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Comparative study of the biomass of submersed aquatic macrophytes in a temporary and permanent freshwater lake in Turkey

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Abstract: The objective of this study was to analyze the impact of desiccation of a freshwater lake on the biomass of the submersed aquatic macrophytes *M. spicatum* and *P. pectinatus.* To this end, the biomasses in temporary and permanent lakes were compared for each submersed macrophyte. Differences in biomass of *M. spicatum* were significant between season ($P<0.001$) and lake x season interaction ($P<0.05$), but not significant between lake ($P=0.114$). On the other hand differences in biomass of *P. pectinatus* were significant between lake ($P<0.001$) and lake x season interaction ($P<0.001$). Significant differences were not found between season.

Keywords: temporary lake, permanent lake, growth rate, aquatic plants, submersed macrophyte, rooted aquatic plant

Introduction

Many factors influence macrophyte communities in aquatic systems and the ability of invasive species to colonize, disperse and become dominant (Martin and Coetzee, 2014). Changes in water quality due to increased nutrient levels can exert strong negative effects on the abundance and species composition of aquatic vegetation in many lakes (Sand-Jensen *et al*., 2000; Körner, 2002). The natural change of water level generally shows a seasonal pattern, with a low water level in the summer and a high water level in the winter, which may encourage the expansion of fringing vegetation around the lake (Korhola, 1992). However, changes in water levels may also have negative effects on the diversity of wetland plants (Zohary and Ostrovsky, 2011) and affect the entire lake system by modifying the light climate for macrophyte growth (Blindow, 1992; Noges and Noges, 1999; Beklioğlu *et al*., 2006). The sensitivity of macrophytes to turbidity can increase during periods of high water due to reduced light penetration to the bottom of the lake. Conversely, low water levels during the summer can encourage macrophyte growth (Havens *et al*., 2004; Tan and Beklioğlu, 2006).

In shallow lakes, changes in the underwater light climate cause changes in the dominant macrophyte species (Coops and Doef, 1996). This suggests that the response of the species is different based on their light harvesting ability. Competitive strategies are associated with the theory of optimal resource-use (Bloom *et al*., 1985; Tilman, 1988), which suggests that plants allocate resources according to their proportional limitation for each resource (Mony *et al*., 2007). Although the interactions among macrophyte species have been studied extensively (Simberloff and Von Holle, 1999; James *et al*., 1999; Richardson *et al*., 2000; James *et al*., 2006), interactions between aquatic macrophytes with similar ecological strategies and growth characteristics have received relatively little attention (Mony *et al*., 2007; Martin and Coetzee, 2014).

Myriophyllum spicatum L. and *Potamogeton pectinatus* L. are macrophyte species native to Turkey; however, native species can also become invasive via their rapid grow rate, which restricts the availability of resources for other species, or by directly competing with other species for space. *M. spicatum* is found at depths of 0.5-3 m, whereas *P. pectinatus* grows at a range of depths, primarily 0.5-1.5 m (Preston and Croft, 1997). Both species can grow together in many water sources.

The objective of the present study was to analyze the impact of desiccation of a freshwater lake on the biomass of the submersed aquatic macrophytes, *M. spicatum* and *P. pectinatus.* For this, the differences in the biomass of the two submersed macrophytes, *M. spicatum* and *P. pectinatus,* were investigated by comparing temporary and permanent lakes. The study also tried to answer the question that how the

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differences between the biomass of macrophytes will be help to management of lake ecosystems.

Materials and Methods

Study Area

Lake Çalı (41o12'N, 43o12'E) is a small, boggy freshwater lake situated 20 km east of Kars, Turkey, adjacent to the road between Kars and Digor that bisects the site (Fig. 1). On the south, there is a 15 ha permanent lake with submersed flora. The area to the north of the road (approximately 10 ha) is seasonal. Two species of macrophytes, *P. pectinatus* and *M. spicatum*, were identified as dominant submersed macrophytes in the lake (Uğran, 2008).

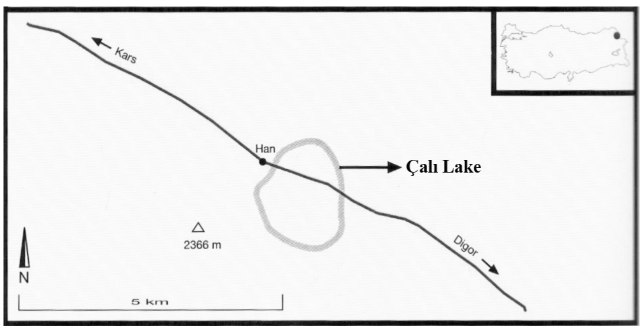

Fig. 1: Map of the study area.

Field Studies

The above ground standing crop of macrophytes was assessed on July 2008 (prior to the dry season), and on May 2009, at the beginning of the growing season. Sampling has been repeated on July 2009, 2010 and May 2010, 2011. Plant samples from squares (0.5 x 0.5 m) were collected, with three replicates around both sites of the lakes. Sampling sites have been choosen from both lakes where the two species, *P. pectinatus* and *M. spicatum,*were grow together. The mean water depth at the sampling sites was 20 cm and 50 cm in July in the temporary and permanent lake, respectively, whereas the mean depth of sampling sites in the temporary lake was 45 cm and 60 cm in the permanent lake in May. The samples were sorted into species (*P. pectinatus* and *M. spicatum*) and dried to a constant weight in an oven at approximately 70 °C. Their dry weight was then measured and the mean m^2 value extrapolated. The number of branches and the total shoot lengths of the plants were measured before the drying procedures. Lakes sediments were collected from both lake sites, with three replicates each, to determine the total phosphorus (TP) and total nitrogen (TN).

At the beginning of the study, the pH, conductivity and dissolved oxygen (DO) levels were measured with a WTW Oxi 197i oxygen meter (Weilheim, Germany), a WTW cond 315i/set meter (Weilheim, Germany) and a WTW = 315i/set pH meter (Weilheim, Germany), respectively. The concentrations of NH_4-N, NO_3-N, and soluble reactive phosphorus (SRP) were analyzed according to American Public Health Association (APHA) methods (1999). Chlorophyll *a* in the water column was extracted in acetone, and the concentration was calculated from the absorbance reading at 663 nm (Talling and Driver, 1961). The lake sediment was analyzed for TP and TN according to Murphy and Riley (1962) and Pella and Columbo (1973), respectively. All statistical analyses were performed using Minitab 11 (Minitab 1996).

Results

In both lakes, the pH, conductivity, DO, and chlorophyll *a* values in the water in July were higher than in May, whereas the concentration of NO_3-N, NH_4-N and SRP was generally lower in July than in May (Table 1).

Differences in the biomass of *M. spicatum* were not significant between lakes (P=0.114), but significant between seasons (P<0.001) and the lake x season interaction (P<0.05) (two-way ANOVA) (Fig. 2). By contrast, differences in the biomass of *P. pectinatus* were significant between lakes (P<0.001), and the lake x season interaction (P<0.001). Significant differences were not found for seasons (P=0.087).

Tab.1: Physico-chemical composition of the water in July and May.

Parameter	Lake	Season	Mean±SD
pH (log unit)	Temporary	July	8.1±0.24
		May	7.6±0.16
	Permanent	July	8.6±0.20
		May	7.5±0.24
Temperature (^{0}C)	Temporary	July	23.7±0.26
		May	15.3±0.44
	Permanent	July	20.7±3.32
		May	14.7±0.50
Conductivity (µscm^{-1})	Temporary	July	178±10.6
		May	112±11.2
	Permanent	July	183±9.17
		May	113±7.48
DO (mg.l^{-1})	Temporary	July	8.6 ±0.29
		May	5.7 ±0.29
	Permanent	July	9.1 ±0.20
		May	5.8 ±0.37

Tab. 1: continued

Parameter	Lake	Season	Mean±SD
NO_3-N (mg.l^{-1})	Temporary	July	0.39±0.03
		May	0.55±0.06
	Permanent	July	0.36±0.03
		May	0.49±0.05
NH_4-N (µg.l^{-1})	Temporary	July	27.4±2.24
		May	27.8±3.28
	Permanent	July	22.9±1.45
		May	27.5±2.37
SRP (µg.l^{-1})	Temporary	July	48.7±4.52
		May	58.5±3.90
	Permanent	July	51.6±1.98
		May	64.3±3.92
Chl *a* (µg.l^{-1})	Temporary	July	9.8±1.00
		May	1.8±0.89
	Permanent	July	6.2±2.31
		May	0.5±0.24

The values shown are the means ± SD, N = 9. DO = dissolved oxygen, NO_3-N = nitrate nitrogen, NH_4-N = ammonium nitrogen, SRP = soluble reactive phosphorus, chl*a*= chlorophyll *a*.

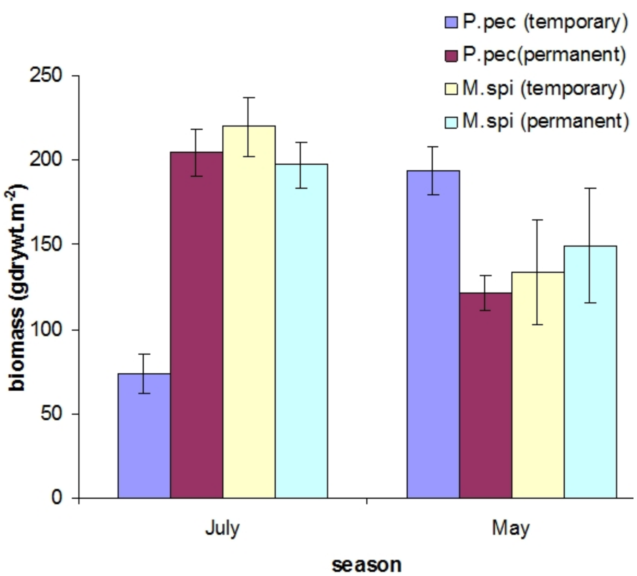

Figure 2. Biomass of *M. spicatum* and *P. pectinatus* in temporary and permanent lake in May and July. Biomass was determined using the plant dry weight. Error bars are shown Means ± SD.

In July, *M. spicatum* produced more lateral shoots but had shorter shoot lengths than in May in the temporary lake (Table 2). In the permanent lake *M. spicatum* produced more lateral shoots and had longer shoot lengths in July than in May. In the temporary lake, *P. pectinatus* produced more lateral shoots and had shorter shoot lengths in July than in May, whereas in the permanent lake, *P. pectinatus* produced more lateral shoots and had longer shoot lengths in July compared to May. However, both species produced the longest shoots in the permanent lake rather than the temporary lake during both seasons.

The total phosphate concentrations in the sediment of the temporary lake ranged from 417 µg.g^{-1} to 721 µg.g^{-1} in July and from 349 µg.g^{-1} to 757 µg.g^{-1} in May, whereas the nitrogen concentration remained less than 0.75% during both seasons (Table 3). In the permanent lake, the total phosphate concentrations in the sediment were 606 µg.g^{-1}and 629 µg.g^{-1}in July and May, respectively. The TN levels were 0.47% in July and 0.51% in May in the permanent lake.

Discussion

The pH and DO of the water increased significantly in July for both lakes. This is likely because of the continuing photosynthetic activity of macrophytes and algae in both lakes. The increase in the conductivity of the water in July was likely caused by ion release from the plants or sediments over time. However, the NO_3-N, NH_4-N and SRP contents of the water decreased in July, likely due to nutrient uptake by the growing macrophytes and algae. Although the macrophytes and algae consumed some nutrients from the water in both lakes based on the present studies, the reduction in nutrient levels was most likely not growth-limiting in both the temporary and permanent lake because nutrient release from the sediment into the water may compensate for the nutrient uptake.

The excessive growth of phytoplankton is often detrimental to underlying host plants, either through shading or a reduction in the exchange of dissolved gases (Phillips *et al*., 1978). However, all chlorophyll levels were <25 µg.L^{-1}, indicating that the phytoplankton levels were low and did not significantly affect the macrophytes, particularly in the temporary lake in July. Accordingly, Becares *et al*. (2008) estimated that a 50% reduction in macrophyte growth should be expected in warm shallow lakes when the chlorophyll *a* concentration ranges from 30–150 µg.L^{-1} compared to lakes with concentrations below this range. It is therefore unlikely that algae affected either of the two species. However, the growth response was not equivalent for all the macrophytes. A higher growth rate was recorded for *M. spicatum* in July in the temporary lake, which was likely due to its differences in the growth form compared to the other studied species. *M. spicatum* is a completely submerged macrophyte, but it can survive on water-saturated sediment by producing a short terrestrial life form; however, *P. pectinatus* cannot produce a terrestrial form. Such a land life form of *M. spicatum* may enable the plants to survive short periods of drying (Bates *et al*., 1985). This characteristic of *M.*

Tab. 2: Number of lateral shoots and the longest shoots of *M. spicatum*, and *P. pectinatus* in July and May.

Species	Lake	Season	Total no. of lateral shoots	Longest shoot length (cm)
M. spicatum	Temporary	July	9.6±2.49	27.9±5.61
	Temporary	May	2.66±0.47	49±2.70
M. spicatum	Permanent	July	3±1.63	105.3±8.64
	Permanent	May	2.66±0.47	88.9±5.84

The values shown are the Means ± SD, N=9.

Tab. 3: The nutrient composition of the sediment in July and May.

Lake	Season	TP ($\mu g.g^{-1}$)	TN (%)
Temporary	July	622±82.7	0.56±0.11
	May	516±97.8	0.49±0.17
Permanent	July	605±66.8	0.42±0.06
	May	697±86.5	0.52±0.08

The values shown are the means ± SD, N=9. TP= total phosphate, TN= total nitrogen.

spicatum may explain why the plant grows well in July (before the dry season) in the temporary lake. By contrast, Moen and Cohen (1989) showed that *P. pectinatus* reduced the individual plant weight of *M. exalbescens*. The ability of *P. pectinatus* to outcompete other species may be related to its rapid growth and ability to form canopy leaves near the water surface, which make it a superior competitor for light. This distinction may explain the lower growth of *M. spicatum* in both the temporary and permanent lake in May and in the permanent lake in July. Furthermore, laboratory studies revealed that *P. pectinatus* grows at a lower temperature (van den Berg *et al*., 1998) and therefore earlier during the spring than *M. spicatum*. In this study, the water temperature was 14 and 15 °C in May and 21 and 24°C in July in permanent and temporary lake respectively, which likely gives a competitive advantage to *P. pectinatus* for grow over *M. spicatum*.

Wersal and Madsen (2011) suggested that the heterophyllous species *Myriophyllum aquaticum* is negatively affected by increasing water levels. Similar characteristics may result in the low growth rate of *M. spicatum*, a completely submersed plant, compared with the other species at increased water levels in May in both the temporary and permanent lakes. In both the temporary and permanent lakes, *M. spicatum* showed a smaller biomass in May with high water (45-60 cm) than in July at depths of 20-50 cm, likely due to greater depths with lower overall light availability. However, *P. pectinatus* grew better than *M. spicatum* in May in both the temporary and permanent lakes. This result suggests that the better growth of *P. pectinatus* may be because of the decreased light availability for *M. spicatum*. *M. spicatum* partly compensated for this by producing fewer branches with greater total shoot lengths in response to low light (Barko and Smart, 1981; Barko *et al*., 1982) (Table 2, permanent lake).

Light is a strong determinant of colonization depth for submerged macrophytes; however, high irradiances can also induce plant stress, and aquatic macrophytes appear more sensitive than terrestrial plants to high light events (Rae *et al*., 2001; Hanelt *et al*., 2006; Hussner *et al*., 2010). This phenomenon may also explain the improved growth rates of *M. spicatum* over *P. pectinatus* in July, with decreasing water depth/increasing irradiance in the temporary lake. This suggests that *M. spicatum*, because it produced a terrestrial form, may be better able to tolerate high irradiances than *P. pectinatus.* By contrast, Beard (1973) found that thin-leaved *Potamogeton* species are resistant to winter drawdown, whereas the *Myriophyllum* species is not resistant (Smith and Barko, 1990). This finding supports the result of the previous study that found a larger biomass of *P. pectinatus* than *M. spicatum* in May in the temporary lake. Therefore, drying may also be a tool to decrease the competitive capacity of *M. spicatum* in favor of *P. pectinatus.* Furthermore, *P. pectinatus* tubers can sprout at temperatures as low as 5.5°C (Van Wijk, 1983), indicating that *P. pectinatus* can establish its biomass from tubers early in the season, and when the temporary lake is flooded in the spring, *P. pectinatus* can rapidly reach a high biomass. Therefore, winter drawdowns in the temporary lake may be most efficient way to recreate conditions favorable for the growth of *P. pectinatus.*

The nutrient composition of the sediment was sufficiently high for the growth of macrophytes. Phosphorus concentrations in the river and lake sediments are generally high due to the capacity of sediments to bind phosphorus on particle surfaces and as minerals with calcium, iron and aluminum (Clarke and Wharton, 2001). By contrast, nitrogen is a small component of lake sediment because sediments are depleted of nitrogen more rapidly than phosphorus, due to the smaller exchangeable pools of nitrogen buffering the plant-available nitrogen in the interstitial water (Barko *et al*., 1991). The nutrient levels in sediment were also different in both lakes. In the temporary lake, the TP and TN were higher in July than in May, whereas in the permanent lake, both the TP and TN were higher in May than July. The sediment became anaerobic because of the rich organic component due to the decomposition of macrophytes in July in the temporary lake. In anaerobic conditions, nutrients become more available for plant growth. For example $PO^{-3}{}_4$, Fe^{+2}, and Mn^{+2} ions are released from the sediment and NO^{-3} is reduced to $NH^{-}{}_4$ (Patrick, 1960; Patrick and Khalid, 1974). Therefore, the TP and TN content of the sediment were higher in July than in May in the temporary lake, but the differences between the season were not significant (P=0.340 and P=0.900, respectively, two-way ANOVA). By contrast, the TP and TN decreased in July due to macrophyte growth in the permanent lake. However, the decreased TP and TN in July in the permanent lake sediment were not significant (Table 4) because macrophyte roots in the lake only occur in the top layer of the sediment. Therefore, because of the upward capillary flux of nutrients, the nutrient loss in the top layer of sediment was partially compensated (De Groot and Van Wijk, 1993).

Conclussion

Management of aquatic plants by reduction of water levels, particularly in shallow lakes and irrigations canals, has been conducted for many years (DSI, 2009). In Miccosukee Lake (USA), after water levels had been reduced for 8 months, the submersed macrophyte biomass remained relatively low (Pieterse and Murphy, 1990). According to the present study, the growth rates of *P. pectinatus* may be controlled by employing water level reduction in Turkish shallow water systems. On the other hand, water level reduction may cause the replacement of sensitive species by tolerant plants (Pieterse & Murphy, 1990). In the present study, *M. spicatum* has been found dominant in July in temporary lake, where the water level was low.

Tab. 4: Results of the two-way ANOVA.

ANOVA	Source	DF	F	P
M. spicatum (biomass)	lake	1	2.63	0.114
	season	1	5.80	0.000
	interaction	1	5.46	0.026
P. pectinatus (biomass)	lake	1	32.33	0.000
	season	1	3.11	0.087
	interaction	1	167.0	0.000
pH	lake	1	0.53	0.472
	season	1	113.44	0.000
	interaction	1	0.98	0.328
Conductivity	lake	1	2.90	0.098
	season	1	134.45	0.000
	interaction	1	3.77	0.061
DO	lake	1	3.34	0.077
	season	1	481.36	0.000
	interaction	1	3.34	0.077
NH_4-N	lake	1	0.94	0.339
	season	1	23.46	0.000
	interaction	1	0.72	0.404
NO_3-N	lake	1	4.13	0.051
	season	1	95.23	0.000
	interaction	1	0.09	0.766
SRP	lake	1	0.06	0.801
	season	1	18.58	0.000
	interaction	1	2.15	0.153
Chl*a*	lake	1	25.02	0.000
	season	1	112.63	0.000
	interaction	1	9.24	0.005
Temperature	lake	1	27.67	0.000
	season	1	441.20	0.000
	interaction	1	0.97	0.331
Longest shoot (*M. spicatum*)	lake	1	584.01	0.000
	season	1	0.38	0.543
	interaction	1	62.69	0.000
Longest shoot (*P. pectinatus*)	lake	1	340.62	0.000
	season	1	18.48	0.000
	interaction	1	57.34	0.000
Lateral shoot no (*M. spicatum*)	lake	1	57.89	0.000
	season	1	47.55	0.000
	interaction	1	35.34	0.000
Lateral shoot no (*P. pectinatus*)	lake	1	0.00	1.00
	season	1	43.36	0.000
	interaction	1	0.24	0.62
TP (sediment)	lake	1	5.43	0.026
	season	1	0.94	0.340
	interaction	1	0.63	0.432
TN (sediment)	lake	1	2.84	0.101
	season	1	0.02	0.900
	interaction	1	3.06	0.09

As a result, *P. pectinatus* may outcompete *M. spicatum* in both lakes in May and in the permanent lake in July. By contrast, the competitive capacity of *P. pectinatus* decreased due to the drying of the temporary lake in July. Because of its ability to produce a terrestrial life form, *M. spicatum* grows better in July in the temporary lake. Detailed and long-term studies, under both laboratory and field conditions, are required to fully understand the competition between these two species in different types of lakes.

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