Analyzing Plant Biometrics in Dense Monospecific Reedswamps is Reliable Even by Using Rather Small Sampling Frames

Engineering

KEYWORDS : Equisetum fluviatile, frame size, macrophytes, sampling,shoot density, *Phragmites australis*, wetlands.

Kai Aulio

School of Science and Engineering, Atlantic International University, Honolulu, HI 96813, USA.

ABSTRACT

Sampling of macrophytic vegetation in the coastal reedswamp wetlands can be extremely difficult because the tall and dense plant communities are often impenetrable. Thus the requirement of random placement of the sampling units, or even the possibilities to reach the desired sites can be challenging. The task in collecting or measuring the tall helophytic shoots is laborious, and thus "total" counting or collecting are impossible, as is the use of wide sampling frames. The present study compares the reliability of shoot density determinations in a reedswamp ecosystem with exceptionally high primary production and high clonal shoot densities. The use of circular frame of 400 cm²(1/25 square meters) gave identical results with the standard 1 m² frame. The results were statistically highly significantly uniform in the stands of the Common reed (Phragmites australis) and the Water horsetail (Equisetum fluviatile).

Introduction

Coastal wetlands, dominated by tall gramineous plants are the most productive ecosystems on the earth. But, in spite of their immeasurable value for both the nature itself and for the economy of humankind, wetlands are destroyed all over the world so seriously that the treasures are highly endangered (Mitsch and Gosselink 2000; Maltby and Barker 2009). Studying the dominant macrophytic vegetation is laborious and thus expensive, and that is why efficient methods of sampling and analyses are necessary. A reliable estimation of one growing season's primary production can be obtained by determining the average weight and the density (the number of individuals per unit area) of plants (Kvet and Westlake 1998). The method sounds unequivocal and easy to perform, but in the nature the task is far from simple. The communities of tall herbs (helophytes) are often so dense that moving and working within the stand is difficult, and the use of standard sampling frames is impossible.

The choice of the quadrat area is vital in assuring the reliability of the sampling. In floristic studies, standard practices in determining the minimal frame size are well-known and commonly used (Kent 2012). In determining the density of individuals or separate shoots (ramets, as specified in clonal plants), the area of the sampling quadrat is usually set by the work contribution required or the task that is possible. In very dense stands of clonal plants, "total counting" of the shoot numbers is impossible, even though sets of individuals were tagged to prevent double-counting or miscounting (Kent 2012). Typical reedswamp communities are monospecific and rather uniform, and in such conditions the use of smaller frames is justified (Downing and Anderson 1985).

The present study demonstrates the reliability of small-area, circular frame on determining the shoot (ramet) density in exceptionally productive and dense monocultures of two dominant wetland macrophytes.

Materials and methods

The present study describes the variations in the shoot densities in monocultures of the Common reed *Phragmites australis*(Cav.) Trin ex Steudel and the Water horsetail *Equisetum fluviatile* L. growing in the Kokemäenjoki River delta, western Finland (Northern Europe, 61°34'N, 21°40'E; Aulio 2015).

The densities of the tall helophytic plants were determined at the time of the plants' maximum biomass, i.e. at the end of August 2013. In all the sites, the samples were taken from pure, single-species (monotypic) stands. Samples were taken from the previously determined "Mature-type" successional phase of the conspicuous and both temporally and spatially directed vegetation development of the Pihlavanlahti estuary (successional stages *sensu* Aulio 2014). Thus, the placement of the study sites could not follow all the typical requirements for randomness, as required for quality confirmation in aquatic vegetation. Nevertheless, the actual measurements and determinations in the field as well as the sampling of the plant material within the sites were taken as randomly as possible. There are several requirements in the definition of randomness (Wheater *et al.* 2011), and all the prescriptions that could be taken into account, were followed in the present study.

In the determinations of the shoot density, the number of individual ramets (= individual shoots in clonal plants) were measured within a one square meter (1 m²) sampling frames, as well as smaller, 0.5 m² and 400 cm² frames. The 400 cm² (1/25 m²) frame was made of a floating rubber tube, capable to be opened-sealed inside the very dense monocultures (Figure 1). The role of the size of the sampling frame was compared by using both parametric and non-parametric statistical tests. The statistical analyses used follow Dytham (2011).The terminology used follows Allaby (2012).

Results and discussion

Shoot (ramet) density

The results of the comparisons in shoot densities in the Common reed (*Phragmites australis*) and the Water horsetail (*Equisetum fluviatile*) at the Kokemäenjoki River delta, western Finland are presented in Table 1. The values for both species would be classified very high anywhere in the world, but the values are exceptional when considering the northern latitude of the study location (cf. Kvet and Westlake 1998).

In the monocultures of *Phragmites australis* the use of randomly assembled one square meter (10 000 cm²) and half a square meter (5 000 cm²) sampling frames gave identical results of the ramet density. The variation between the replicates was slightly higher – as supposed – in the larger frame, but the difference is negligible.

Table 1. The density of individual aboveground shoots (= ramets) of *Phragmites australis* and *Equisetum fluviatile*, determined with different frame sizes in the Kokemäenjoki River delta, western Finland.

Phragmites australis		
	1 m² frame	0.5 m²sample
Mean density (± 1 S.E.)	218.7 ± 6.58	219.7 ± 6.52
Coefficient of variation (CV)	15.0	14.0
Equisetum fluviatile		
	1 m² frame	400 cm²sample
Mean density (± 1 S.E.)	408.4 ± 9.91	406.7 ± 9.23
Coefficient of variation (CV)	12.2	11.3

The results of the ramet densities of *Phragmites australis* were practically identical as determined by using the 1 m2 and the 0.5 m² sampling frames (Table 1). In the parametric t-test, the results were statistically the same: t = 0.11, P = 0.9110, df = 48. The material of the field measurements of the clonal plant shoots is not, however, normally distributed. Thus, the reliability of the data were tested by using the non-parametric Kruskall-Wallis one-way analysis of variance, and the results were again identical in the two samplings: $\chi 2$ = 0.00. P = 0.9458, df = 1, N = 50.

The mean shoot (ramet) density in the *Phragmites australis stands*at the Kokemäenjoki River delta often exceed 250–400 ramets per square meter in the most productive Pioneer-phase of succession, and in the mature communities the density obtained here is quite normal. Densities in *Phragmites* reedswamps growing at ”good sites” in temperate climatic zone typically vary between 120–140 ind./m^2 (Kvet and Westlake 1998; Haslam 2010). So the stands studied in the present study represent one of the most productive wetland habitats in Europe.

In exceptional cases, the shoot density of helophytes can be very high, and the use of smaller than the standard sampling frame is justified – or practically inevitable (Downing and Anderson 1985).

In *Equisetum fluviatile*, the shoot densities (407–408 individuals per square meter; Table 1) measured in the present study represent lower than average for the species at this exceptionally productive site. In the Kokemäenjoki River delta, the density of the water horsetail stands can reach levels of 500–800 individuals per square meter, whereas in the stands at the Mackenzie River delta, Northern Canada, the density was 250 ramets per square meter on the average, and the maximum density was 400 ind./m^2 (Pearce and Cordes 1988).

Figure 1. Circular, floating frame of 400 cm^2 was the most practical device in determining shoot density in very dense stands of *Equisetum fluviatile*. The shoot density at this site was 425 individuals/m^2 (17 ramets inside the frame).

Statistical tests confirmed that the results of the density measurements between the sampling units, i.e. the 1 m^2 rectangular frame and the circular 400 cm2 frame, were uniform (Table 1).

In the parametric t-test the differences between the pairs were non-significant: t = 0.13, P = 0.8976, df= 48. However, the use of a parametric test has risks, because in the natural communities of clonal plants the distributions are seldom normal – as the test assumes. The distributions of the present materials were tested by using the Kolmogorov-Smirnov test, and the result showed a slightly skewed distribution. In the “absolute count”, i.e. by using the one square meter frame, D = 0.17, P = 0.065, and accordingly, by using the 400 cm^2 frame, D = 0.14, P> 0.10, df = 48.

Due to the skewness of the distribution, the results of the density comparisons were further tested by using the non-parametric Kruskall-Wallis one-way analysis of variance. The results of the shoot densities between the two frames were uniform also in this comparison: χ^2 = 0.00, P = 0.9536, N = 50.

The similarity of the two density estimations was confirmed also by the minor variation in the density values within each of the frames. The values of the coefficient of variation were uniform (Table 1).

Conclusion

The size of the sampling frame is a crucial factor in determining the time and effort required for the field work in vegetation analyses. The present study proved that the use of the one square meter sampling frame – typically used in vegetation analyses – is not necessarily required to ensure reliable data of the shoot density in dense monocultures, as identical and reliable results can be obtained with much smaller efforts.

REFERENCE

Allaby M. 2012. Oxford Dictionary of Plant Sciences. Third Edition. Oxford University Press, Oxford. | Aulio K. (2014). Strategies in growth of the common reed (Phragmites australis) as related to successional stages in a rapidly varying estuary. Research Journal of Biology 2: 11-17. | Aulio K. 2015. Kokemäenjoki River delta, western Finland – Natural treasury in an exceptionally rapidly changing aquatic environment. International Letters of Natural Sciences 5(2015): 36-53. | Downing JA and Anderson MR. 1985. Estimating the standing biomass of aquatic macrophytes. Canadian Journal of Fisheries and Aquatic Sciences 42(12): 1860-1869. | Dytham C. 2011. Choosing and Using Statistics. A Biologist's Guide. John Wiley & Sons, Chichester. | Haslam S. 2010. The Book of Reed. Forrest Text, Swn y Nant. | Kent M. 2012. Vegetation Description and Data Analysis. A Practical Approach. Second Edition. Wiley-Blackwell, Chichester. | Květ, J and Westlake DF. 1998. Primary production in wetlands. In: Westlake DF, Květ J and Szczepański A. (Editors), The Production Ecology of Wetlands. The IBP Synthesis, Cambridge University Press, Cambridge, pp. 78–168. | Maltby E and Barker T. (Editors) 2009. The Wetland Handbook. John Wiley & Sons, Chichester. | Mitsch WJ and Gosselink JG. 2000. Wetlands. Third Edition. John Wiley & Sons, New York. | Pearce CM and Cordes LD. 1988. The distribution and ecology of water horsetail (*Equisetum fluviatile*) in northern wetlands. Journal of Freshwater Ecology 4(3): 383-394. | Westlake DF, Květ J and Szczepański A. (Editors) 1998. The Production Ecology of Wetlands. The IBP Synthesis. Cambridge University Press, Cambridge. | Wheater CP, Bell JR and Cook PA. 2011. Practical Field Ecology. A Project Guide. John Wiley & Sons, Chichester. |