) and the second value to the IV. group (sparse flowering).

The values for the other months fall in the medium flowering group. The rate of flowers was again the highest at the 4-7 m depth in January (33 %), which is greater than the value found by Pergent G. And Pergent C. (1984) on the Urla Coast in the Gulf of Izmir. The Inflorescences number (136/m^2) and the shoot density (412/m^2) of the Urla samples had higher values than those of the Akkum samples, which explains why the rate of flowers was higher in the Urla samples.

b) Flower Development and Fruiting

The number of hermaphrodite flowers was determined. A one-way variance analysis revealed that the decrease in the number of fertile flowers changed according to depth (P-value=0,01<0,05). On the other hand, ovarium dimensions were seen to have increased in time. Also, a two-way variance analysis revealed the existence of a relation between the months and the depth (P-value=0,03<0,05) (Figure 6).

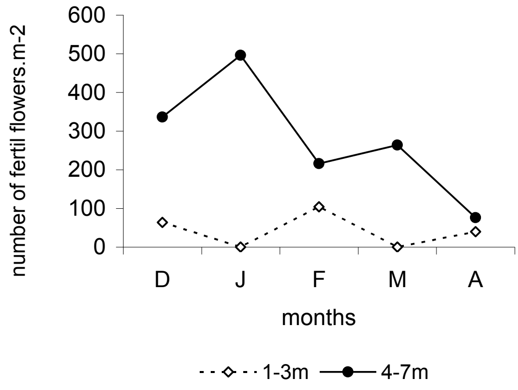

Figure 6. Monthly change in number of fertile flowers according to depths

A decrease in the number of inflorescences from all the stations was observed in April, which was accompanied by a drop in fertilization at the 1-3 m depth. Fruit born by May samplings was insignificant. In early July of the same year, in a sheltered and extremely narrow tidal pool located in a reefy coastal site, an uncracked fruit with a germinating seed was found lying on a sediment with a depth of -10 cm and a thickness of 5 cm. The fruit had an 8 mm-long primordial root on the negative pole as well as several other roots just below the plumule. Several leaf bundles were seen to be emerging under this formation. As the fruit failed to develop healthily, it was moved to the laboratory where it was studied together with other flowers and fruit collected earlier (Figure 7).

A complete phenological process could not be observed on the samples taken from either depth for five months. This was especially true for the 1-3 m depth oving to the fact that these beds are newly formed and display a vegetative nature. These plants, often with plagiotropic rhizomes, are in a fierce competition with thin *Cymodocea nodosa* (Ucria) Archerson on shallow, sandy sediments.

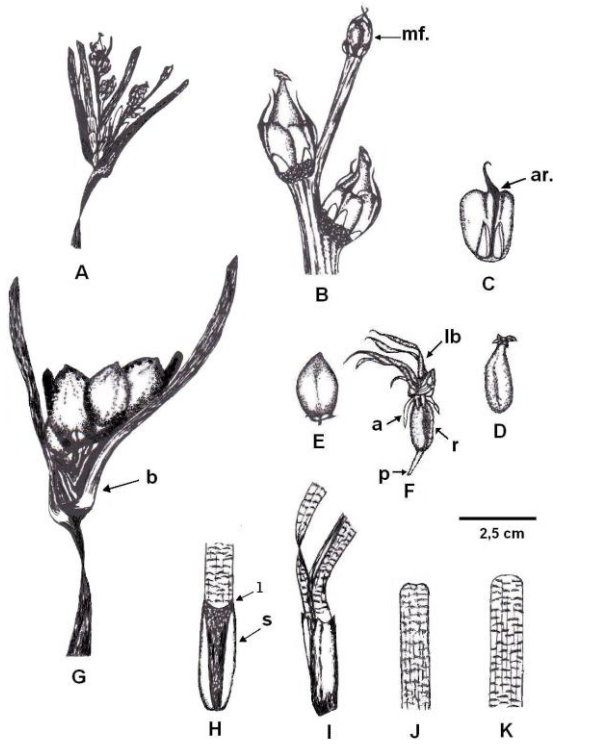

Figure 7. Phenological appearances of the flowers, fruits and leaves of *P. oceanica.* A: inflorescence with two combined spika order; B: hermaphrodite flowers (under); m.f.:male flower; C: andrekium; ar: arista; D: joung fruit; E: mature fruit; F: approximately one month ore, r: raphe, l.b: first leaf bundle, p: primary root, a.: adventive root G: mature fruits; H: old leaf and basal area; s: sheath; l: ligule; I: a leaf bundle surroundet by persisting scale; J: an adult leaf with typs emarginate K: old leaf with obtuse.

Homogenous and pure beds start at a depth of –8 and -10 meters, continue down to -20 meters where it start to lessen and eventually diminish at –28 meters. Deeper flowers were not studied and observations were confined to shallow waters where flowering was mostly observed. Previous works on the subject have shown that the data were obtained mostly through haphazard observations and that fruiting might be associated with shallow beds (Mazzella et al. 1984).

Phenological records obtained from works conducted in various regions of the Mediterranean date back to the 1940’s. In the past 50 years, 6 flowering phonemona have been spotted in Banyuls Sur Mer, and the flowering index was 17 % in 1983. Corsica have had a 10 % index with 10 flowering events in the last 30 years. Moreover, Kerkennah Islands (Tunusia) and Urla (Turkey) had indices of 29 % and 12 % respectively. The 33 % index value obtained in this study has now surpassed the 29 %, the highest index in the past 60 years. In another study performed along a single transect reaching a depth of -20 meters, an inflorescence was found at -15 meters in March, 1998. Yet another flowering had been observed by pure chance in the same area four years ago. However, periodical observations are required in specified areas.

Water temperature is not generally considered a factor controlling flowering (Pergent et al. 1989). Nevertheless, the temperatures recorded in a specified bed in the last four years varied greatly. The water temperatures determined in the first sampling periods of December 1993 and April 1994 ranged between 15.5 and 16.5 ^{o}C while the temperatures in the second sampling period from April to December 1998 were between 16.6 and 18 ^{o}C. No shallow flowering event could be observed in the second sampling period in 1998. Apart from all these, the sampling area was clear, safe from any polluting agent. Vulnerable to winds and rich in oxygen. It can be concluded that internal futures like the genetical structure as well as environmental factors such as photoperiod, temperature, light and the quality of the water need to be considered as parts of the whole process.

Özet

Akkum sahillerindeki (Sığacık Körfezi, Ege Denizi, Türkiye) *Posidonia oceanica* çayırlarına ait fenolojik gözlemler, Aralık 1994 ve Nisan 1995 tarihleri arasında iki sığ derinlikte (1-3 m; 4-7 m) yapılmıştır. En yüksek çiçeklenme yoğunluğu, (136 infloresens / m^2) Ocak 1995’de 4-7 m derinlikte tespit edildi. En yoğun çiçeklenmeye, ortotropik rizomların bulunduğu yoğun yataklarda rastlandı. Her infloresens çoğunlukla 2 nadiren 1-3 spikalı ve her spika distik yerleşmiş genellikle 2, (-3) çiçek, ve uçta steril uzantısı bulunan erkek çiçek

taşımaktaydı. Meyveler Şubatta başlamak üzere Nisan aylarına kadar tam olarak olgunlaşma gösterdi. Bitkiler, 4-7 m derinliklerde metrekare başına toplam 7 infloresensteki 19 çiçekten 15 meyve üretti. Sürgün yoğunluğu da 4-7m de, yine metrekare başına 7420 yaprakla Aralık ayında maksimumdu (880 sürgün// m^2). Yaprak uzunluğu, 4-7 m de Aralık ayından Nisan'a kadar kademeli olarak artış gösterdi. Her iki derinlik arasındaki fenolojik farklılıklar, falsiform, kısa yapraklı sığ ve izole yataklardaki bitkilerle daha derindeki merkezi kısımda yer alan yataklardaki bitkiler arasında daha belirgin olarak görüldü.

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