

Dynamics of the reedbed at the interface of *Typha angustifolia* and *Phragmites australis* patches

Results for 2018 and 2019

Report within the framework of
LIFE Project "Prespa Waterbirds"
LIFE15 NAT/GR/000936



Tour du Valat
May 2020



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Proposed citation: Grillas P. & Sakellarakis F.-N. 2020. Dynamics of the reedbed at the interface of *Typha angustifolia* and *Phragmites australis* patches: Results for 2018 and 2019. Report within the LIFE15 NAT/GR/000936 Bird conservation in Lesser Prespa: benefiting local communities and building a climate change resilient ecosystem. 32 pp.

Abstract

Aim: During the last 35 years, large scale changes have been observed in the reedbed communities of Prespa National Park (PNP), especially around the area of Vromolimni. More specifically, narrowleaf cattail (*Typha angustifolia* L.) has largely encroached upon common reed [*Phragmites australis* (Cav.) Trin. ex Steud.] stands. In previous works with field research and experiments, we hypothesized that (1) the underlining cause was disturbance events and (2) in the absence of disturbance *P. australis* should outcompete *T. angustifolia*. The aim of this work is to assess if the expansion of *T. angustifolia* against *Phragmites australis* is still an ongoing process or conversely if *P. australis* is increasing its extension at the expense of *T. angustifolia*.

Methods: 10 transects, 30 m each, were established at the interface of the dominant vegetation types and were marked with metal piles. On each transect, the same 30 quadrats (0.4 X 0.4m) were sampled in 2018 and 2019. The structure of the helophyte vegetation (for each species the density of living and dead shoots, the height and basal diameter of the tallest shoot), the water level, and the species composition of vegetation (cover estimated for each taxon) were recorded in each quadrat.

Analyses: The change in the number of quadrats occupied by each species between 2018 and 2019 was tested using Wilcoxon non-parametric analysis of variance. Analysis of variance for repeated measures (MANOVA) with post hoc tests (LSD Fisher) were applied to test changes between years in the parameters of the structure (density, shoot diameter and height). The effect of topography on changes in the parameters of structure was tested using nested variance analysis. All analyses were performed with Statistica software.

Results: 2018 and 2019 were contrasted years, the latter being characterized by a severe drought and extensive wildfires throughout most of the reedbed. *P. australis* showed an overall 14% increase in the number of quadrats occupied (+27) between 2018 and 2019. Conversely, *T. angustifolia* showed a 7% decrease (-14). The structure of the populations of *P. australis* and *T. angustifolia* showed significant differences between years and between sites. The density of *P. australis* had more than doubled between 2018 and 2019 but with large differences between sites. In contrast the density of *T. angustifolia* decreased by 29% with also large differences between sites. The decrease trend for shoot height was similar for both species but smaller for *P. australis* (-28%) than for *T. angustifolia* (-35%). Similarly, the basal shoot diameter decreased by 13% for *P. australis* and 18% for *T. angustifolia* with large differences between sites for both species. Although large differences between sites were found in these changes, no correlation could be found between the changes in density of *Typha* and *Phragmites* and these changes were not significantly related to water depth (topography and hydromorphy).

Main conclusions: The observed trends in quadrat occupancy by *P. australis* and *T. angustifolia* are consistent with our previous hypothesis of recolonization of *P. australis*. However, Prespa reedbeds experienced unpredicted disturbance with large scale impact of snowfall, wildfires and severe drought. The interaction between these factors are probably responsible for the lack of correlation between topography (and thus hydromorphy) and the parameters of the structure of the populations for both species. The results of the monitoring in 2020 are needed to confirm 2019 results.

Keywords: *Phragmites australis*, common reed, *Typha angustifolia*, Prespa National Park, reedbed, ecotone, vegetation dynamics, reedbed encroachment, vegetation management

1. Introduction

The Common reed [*Phragmites australis* (Cav.) Steud.] and the Narrow-leaf cattail (*Typha angustifolia* L.) are among the most common species in tall helophytes wetland communities and are found in a wide range of conditions (soil, climate and nutrients). Both species tend to establish monospecific stands along lake shorelines resulting in a strong zonation pattern. This zonation results from the interplay between plant traits and various environmental factors among which hydrology and nutrients are the most frequent drivers (review in Grillas et al. 2018). During the last 30 years, changes at the helophyte vegetation of Lesser Prespa, NW Greece, have occurred, and more specifically around the area of Vromolimni (Figure 1). In this area narrow leaf cattail encroached against the common reed. During the same period the fluctuation of the water level of Lesser's Prespa has been reduced after the creation of a sluice on the river that connects Lesser and Great Prespa while, in addition, the intensity of agriculture was strongly intensified resulting in a high nutrient inflow.

Physico-chemical factors are usually found as the main determinants of plant distribution in wetlands (e.g. Hutchinson 1975, Spence 1982, Duarte & Kalff 1986). Water depth have been identified as the main environmental factor selecting species on their total height, and thus access to air, and tolerance to flooding constraints (Seabloom et al. 2001, Sorrell & Hawes 2010, Sorrell, Tanner & Brix 2012). Other abiotic factors can play a role, notably wave energy, soil. However, clonal growth and high biomass favours establishment of plant communities heavily dominated by a single species (e.g. *Phragmites australis*, *Typha* spp., *Scirpus* spp.) where competition plays an important role (Grace & Wetzel 1982, Wilson & Keddy 1985, Weisner 1993). Grazing can modify the outcome of competition and influence zonation patterns.

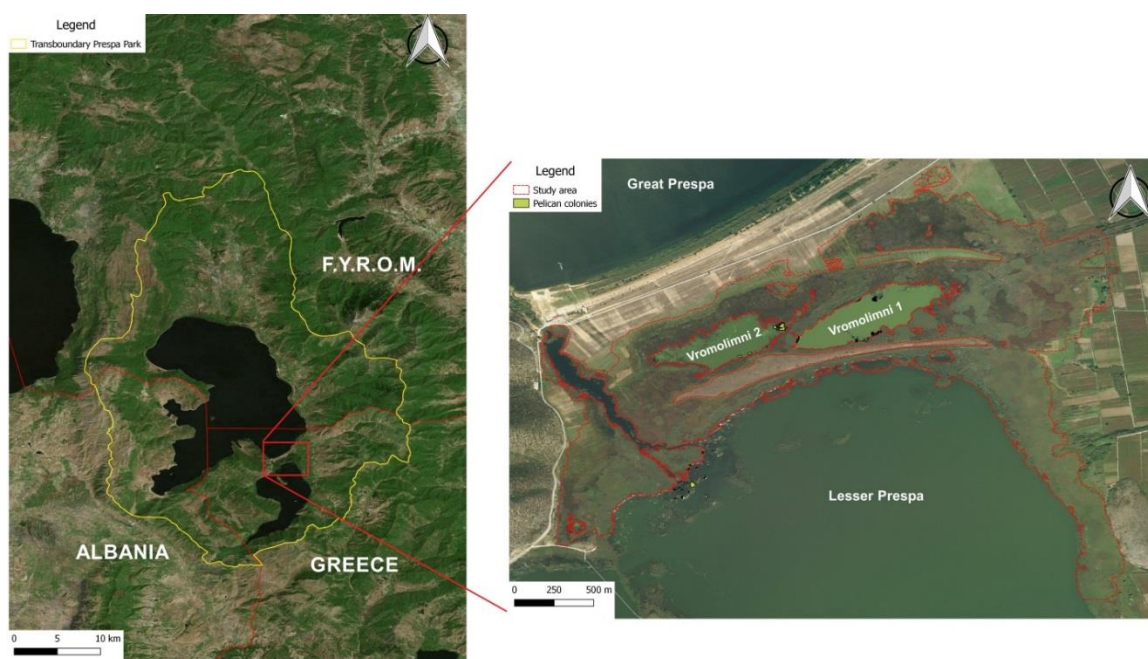


Figure 1. Study area.

The conclusions of previous works searching for the potential causes of the encroachment of *T. angustifolia* in *P. australis* stands (Grillas *et al.* 2018; Sakellarakis *et al.* 2018; Sakellarakis & Grillas, 2019) were the following:

- The depth distribution of *P. australis* and *T. angustifolia* did not differ across the stations studied;
- Although some differences in soil chemistry were found between stations, no significant relationship could be documented between the two main dominant species;
- The nitrogen and phosphorus content of *P. australis* and *T. angustifolia* plant tissues did not differ significantly, further suggesting that nutrient status is not a key variable for explaining the dominance of species;
- The structure of the reedbed (density, height, diameter of shoots) suggests competitive interactions but did not allow identifying a competitive hierarchy;
- The floristic composition of the companion species only marginally differed between reedbed types;
- Therefore, the remaining hypothesis to explain *T. angustifolia* encroachment is a major disturbance which may have killed large areas of *P. australis*. The severe drought experienced by the lake in 1989 – 1990 could be such an event. The highest water level observed the following year could further explain *T. angustifolia* establishment: this species produces many more seeds than *P. australis* and their seedlings are more tolerant to flooding. Once established, *T. angustifolia* can prevent the germination of *P. australis*. However, the latter is expected to be more competitive than *T. angustifolia* and should have recolonized the lost area by lateral (vegetative) growth. Frequent fires may stop and reverse this succession. This hypothesis has been supported with field experiments that showed that long flooding after wildfire events or cutting results in strong decrease of the density of *P. australis* culms and can significantly modify all of its important structural parameters (Sakellarakis & Grillas, 2019).
- More work is needed to understand the dynamics of the reedbeds in the Vromolimni area. It will include experimental management, monitoring of the interaction between *T. angustifolia* and *P. australis* by field measurement and drone survey.

In this perspective, the general objective of this work was to monitor the dynamics of the reedbed at the interface of *Typha* and *Phragmites* patches in order to identify a potential spatial trend of these two species and identify the competitive dominance at the interface of their patches.

The specific objectives were to answer the following questions / hypotheses:

- In absence of disturbance is *Phragmites* encroaching on *Typha* dominated stands?
- Is the structure of *Typha* population showing a declining trend (decreased density, height and diameter of shoots) possibly resulting from competitive dominance of *Phragmites*?

2. Methods

2.1. Site selection

Twelve transects, in blocks of three, were randomly selected at the interface of *Phragmites australis* and *Typha angustifolia* dominated patches (Figure 2). On each station a 30m permanent transect was established in 2018 and disposed in order to include approximately

3 different zones, (1) a pure stand of *P. australis*, (2) a pure stand of *T. angustifolia* and (3) a mixed zone at their interface.

On every sampling station, the start and the end of each transect was marked with an iron bar and their coordinates taken using a handheld GPS (Garmin 64 Map).

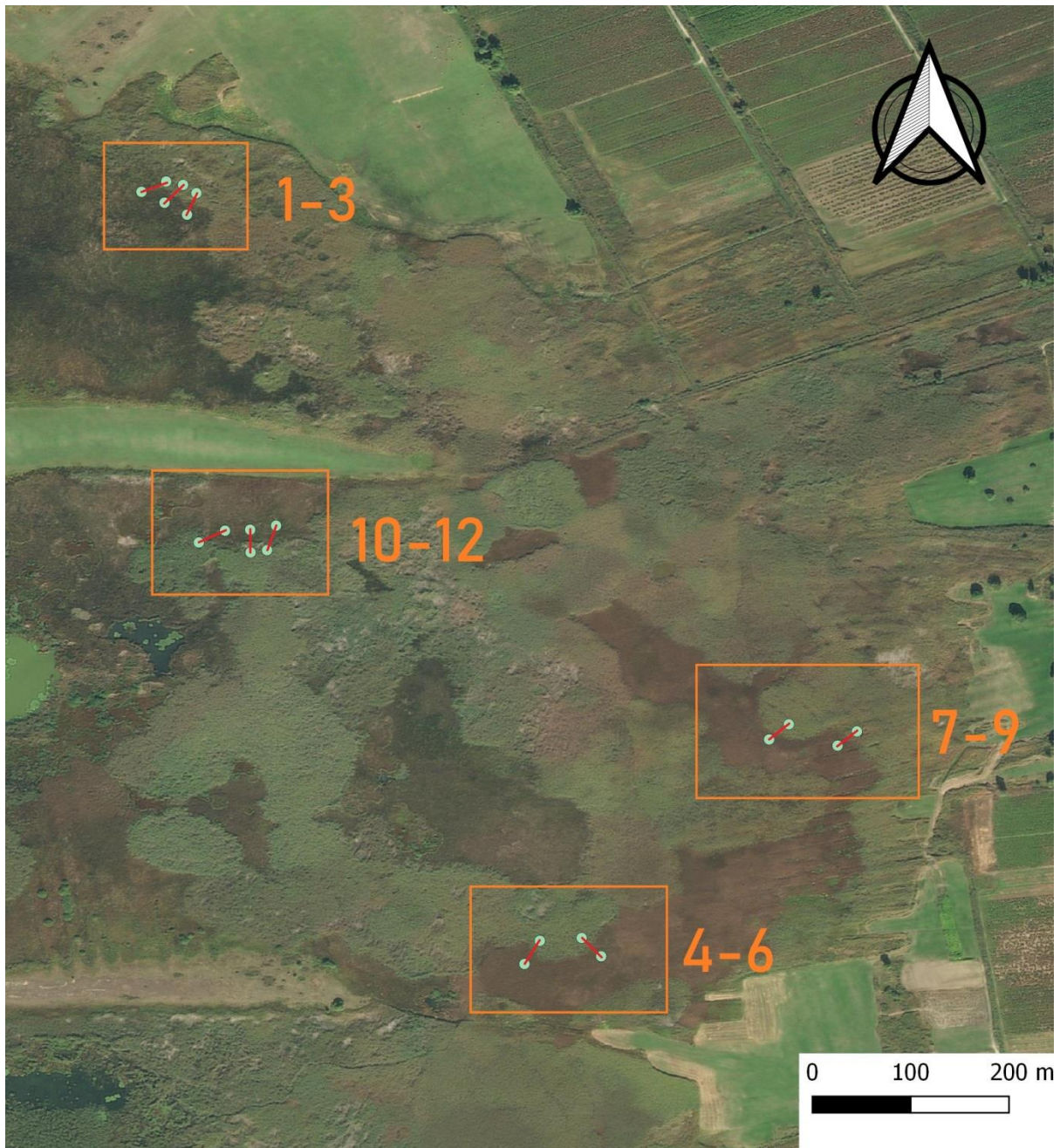


Figure 2: Location of the transects.

2.2. Vegetation measurement

On each transect the structure of the reedbed was measured on 30 quadrats (0.4 X 0.4m) placed every meter. In these quadrats were measured the number of living and of dead shoots of *Phragmites australis* and *Typha angustifolia*, and for each of these species the total height and the basal diameter (measured about 10cm above soil surface) of the tallest shoot. In

addition, the cover of all living plant species in the quadrat was estimated according to a modified Braun Banquet scale (1964; see Grillas et al. 2018). When present, water depth was measured on every quadrat.

2.3. Environmental conditions

According to Giannakis *et al.* (2011), the climate of Prespa area can be characterized as subcontinental-continental. The average yearly temperature is 11.1 °C (average maximum: 23.3 °C, average minimum: 11.7 °C) while the total yearly rainfall is 516.3 mm (Koula meteorological station). The dry season lasts for 80 days starting in the end of May until the end of August (Figure 3).

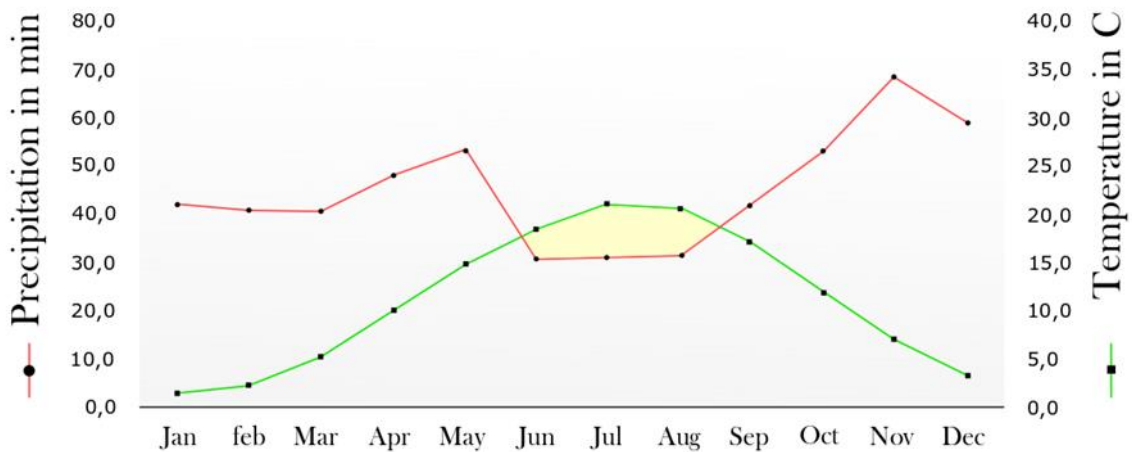


Figure 3. Ombrothermic diagram of Prespa area
(Data from the meteorological station of Koula, period: 1965-2002).

During winter 2018 an extreme event of snowfall was recorded which resulted in heavy damaged across the whole reedbed vegetation of Lesser Prespa. On the 19th of November 37 mm of snowfall together with 8.5 mm of rainfall were recorded at the Agios Germanos rain gauge (SPP data, unpublished); the average yearly snowfall is 61.1 mm (Agios Germanos meteorological station, available data: 1965-2002). This event which had an effect on all sampling stations broke the standing stems of *Phragmites* (Photo 1) and additionally transformed the *Typha* stands with the creation of a closed and compact layer of dead biomass.



Photo 1. Effect of November's 19th snowfall on the structure of the reedbed.
(Photo credit: G. Catsadorakis)

It has to be noted that 2019 was a very dry year, with the water level of Lesser Prespa reaching a very low level especially during the period mid-March until the end of July (Figure 3), a critical period for the growth of the characteristic halophyte species that compose the reedbeds of Prespa.

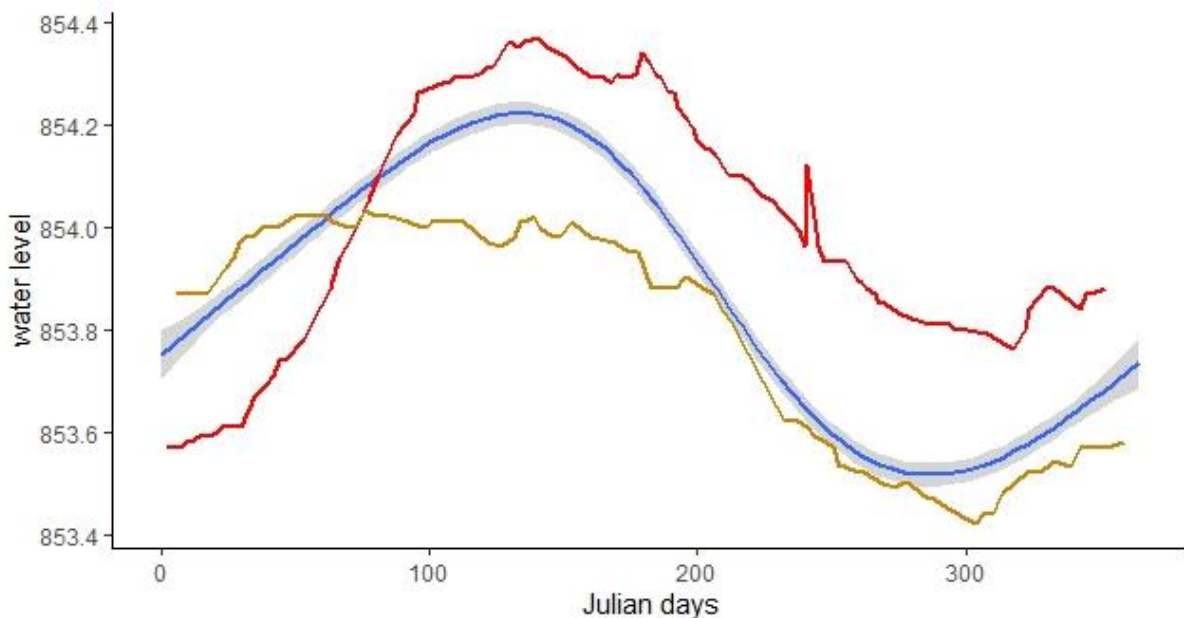


Figure 3. Water level (m) of Lesser Prespa during 2018 (red) and 2019 (dark yellow); Julian day 0 is the 1st of January. Water level fluctuations from 1995 are depicted. Blue line corresponds to the mean and grey intervals to the standard error.

Additionally, during winter-spring 2019 large scale fire events occurred in the reedbeds of Lesser Prespa (Photo 2) resulting in 300 hectares of burnt reedbed (Figure 4; Willm, 2019). All sites, except transect 10, 11 and 12 were affected by these wildfires, even though not in the same degree. Transect 9 was partially burnt.

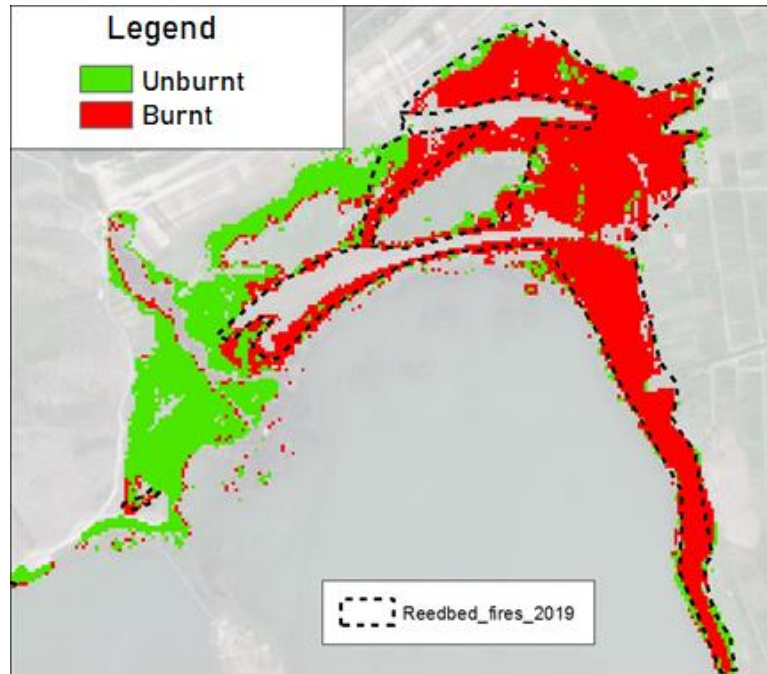


Figure 4. Burnt areas (red) during the large wildfire events that occurred in Prespa during winter-spring 2019 (from Willm 2019).



Photo 2. Burnt reedbeds in the area of Vromolimni, Sloggi and Slatina Laimou (Photo: Lazaros Nikolaou, 14th of February 2019).

2.4. Data analysis

Due to the intense wildfires that occurred in early 2019, two transects (T5 and T8) were not possible to be relocated, thus only 10 transects were further used for the data analyses.

2.4.1. Physical expansion of the *Phragmites* and *Typha* along permanent transects.

For each species (*Phragmites australis* and *Typha angustifolia*) the number of quadrats occupied in 2018 and 2019 were compared and identified for each quadrat as +1 when a new quadrat was occupied in 2019 compared to 2018, -1 when the species disappeared from that quadrat and "0" when no change occurred (remained empty or remained present both years). The sum of the values per quadrat was calculated as the net budget of increases and decreases. A Wilcoxon non-parametric analysis of variance for paired samples was used to compare the trends of *Phragmites australis* and *Typha angustifolia* over the 10 transects.

2.4.2. Dynamics of the structure of the reedbed between 2018 and 2019

The parameters of the structure studied were for each species the density of living shoots, and the height and shoot diameter of the dominant (tallest) living shoot per quadrat. Previous work in Prespa reedbeds showed that these parameters are strongly correlated between them for each species and are good descriptors of the structure of the reedbed for both species (Grillas et al. 2018). The shoot density values per quadrat were transformed ($\sqrt{\text{density}}$) for variance analyses in order to meet the distribution assumptions while no transformation was needed for the height and the basal diameter of shoots.

The variations between 2018 and 2019 of the parameters of the structure for *Phragmites australis* and *Typha angustifolia* were studied using analysis of variance for repeated measures (MANOVA) where quadrats were considered as samples within transects. Only quadrats where the species was present in at least one year were used in order to reduce the number of zero values and prevent bias in mean values. In these MANOVA the effects tested were the Year, Transect and their interaction. When significant differences were found, a post hoc test (LSD Fisher) was performed for pair comparisons.

2.4.3. Drivers of change in the structure of reedbed

The relationships between the changes in the structure of the *Phragmites* and *Typha* communities was studied using three variables for each species constructed on the difference per quadrat between 2019 and 2018 in the shoot density, the height and the basal diameter of the tallest shoot (value 2019 - value 2018). The relationships between these variables and independent variables were tested using nested variance analysis where the independent variable is nested in the Transect effect. This procedure does not allow for testing several variables at the same time therefore the analysis was repeated using the variables water depth in 2018 (a proxy of relative topographic location at the edge of the lake) and the density and height of *Typha angustifolia* in 2018 to explain the changes in the structure of *Phragmites* populations. Similarly, the effects of water depths and of the density and height of *Phragmites* in 2018 were tested on the structure variables of *Typha angustifolia* populations.

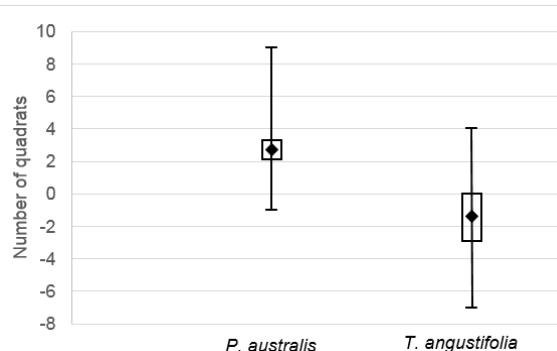
3. Results

3.1. Physical expansion of *Phragmites* / *Typha* along permanent transects

Phragmites australis and *Typha angustifolia* showed weak but contrasting trends between 2018 and 2019 (Table 1). *P. australis* was present on 188 quadrats in 2018 and 215 quadrats in 2019 (+27 quadrats, i.e. 14% increase). The number of quadrats occupied by *P. australis* was higher in 2019 in 8 / 10 transects, with one transect showing no change (T1) and a small decrease on one transect (T2). *T. angustifolia* was present in 2018 on 207 quadrats and on 193 quadrats in 2019 (-14, i.e. 7% decrease). The number of quadrats occupied by *T. angustifolia* decreased on 7 transects, remained stable on 1 transect and increased on 2 transects.

Table 1. Variation between 2018 and 2019 in the number of quadrats occupied by *Phragmites australis* and *Typha angustifolia* in each transect and the cumulated sum of these changes; The figure shows the mean (diamond), the quartile (25-75%: box) and the full range of values for each species.

Transect	<i>P. australis</i> (nb quadrats)	<i>T. angustifolia</i> (nb quadrats)
1	0	-7
2	-1	1
3	3	-1
4	2	4
6	9	-2
7	3	0
9	2	-3
10	5	-2
11	2	-1
12	2	-3
Sum	27	-14



The trend in the number of quadrats occupied between 2018 and 2019 differs significantly between *P. australis* and *T. angustifolia* (Wilcoxon for paired samples, $Z = 2.497271$, $T = 3$, $p = 0.012516$). However, no correlation was found between the changes in the number of quadrats occupied by both species between 2018 and 2019 (Spearman $R = -0.006331$; $p > 0.05$).

No spatial pattern and no correlation with water depth was found with the changes in the number of quadrats occupied by *P. australis* (water level: $F = 0.9667$, $p = 0.354$) or *T. angustifolia* (water level: $F = 0.1173$, $p = 0.740$).

3.2. Structure of the reedbed

The density, height and basal diameter of shoots of *Typha angustifolia* and *Phragmites australis* on each quadrat are shown for each transect in Annex 1.

Phragmites australis

The density of living shoots of *Phragmites australis* was significantly higher in 2019 than in 2018 with a significant effect of the Transect and of the interaction Transect X Year (Table 2a, Figure 5a). The mean density of living shoots had doubled in 2019 (from 4.1 to 8.4 shoots/quadrat) with large differences between transects. The increase was the largest in

transects 3- 2- 1 (respectively +296%, +271%, +158%, $p < 10^{-7}$). The increase of density between 2019 and 2018 were smaller but significant for T6 ($p = 0.000036$) and T12 ($p = 0.000081$) (pair comparisons, post hoc LSD test Fisher) and not significant for other transects (T4, T7, T9 and T10) (Table in Figure 5).

The height of shoots of *P. australis* was significantly smaller in 2019 (mean= 3.0m) than in 2018 (mean: 4.1m) with a significant effect of the Transect and of the interaction Transect X Year (Table 2b, Figure 5b). The difference between years was significant for each transect ranging from -12% (T10) to -43% (T3, $p < 10^{-7}$) (Table in Figure 5). There was no significant relationship between the height decrease per station with the topographic level (i.e. water level in 2018).

The basal diameter of shoots was significantly different in 2019 (mean: 9.14mm) than in 2018 (10.5mm) with a significant effect of the Transect and of the interaction Transect X Year (Table 2c, Figure 5c). The relative difference between years ranged from +6% (T12, the only positive value but difference not significant $p = 0.92$) to -25% (T3, $p = 0.0026$). The differences between years were significant for 6 transects T1, T3, T4, T7, T9 and T11 (Table in Figure 5).

Table 2. Results of the MANOVAs testing for the effects of Year, Transect and their interaction on the variation between 2018 and 2019 of a) shoot density, b) Height and c) basal diameter of shoots of *Phragmites australis*.

a) Density					b) Height				
Effect	SC	D. of freed.	F	p	Effect	SC	D. of freed.	F	p
ord. origine	1544.430	1	529.99	0.000000	ord. origine	4473.764	1	14358.76	0.000000
transect	86.922	9	3.31	0.000719	transect	84.515	9	30.14	0.000000
Erreur	845.081	290			Erreur	54.525	175		
YEAR	61.933	1	115.43	0.000000	YEAR	112.720	1	546.12	0.000000
YEAR*transect	30.036	9	6.22	0.000000	YEAR*transect	12.427	9	6.69	0.000000
Erreur	155.597	290			Erreur	36.121	175		

c) Diameter				
Effect	SC	D. of freed.	F	p
ord. origine	34206.18	1	9270.93	0.000000
transect	1106.92	9	33.33	0.000000
Erreur	641.99	174		
YEAR	152.22	1	43.02	0.000000
YEAR*transect	62.35	9	1.96	0.046885
Erreur	615.62	174		

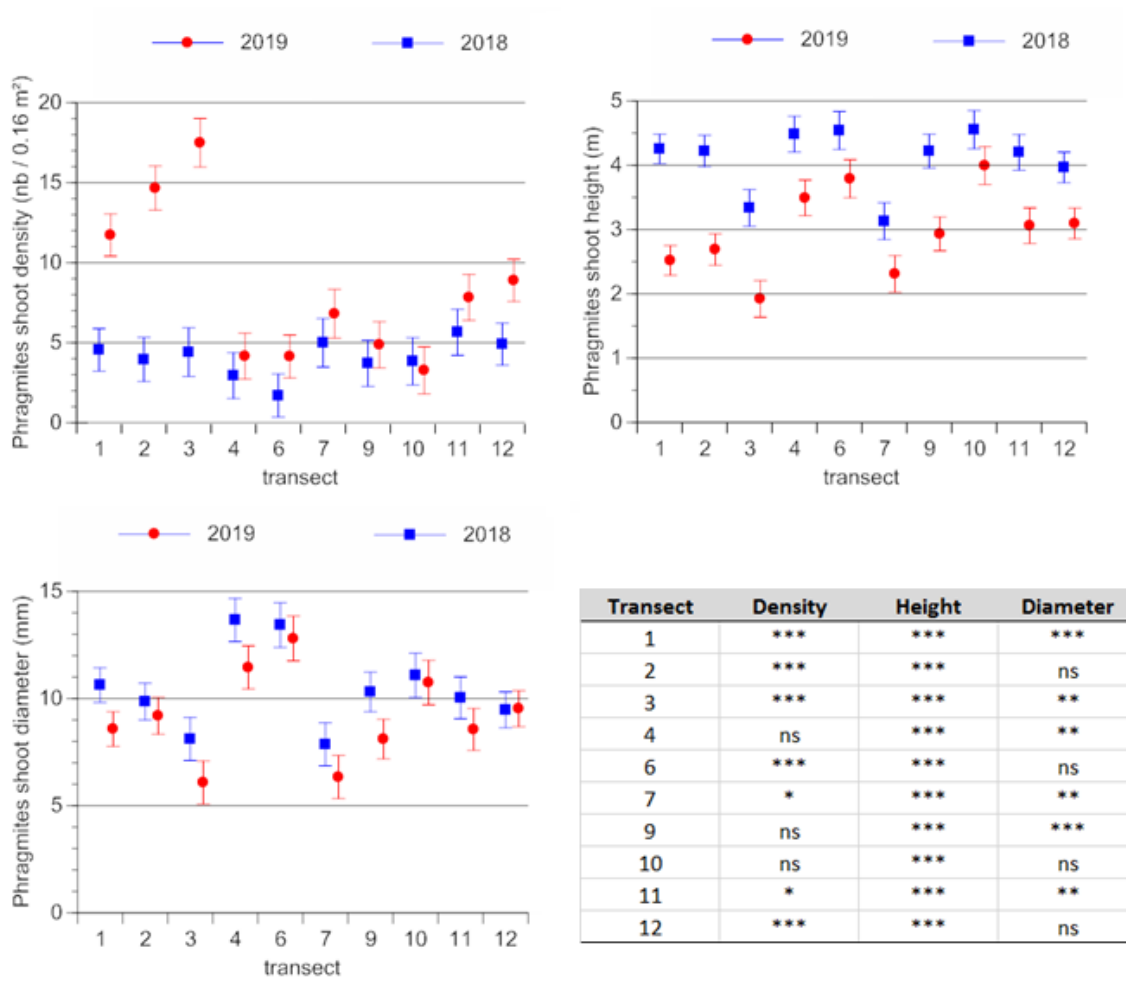


Figure 5. Mean values and confidence limits (95%) per transect for the density of shoots, the height and the basal diameter of shoots of *Phragmites australis* in 2018 and 2019 on the permanent transects; the table indicates significant differences between years for these three variables.

Typha angustifolia

The density of living shoots of *Typha angustifolia* was significantly smaller in 2019 than in 2018 (from 4.6 shoots /quadrat to 2.9 shoots / quadrat) with a significant effect of the Transect and of the interaction Transect X Year (Table 3a, Figure 6a). The change in the density of living shoots of *T. angustifolia* between 2018 and 2019 ranged from +11% (T10, difference not significant $p= 0.624$) and – 69% (T1, $p < 10^{-7}$) (mean -29%); the differences were significant only for 5 transects, T1, T2, T3, T7 and T9 (Table in Figure 6).

The height of shoots of *T. angustifolia* was significantly smaller in 2019 (1.9m) than in 2018 (3.0m, i.e. 35% reduction in height) with a significant effect of the Transect and of the interaction Transect X Year (Table 3b, Figure 6b). The difference between years was significant for each transect except T10 (but close from significant $p= 0.075$) and ranged from -7% (T10) to -70% (T3 where *Typha* shoots did not reach 1m total height in 2019) (Figure 6).

The basal diameter of shoots of *T. angustifolia* was significantly smaller in 2019 (mean: 14.7mm) than in 2018 (mean 17.9mm) with a significant effect of the Transect and of the interaction Transect X Year (Table 3c, Figure 6c). The difference between years ranged from +38% (T10, $p= 0.000029$) to -59% (T3, $p < 10^{-7}$) and the trends contrasted between transects T1, T2, T3 and T7 where the basal diameter was smaller in 2019 than in 2018 and Transects T10 and T12 where the diameter was larger in 2019 (Figure R2). Transects T4, T6, T9 and T11 do not show any significant trend between 2018 and 2019.

Table 3. Results of the MANOVAs testing for the effects of Year, Transect and their interaction on the variation between 2018 and 2019 of a) shoot density, b) Height and c) basal diameter of shoots of *Typha angustifolia*.

a) Density					b) Height				
Effect	SC	D. of freed.	F	p	Effect	SC	D. of freed.	F	p
ord. origine	1775.61	1	1413.926	0.000000	ord. origine	2105.31	1	25140.80	0.00
transect	44.41	9	3.929	0.000122	transect	22.91	9	30.40	0.00
Erreur	263.72	210			Erreur	14.24	170		
YEAR	28.48	1	85.629	0.000000	YEAR	100.51	1	1071.01	0.00
YEAR*transec	26.99	9	9.018	0.000000	YEAR*transec	46.10	9	54.58	0.00
Erreur	69.84	210			Erreur	15.95	170		

c) Diameter				
Effect	SC	D. of freed.	F	p
ord. origine	92193.21	1	3696.097	0.000000
transect	1278.80	9	5.696	0.000001
Erreur	4240.38	170		
YEAR	826.07	1	54.994	0.000000
YEAR*transec	2773.72	9	20.517	0.000000
Erreur	2553.58	170		

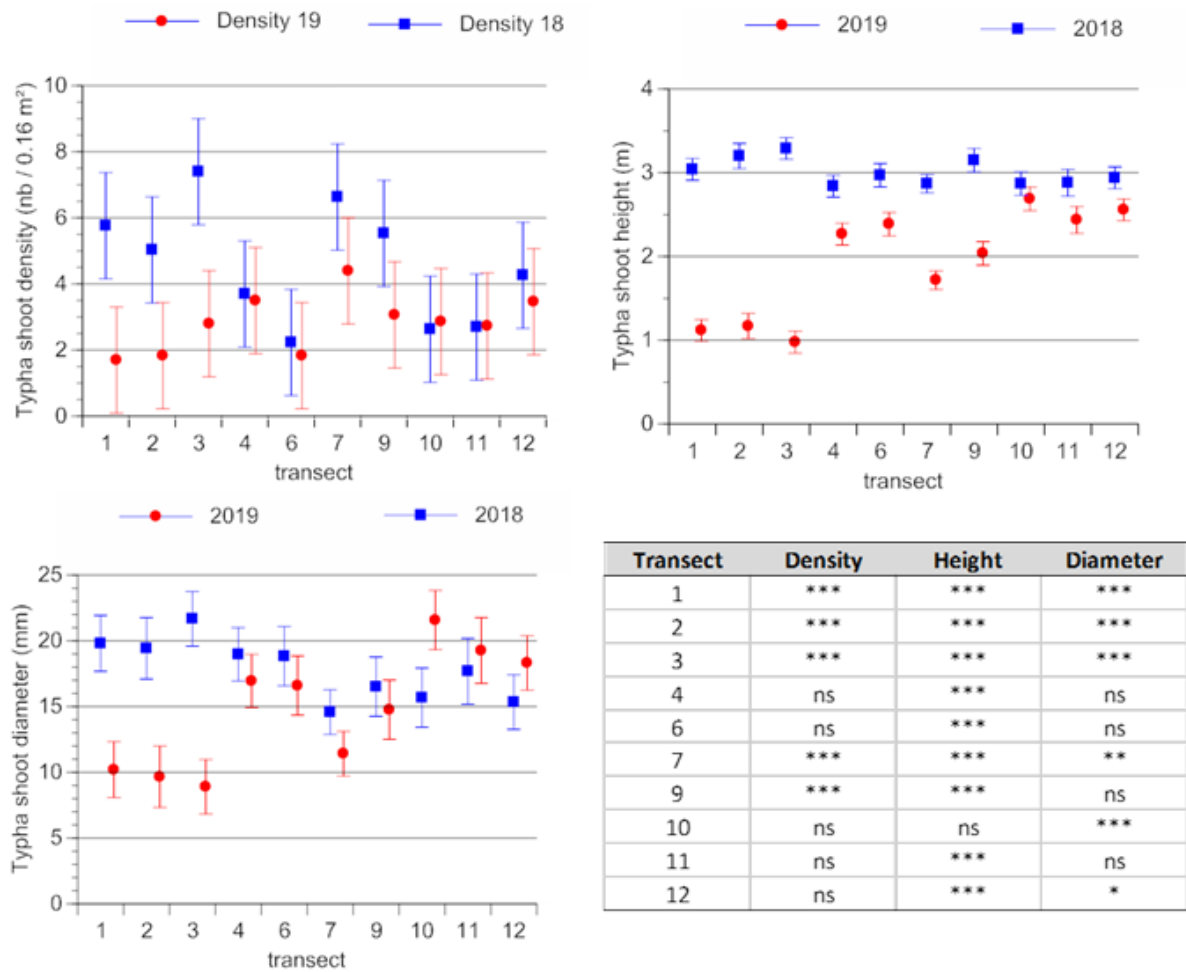


Figure 6. Mean values and standard deviation per transect for the density of shoots, the height and the basal diameter of shoots of *Typha angustifolia* in 2018 and 2019 on the permanent transects; the table indicates significant differences between years for these three variables.

3.3. Drivers of change in the structure of reedbed

The first 2 axes of the correspondence analysis (CA) explain respectively 31 and 28% of the total variance (Figure 7). With only 14% of variance explained axis 3 is very close to the threshold for significant axis and is not further considered in the analysis. On the biplot ½ the variables related to the changes between 2018 and 2019 of the structure of *Typha* populations are negatively correlated with axis 1 and those related to *Phragmites* are correlated to axis 2 except the density of living shoots (PA-L). This variable is weakly positively correlated to both axes and opposed to the variables related to *Typha*. The orthogonal respective positions of *Typha* and *Phragmites* variables suggest weak correlations between them. The water level is weakly negatively correlated to axis 1 and weakly positively correlated to axis 2. The position of the water level variable is intermediate between *Phragmites* and *Typha* variables.

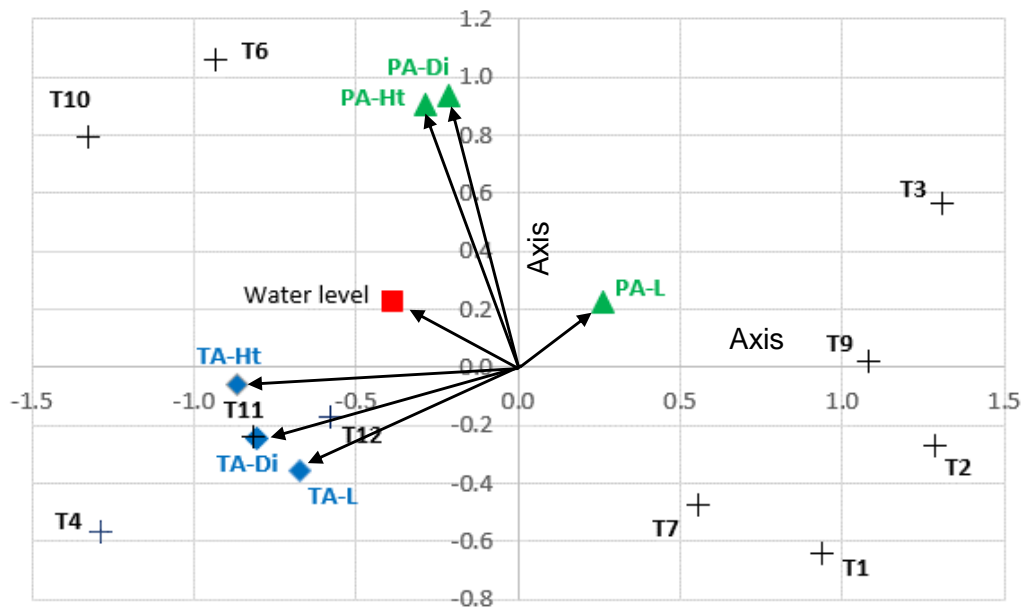


Figure 7. Projection of stations (transects) on biplot 1 / 2 of the Correspondence Analysis showing the transects (T1 - T12), the variables of the structure of the reedbed (PA for *Phragmites australis*, TA for *Typha angustifolia*, L= density of living shoots, Ht= height of the tallest living shoot per quadrat and Di= diameter of the tallest living shoot per quadrat, and Water level. The variables related to the structure of *Typha* and *Phragmites* are measuring changes between 2018 and 2019 (variable= value 2019-value 2018, see Methods section).

Axis 1 on the CA separates two groups of transects (T1-T2-T3) and (T7-T9) from the 5 other transects (Figure 7). This contrast corresponds to the amplitude of changes in structure variables between years, the largest changes being recorded on the positive side of axis 1. The coordinates on axis 1 of the different transects gather transects from the same area (see Figure 2) while on axis 2 the coordinates are more dispersed. The topographic position of the transects (Water level variable) shows little weight in this analysis.

4. Discussion and preliminary conclusions

The two years of monitoring were contrasting; 2018 was a “normal” year while 2019 accumulated potential causes of disturbance for the reedbed. During November heavy snow laid down the shoots of *P. australis* and *T. angustifolia*. At the end of winter large parts of the reedbeds (including 9 out of our 10 monitoring transects) were totally or partially burnt by wildfires. Finally, the severe drought the lake experienced during the same year, probably facilitated the wildfires spread.

In this context Reed and Cattail populations showed in 2019 some changes as compared to 2018 in their extension and their structure.

The extension of Reed and Cattail, measured as the number of quadrats occupied per transect showed contrasting trends but with a small magnitude: *P. australis* was found on 14% more quadrats in 2019 than in 2018 while the number of quadrats occupied by *T. angustifolia* decreased by 7%. Most of these changes occurred at the edges of their populations suggesting

spatial colonization rather than increased density within patches. No spatial pattern was found in the trends of the populations of these two species. However, these trends were not significantly correlated and there is no evidence of a direct relationship between them. Although limited, these changes are consistent with the hypothesis we proposed previously (Grillas et al. 2018) of a competitive dominance of *Phragmites* on *Typha* resulting from their taller shoots.

The changes in the structure of the populations of *P. australis* and *T. angustifolia* between 2018 and 2019 were more important than the changes in their extension. The changes were more important in the density and the height of shoots for both species. The changes in the density of shoots were contrasting between species and between sites. The density of *P. australis* had more than doubled between 2018 and 2019 but with large differences between sites (range +296% - -14%). In contrast the density of *T. angustifolia* decreased by 29% with also large differences between sites (range +11% - -69%). The trend was similar for shoot height with 28% reduction in *P. australis* (range -12% - -42%) and 35% reduction in *T. angustifolia* (range: -7% -71%).

Although large differences between sites were found in these changes, no correlation could be found between the changes in density of *Typha* and *Phragmites* and these changes were not significantly related to water depth (topography and hydromorphy).

The increase of the density of *P. australis* can probably be explained by the wildfires. The short term impact of fire on the *Typha* and *Phragmites* plants is similar to mechanical cutting if soil remains water saturated or flooded.

Many studies have shown that winter harvesting (or fire), results in various impacts on reedbed structure (Table 4):

- An increase in culm density (Ingram *et al.*, 1980; Björndahl 1985; Thompson & Shay 1985; Granéli 1989; Cowie *et al.*, 1992; Ostendorp 1999; Poulin & Lefebvre 2002; Schmidt *et al.*, 2005).
- A decrease in culm height (Ingram *et al.*, 1980; Björndahl 1985; Granéli 1989; Cowie *et al.*, 1992; Ostendorp 1999); however other studies did not find significant differences (Granéli 1989; Schmidt *et al.*, 2005). In a previous experiment, we found no impact of winter harvest on shoot density of *P. australis* when cutting was high enough (1m above soil level) to prevent submergence of cut shoots (Sakellarakis & Grillas 2019).
- No significant effect was found by Poulin & Lefebvre (2002) on culm diameter after winter harvesting, however, a significant decrease of culm diameter was found after summer harvesting by Karunaratne *et al.* (2004).

Fire alone has produced variable results and has even stimulated *Phragmites* growth and stand development (van der Toorn & Mook 1982; Thompson & Shay 1985, Holm 1991). However, fire has little lasting impact on both species unless it reaches underground parts or coupled with either hydrological restoration (Sakellarakis & Grillas, 2019) or herbicide application (Marks *et al.* 1994). The very dry season which followed the wildfires prevented the rise of the water level of the lake and thus the negative impact of submergence of the remaining culms (Motivans and Apfelbaun, 1987, Sinnassamy & Mauchamp 2001). Our results suggest more sensitivity of *Typha* to wildfires than *Phragmites* although the drought is probably an additional interacting factor.

The large differences in the changes in the density of *P. australis* could not be explained by the topography. Fire local intensity could probably play a role (Qianet al. 2009) and be partly

related to hydromorphy but also to the dominant species (dead shoots of *Typha* retains more humidity than those of *Phragmites* thus reducing fire temperature) and stochastic events such as snow fall which may have compacted shoots.

Table 4. Summary of the mean changes between 2019 and 2018 in the density of shoots, the height and the diameter of the tallest shoot per quadrat

Species	Density	Height	Diameter
<i>P. australis</i>	+109%	-28%	-13%
<i>T. angustifolia</i>	-29%	-35%	-15%

The changes in shoot height is similar for *P. australis* and *T. angustifolia* (mean of transect means, respectively -1.12m and -1.08m) and the change in mean height per transect are strongly correlated ($F= 13.346$, $p= 0.0031$). The difference between years in shoot height is however relatively more important for *Typha* with a mean height in 2018 1m smaller than *Phragmites* (3.0m for *Typha* and 4.1m for *Phragmites*). This change between years seems clearly related to the drought and low water level of the lake and *T. angustifolia* was clearly more stressed than *P. australis*. However, the height difference between years of shoots should have been correlated with hydromorphy which is not the case.

The basal diameter of shoots showed the smallest change between years for both species, a decrease of 13% for *P. australis* and 15% for *T. angustifolia*. The magnitude of change was not correlated between species and was not correlated with the water level (= topographic position and hydromorphy).

Conclusions

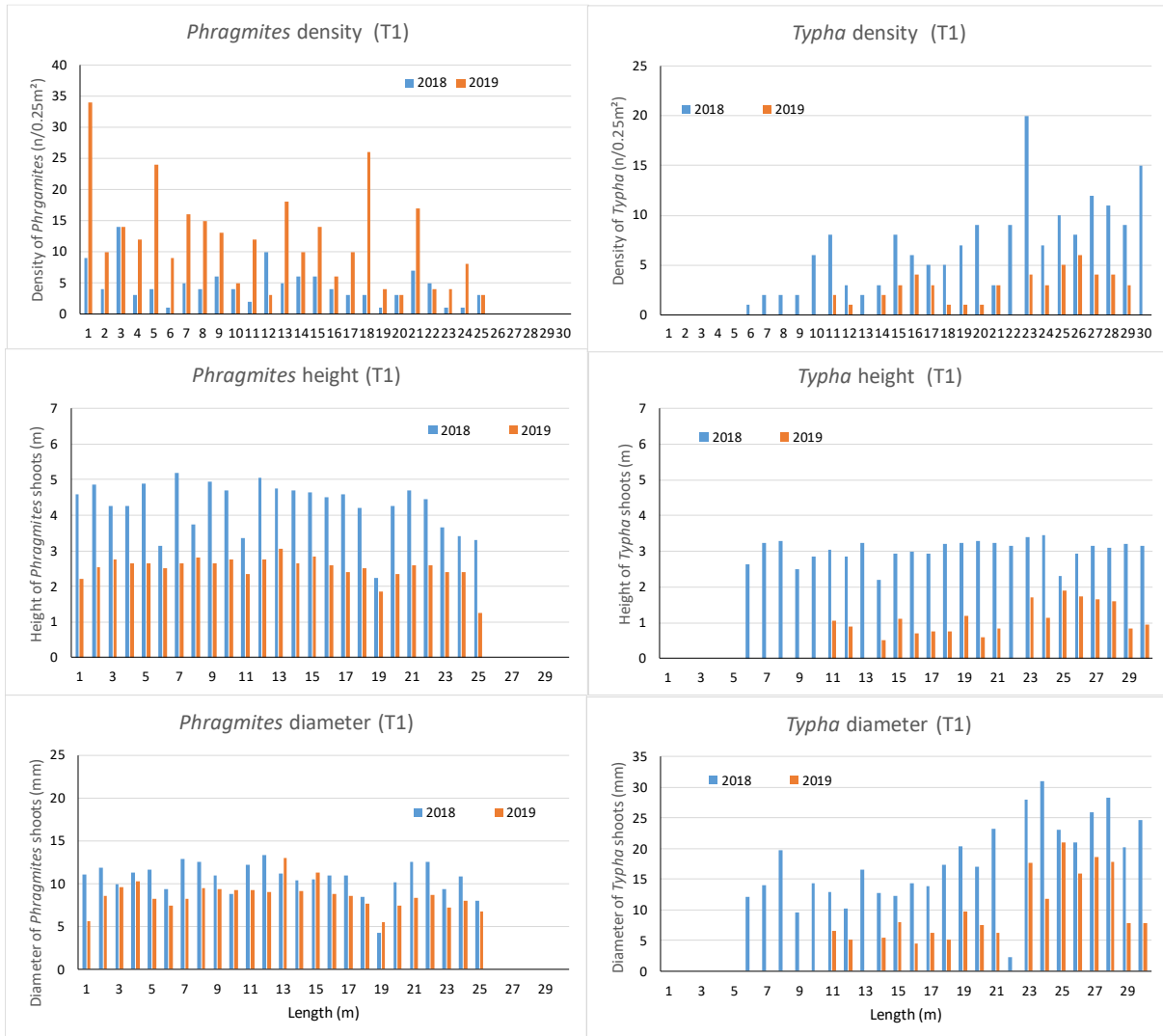
After one year only of monitoring at the interface between *T. angustifolia* and *P. australis* patches, the extent of Common reed increased while that of *T. angustifolia* decreased. This change is consistent with our hypothesis of a higher competition value of *P. australis* in the absence of disturbance. However, disturbances occurred during winter 2018/2019 with both heavy snow bending or breaking shoots, extensive wildfires and a severe drought. These results need to be consolidated with an additional year of monitoring hopefully in more “normal” conditions. However, the water level of the lake remained very low during winter 2019-2020 and the dynamics of vegetation could be more controlled by the adaptation to dry conditions than by the competition between *P. australis* and *T. angustifolia*. Although long-term conclusions cannot be drawn from any given climatic event (2019 drought), climate change adding to water uptake for agriculture will most probably have an increasingly important long-term effect on Prespa lakes water levels and thus on their riparian vegetation (van der Schriek, Giannakopoulos and Varotsos 2020).

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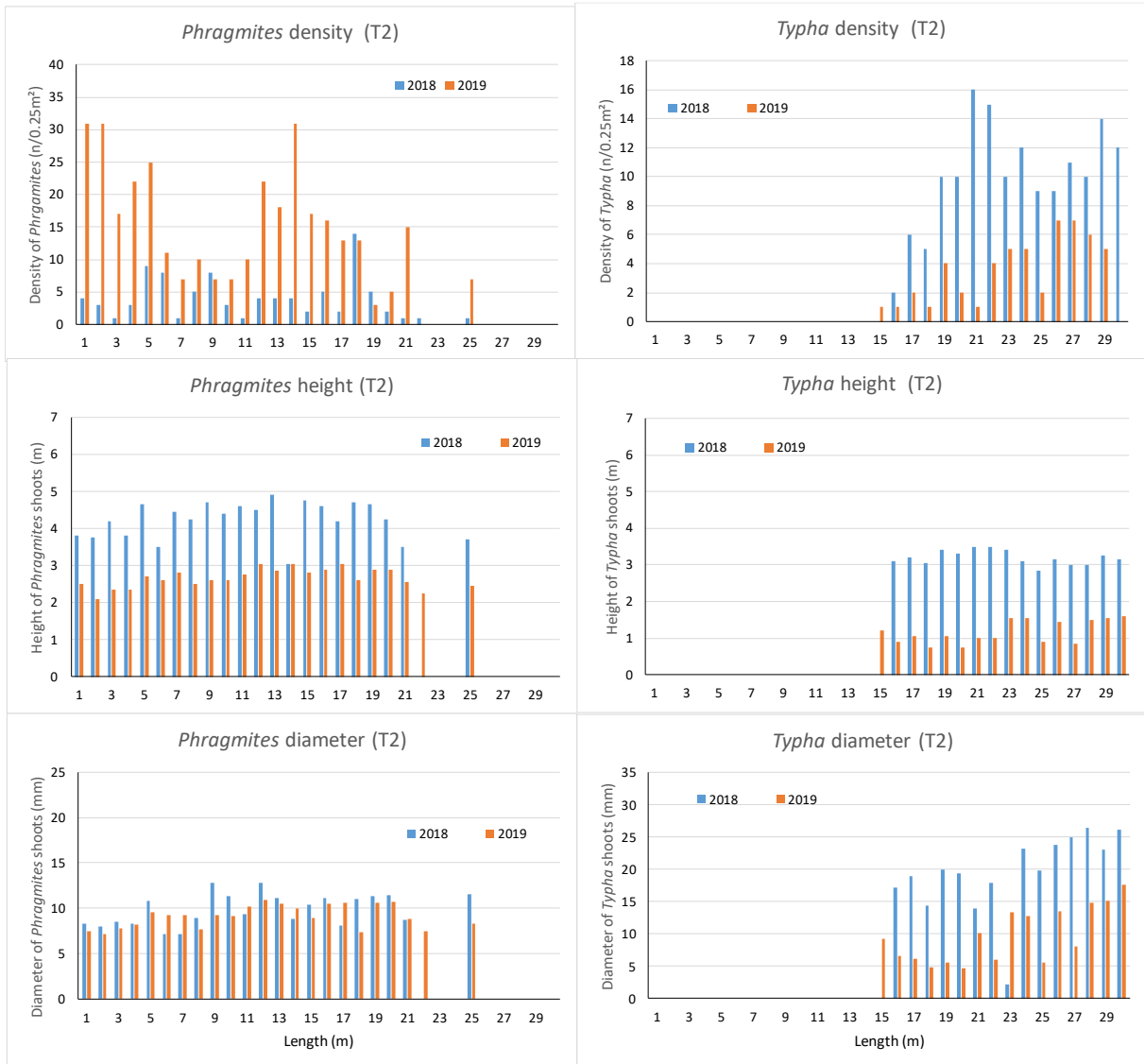
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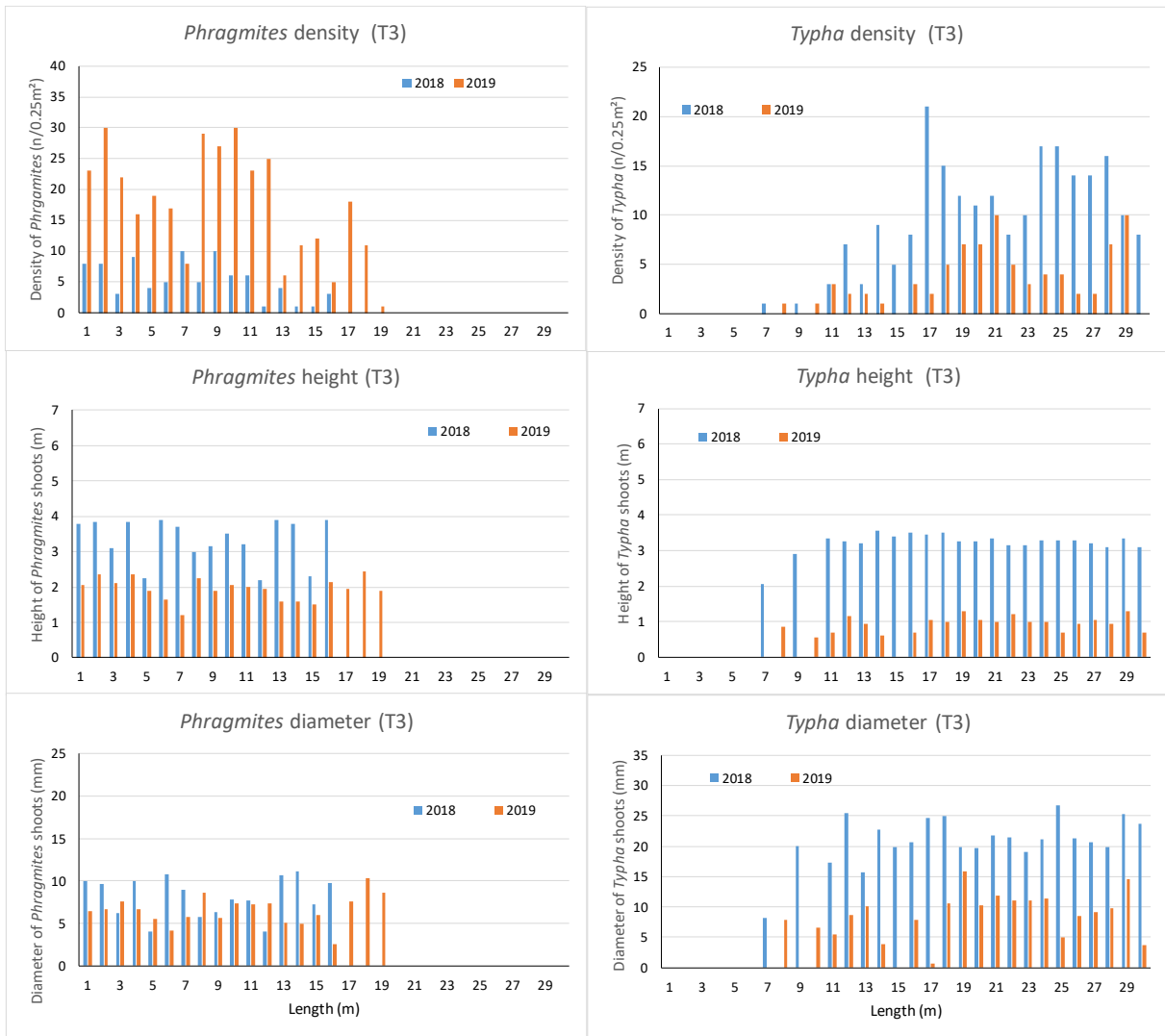
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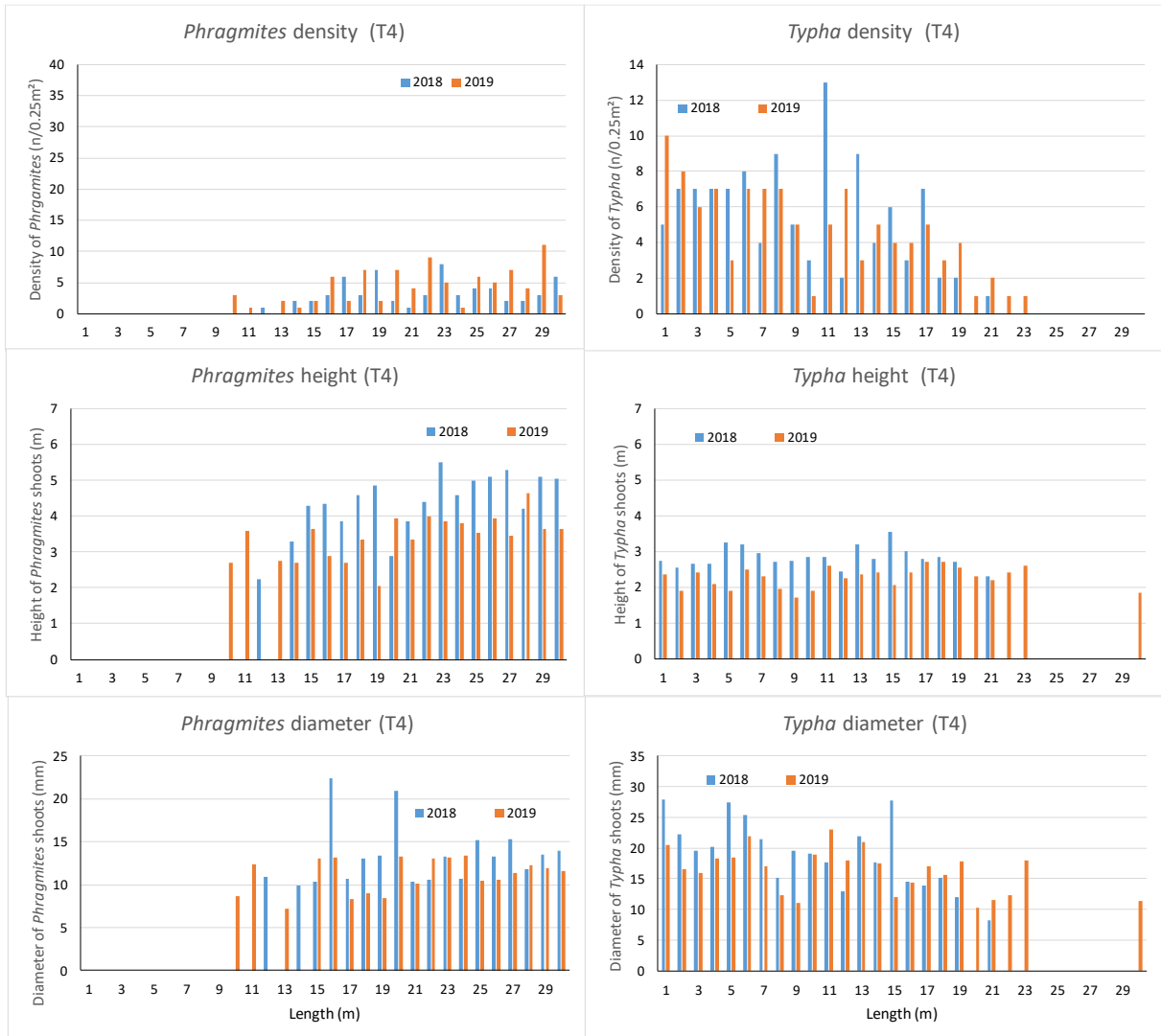
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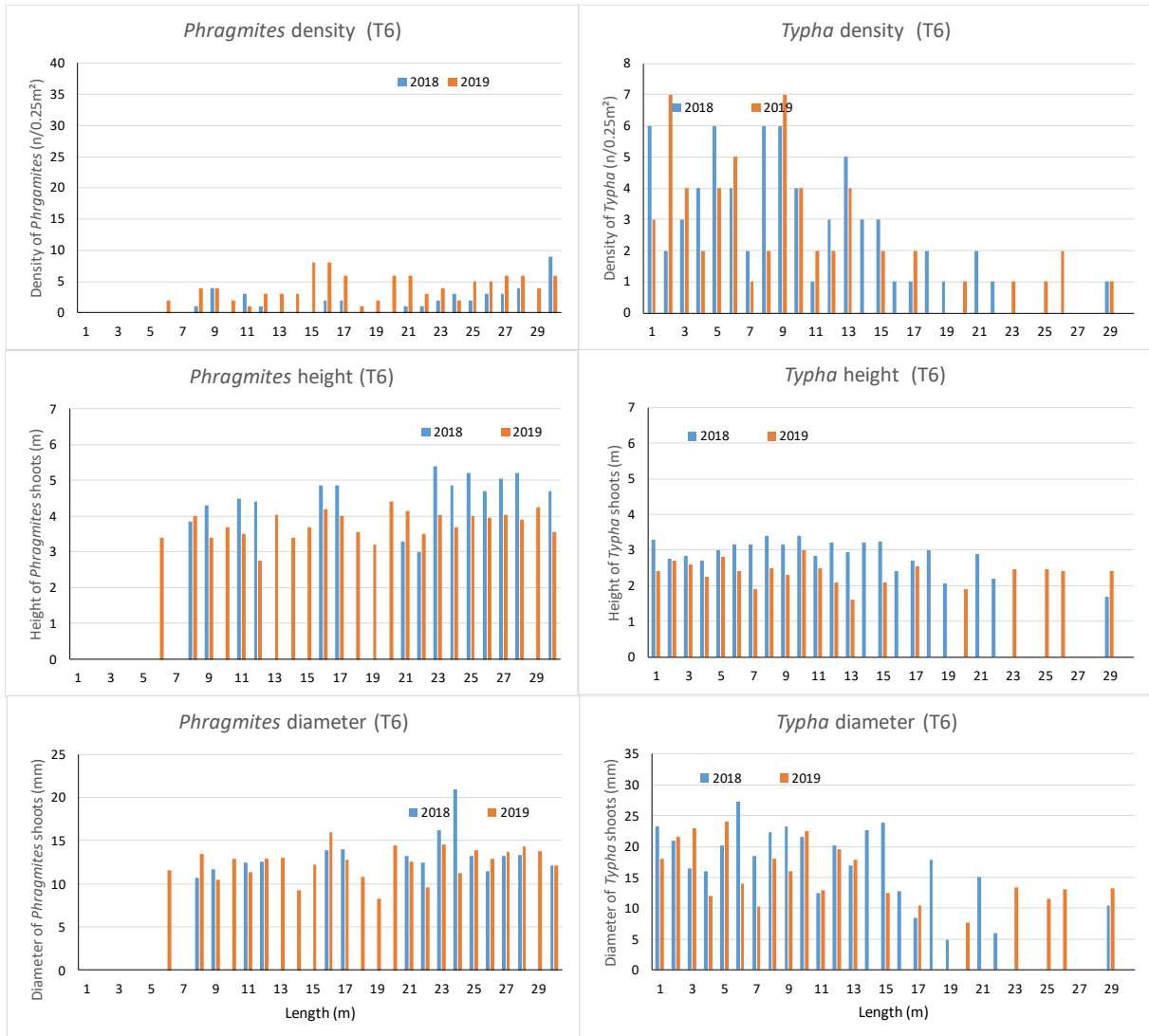
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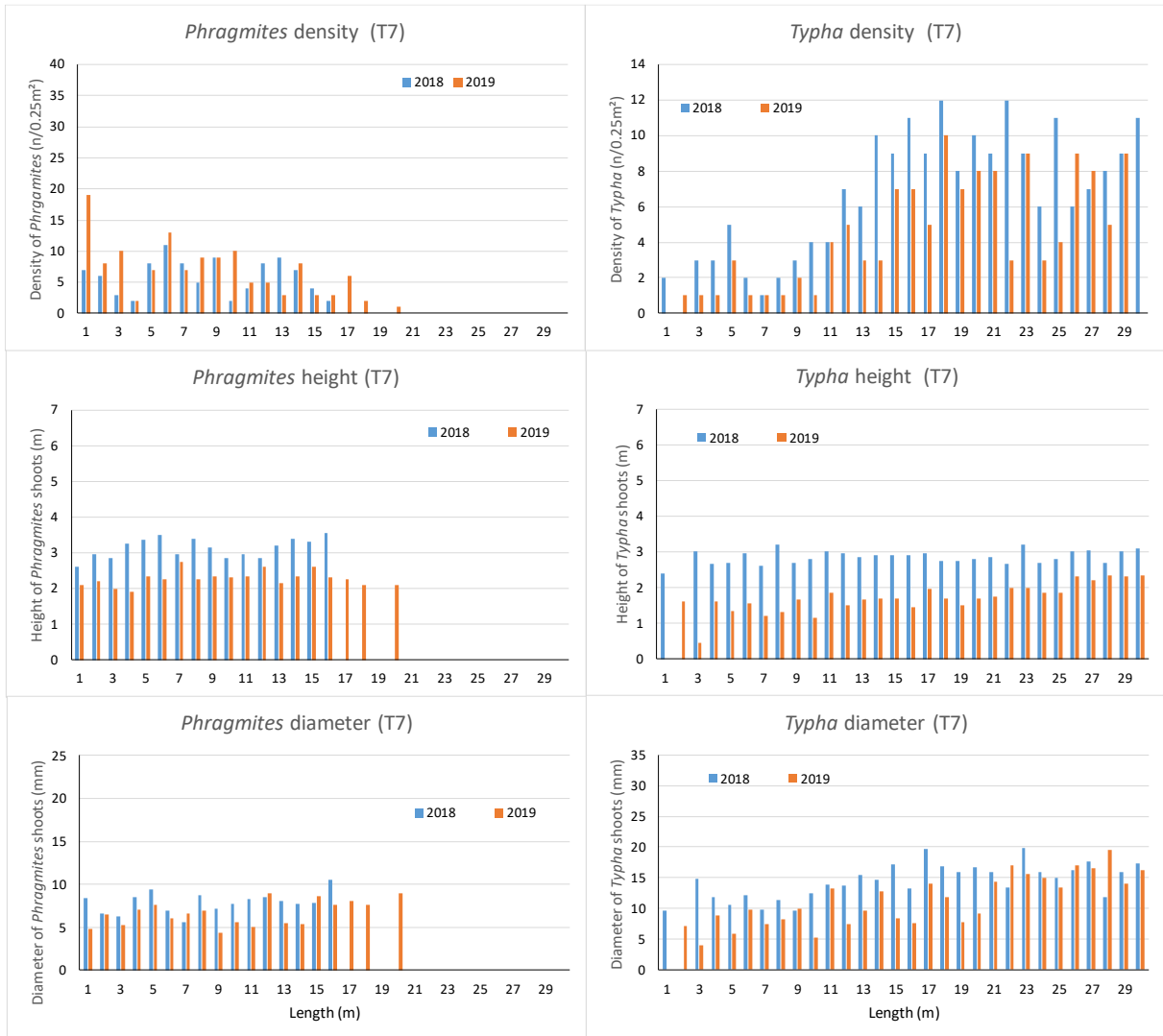
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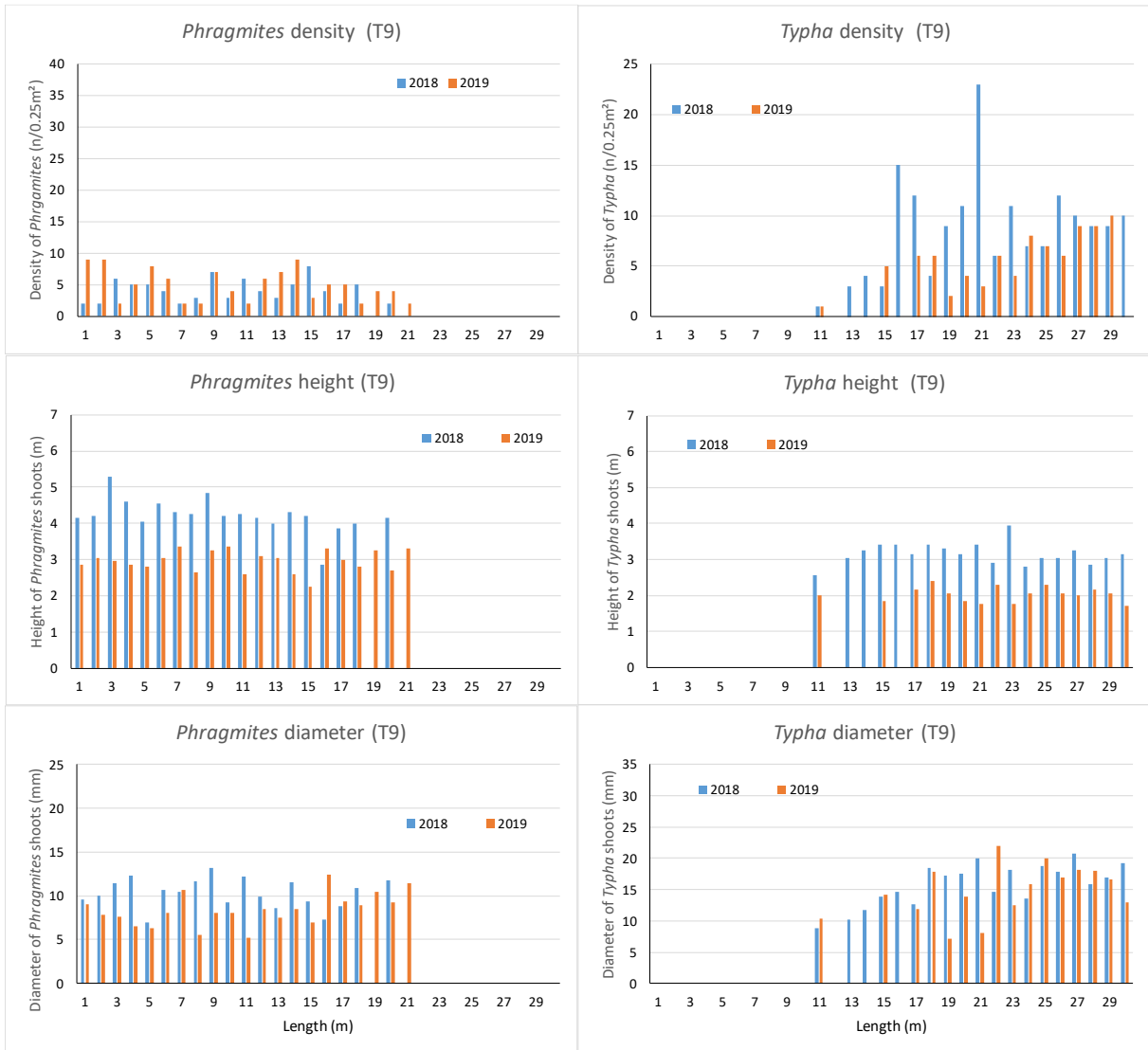
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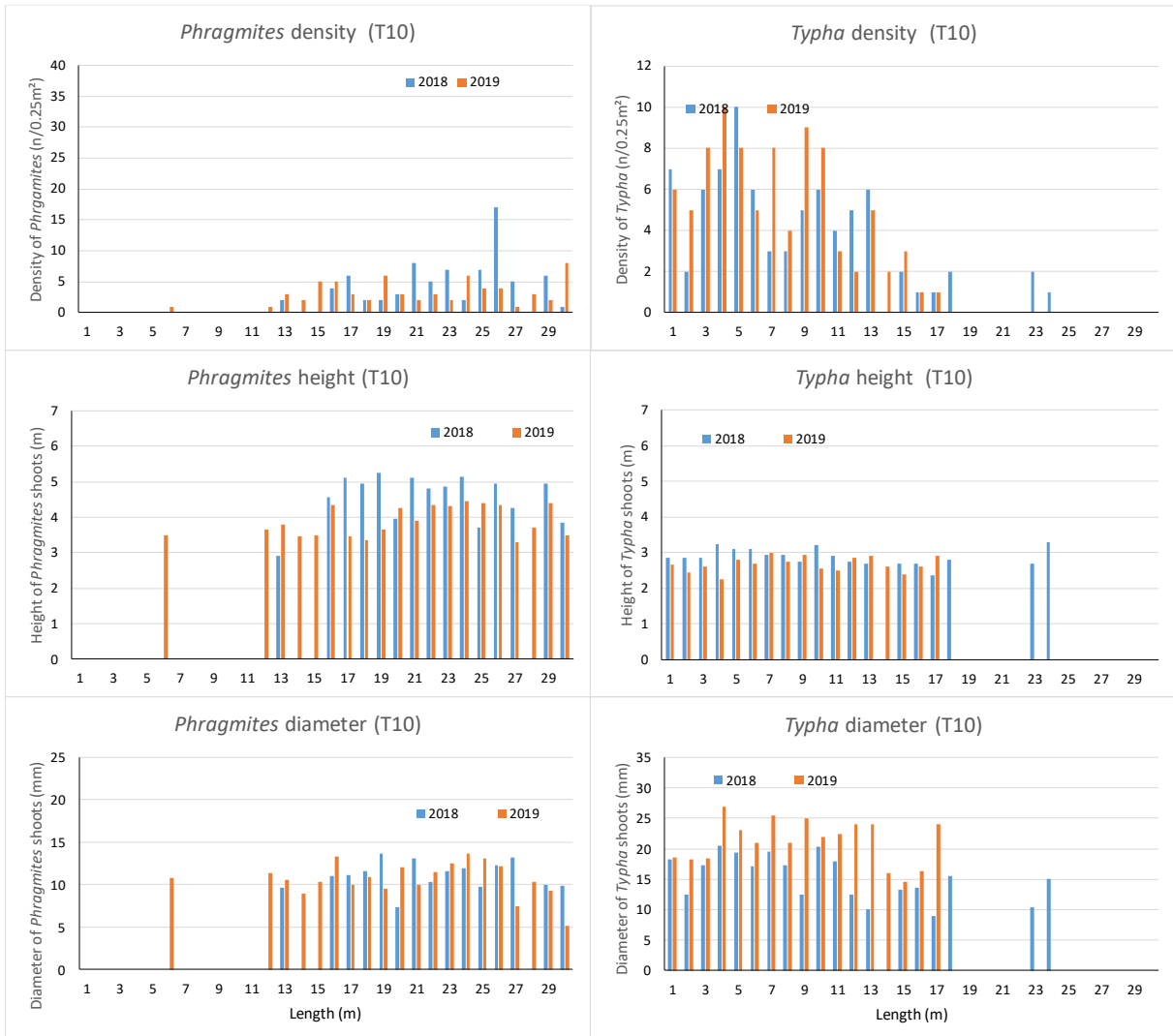
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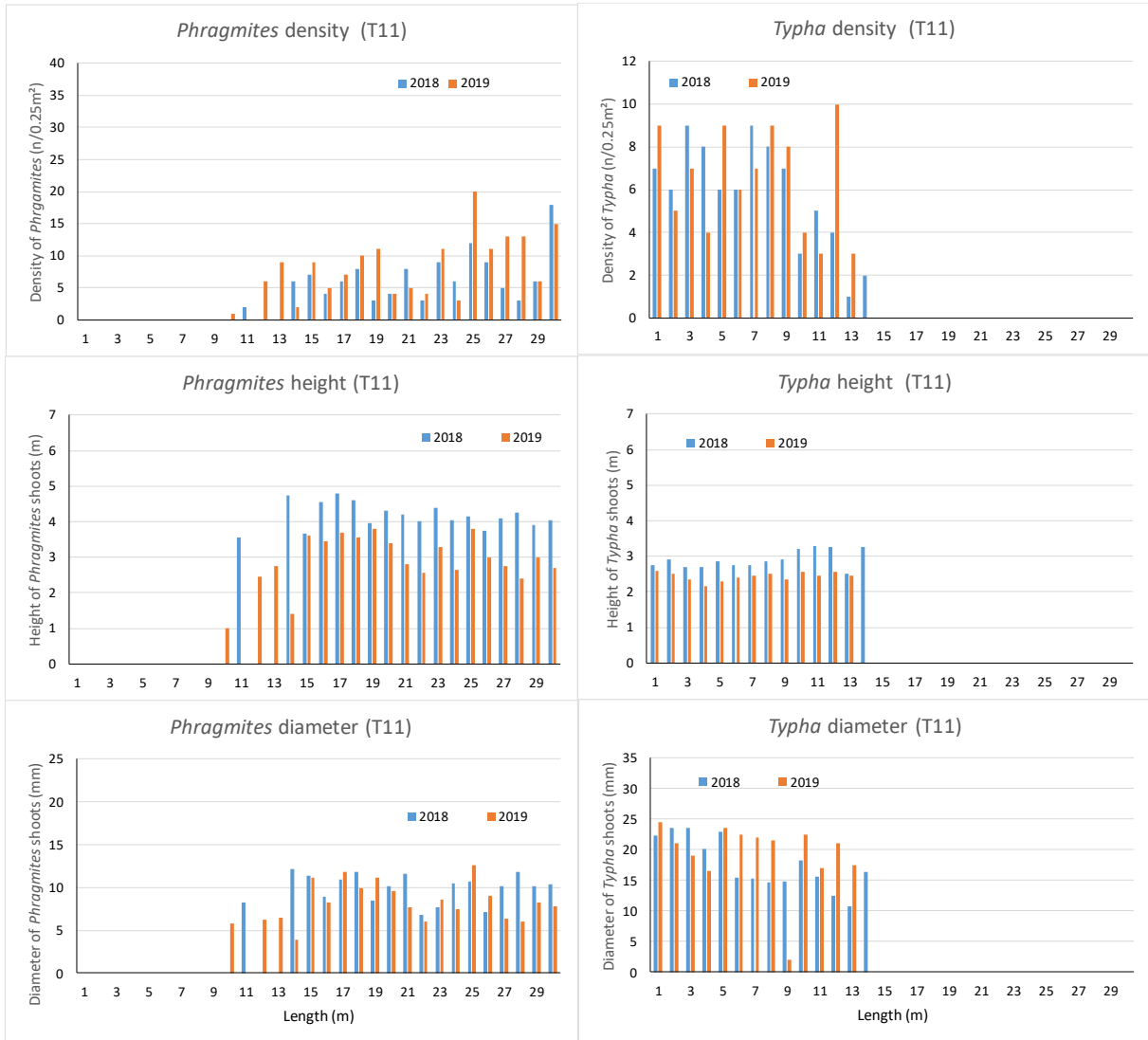
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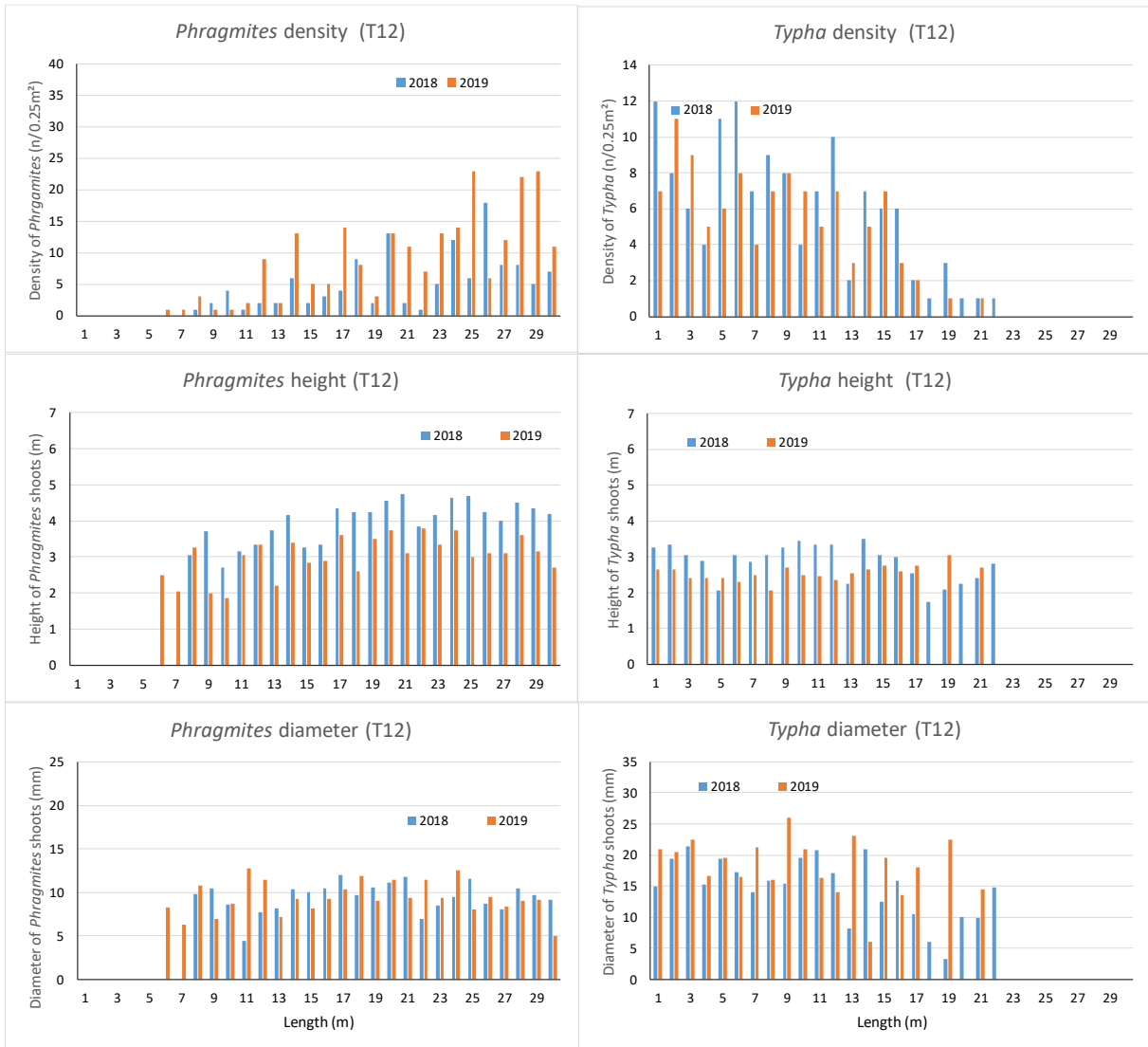
Annex I: Transect 10



Annex I: Transect 11



Annex I: Transect 12



Annex II: Position of the transects (WGS 84 / UTM zone 34N - EPSG:32634)

Transect	Start		End	
	x	y	x	y
1	21°06.132	40°49.167	21°06.115	40°49.164
2	40°49.175	21°06.119	40°49.163	21°06.105
3	40°49.178	21°06.110	40°49.167	21°06.094
4	40°48.617	21°06.422	40°48.629	21°06.411
5	40°48.611	21°06.369	40°48.625	21°06.386
6	40°48.614	21°06.375	40°48.630	21°06.379
7	40°48.767	21°06.609	40°48.767	21°06.595
8	40°48.758	21°06.574	-	-
9	40°48.783	21°06.562	40°48.774	21°06.547
10	40°48.924	21°06.151	40°48.915	21°06.134
11	40°48.926	21°06.168	40°48.911	21°06.172
12	40°48.927	21°06.189	40°48.914	21°06.181