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Effects of abiotic conditions on *Phragmites australis* along geographic gradients in Lake Burullus, Egypt

Ebrahem M. Eid [a,c,*], Kamal H. Shaltout [b], Yassin M. Al-Sodany [a], Kai Jensen [c]

[a] *Botany Department, Faculty of Science, Kafr El-Sheikh University, 33516 Kafr El-Sheikh, Egypt*
[b] *Botany Department, Faculty of Science, Tanta University, Tanta, Egypt*
[c] *Applied Plant Ecology, Biocenter Klein Flottbek and Botanical Garden, Hamburg University, Ohnhorststraße 18, 22609 Hamburg, Germany*

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ABSTRACT

Stand structure and biomass production of *Phragmites australis* (Cav.) Trin. ex Steud. were analyzed along north–south and east–west transects in the Burullus coastal lagoon (N Egypt, 410 km^2) at monthly intervals over a period of 1 year (February 2003 until January 2004). For this purpose, young and old stands were selected at eight different locations in the lagoon. It was found that the north–south transect mainly represented a fertility gradient (207–286 mg l^{-1} TN, 30–106 mg l^{-1} TP), while the east–west transect was associated with significantly decreasing salinity (7–4 ppt). All morphological and biomass variables of *P. australis* were significantly different between young and old stands. On average, the old (7.3 ± 0.2 kg DW m^{-2}) accumulated three times more total above-ground biomass than the young stands (2.5 ± 0.1 kg DW m^{-2}). Shoot height, diameter and shoot dry weight significantly increased by 25–50% with increasing fertility along the north–south transect. Shoot density significantly decreased from north to south, while it almost doubled in the north sites from 109 ± 6 to 216 ± 7 shoots m^{-2} along the west–east transect. In separate stepwise multiple regressions, variation in water quality explained 34–63% of the variation in morphology and total above-ground biomass in the old stands (salinity and water level were most important for biomass, transparency also for height and density) while it explained 16–42% of variation in young stands (mainly transparency).

1. Introduction

Common reed, *Phragmites australis* (Cav.) Trin. ex Steud., has a high above- and below-ground productivity (Haslam, 1972), its aerenchyma enhance oxygen availability in wetland soils (e.g. Brix and Schierup, 1989) and the species plays an important role in the N, P and Si balances of its habitats (Hocking, 1989a; Struyf et al., 2007). Along the Deltaic Mediterranean Coast of Egypt, reed stands are important for wintering, foraging, refuge and breeding of the migrant birds (Kassas, 2002). These stand probably also play an important role in the nutrient budget of the Mediterranean coastal waters and lakes. All these functions depend on the stand structure of *P. australis*. As a clonal plant, the species can develop large and almost monospecific stands. It has been shown previously that chemical (e.g. N and P availability, salinity; Ulrich and Burton, 1985; Lissner and Schierup, 1997), physical (e.g. water depth, wave exposure; Coops and Van der Velde, 1996) and biological (e.g. population age, herbivory; Hara et al., 1993; Van den Wyngaert et al., 2003; Křiváčková-Suchá et al., 2007) factors determine the structure of *P. australis* stands.

We analyzed variability of *P. australis* stand structure and demography along major environmental gradients in Burullus coastal lagoon, Egypt. *P. australis* occurs throughout Egypt (Täckholm, 1974; Zahran and Willis, 2009). The species is known to be the major component of reed stands along the shores of Burullus coastal lagoon (Shaltout and Al-Sodany, 2008). As a consequence of human alteration, both fertility and salinity vary along the geographic north–south and east–west transects in this 410 km^2 sized lagoon today. The construction of the Aswan High Dam and the impoundment of Lake Nasser in 1964 upstream along the Nile River changed the hydrology of Burullus coastal lagoon. Today, irrigation water from Lake Nasser and waste water from fish farms enter Burullus coastal lagoon from the south. This leads to a pronounced fertility gradient from the south to the north. In addition, the discharge of freshwater from Birimbal Canal in the

* Corresponding author at: Botany Department, Faculty of Science, Kafr El-Sheikh University, 33516 Kafr El-Sheikh, Egypt. Tel.: +2 011 4450034; fax: +2 047 3223415.
E-mail address: ebrahem.eid@gmail.com (E.M. Eid).

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southwest and the intrusion of salt-water through the natural outlet (Al-Bughaz) create a strong salinity gradient from east to west. Salt-water intrusion to the middle and western parts of Burullus coastal lagoon takes only place during the winter closure of the Aswan dam when the water level of Burullus coastal lagoon decreases considerably (Shaltout et al., 2004).

Recently, Křiváčková-Suchá et al. (2007) found that old stands of *P. australis* are affected by environmental factors to a higher extent than young stands. In the present study, we distinguished a priori two different stand morphotypes (young and old) of *P. australis*. Our aim was to quantify morphometric and biomass variability among reed beds along a fertility and salinity gradient in this SE Mediterranean lagoon, whilst distinguishing between well-established old and young clonal stands. Our hypotheses are: (1) water characteristics vary along the geographic north–south and east–west transects in Burullus coastal lagoon and (2) morphology and biomass of *P. australis* vary between young and old stands and between different locations along the north–south and east–west transects.

2. Materials and methods

2.1. Study area

Burullus coastal lagoon is one of the Egyptian northern lakes. Thus, it is a part of the Deltaic Mediterranean Coast, which belongs to the arid region with warm summers (20–30 °C) and mild winters (10–20 °C). Burullus coastal lagoon connects with the Mediterranean Sea through a natural outlet. It is bordered from the south by agricultural lands of the Nile Delta, while in the north a sand bar separates it from the Mediterranean Sea. The lagoon has a total area of 410 km^2, an oblong shape and it extends for a distance of 47 km along its NE–SW axis. The lagoon comprises eastern, middle and western basins. The western basin is the narrowest with a width not exceeding 5 km (in a north–south direction), while the middle basin is the widest with a maximum width of 14 km. The depth of this lagoon varies between 20 cm close to the shore of the eastern basin and 200 cm in the middle basin and near the sea outlet. Some 30 islets of different sizes are distributed within the lagoon, where they form the physical isolations between its three basins (Shaltout and Khalil, 2005). Heavy growth of reed plants (e.g. *P. australis* and *Typha domingensis*) may lead to the merger of adjacent (e.g. Shishit Al-Aggari and Makatee Al-Aggari islets; El-Bayomi, 1999). Economically, the main activity in Burullus coastal lagoon is fish production, with a fish yield of 52,000 ton year^{-1} (Khalil and El-Dawy, 2002). The coastal lagoon is one of the major disposal areas for agricultural drainage water in Egypt. It receives most of the drainage water of the Nile Delta that feeds the lagoon with about 4 billion m^3 annually (El-Shinnawy, 2002).

2.2. Plant sampling, morphological features and total above-ground biomass

Sampling was carried out in the eastern (Lat. 31°27′13.8″ to 34′08.4″N, Long. 30°57′48.9″ to 58′35.7″E), middle (Lat. 31°25′01.7″ to 30′25.0″ N, Long. 30°48′42.6″ to 49′28.8″E) and western (Lat. 31°23′41.6″ to 26′17.9″N, Long. 30°38′26.0″ to 39′32.2″E) basin of Burullus coastal lagoon. In each of the eastern and middle basins, three sites were selected to represent the northern, middle and southern parts of the lagoon. In the western basin, only two sites were selected because of the narrow width of this basin. All these eight sites were pure or nearly pure *P. australis* flooded stands during the whole year. The other associated species (*Echinochloa stagnina, T. domingensis, Vossia cuspidata*) form less than 10% of the total standing biomass. We distinguished a priori two different stand morphotypes of *P. australis*: (1) more than 10 years old, high reed with thick stems ≥1 cm in diameter ("old stands"), and (2) less than 1-year old, short reed with thin stems <1 cm in diameter ("young stands"). In all sites except the southern site in the western basin (where only an old stand occurred) both the young and the old stands were sampled. Thus, 15 stands (eight old and seven young) were sampled. In each of the sampled stands, morphology and biomass were recorded monthly over a period of 1 year (February 2003 to January 2004) using six randomly distributed quadrats (0.5 m × 0.5 m) (Lee, 1990; Serag, 1996; Shaltout et al., 2004).

All *P. australis* shoots within a sample quadrat were cut off at the lagoon—bed level. The total number of *P. australis* shoots (shoot m^{-2}) was counted. A sub-sample of 10 randomly chosen shoots was taken from each quadrat and transferred to the laboratory in polyethylene bags. Stem height, basal stem diameter (at the first complete internode above the basal cut surface; Björk, 1967), and the number of leaves were measured. Leaf area (single sided) was measured using a leaf area-meter (Dynamax AM 300). After morphometric analysis, shoots were cut into fragments of 5 cm length and oven-dried to constant weight at 105 °C to give values for dry weight. The average dry weight of the shoots was calculated (g shoot^{-1}) and multiplied by the number of shoots m^{-2} to give the total above-ground biomass (kg DW m^{-2}).

2.3. Water sampling

At each site, three water samples were collected monthly from haphazard positions. The water samples were taken as integrated composite samples from the top of the water surface down to 50 cm depth. The samples were collected in plastic bottles and brought to the laboratory shortly after collection. Water level and transparency were measured in the field using a levelling rod and Secchi disc of 25 cm in diameter, respectively. Some water parameters were measured directly after collection (pH, salinity, total P and total N). After measuring these, samples were deep-frozen for further analysis of Na, K, Ca, Mg. Salinity and pH were measured using conductivity and pH-meters (Model DA-1 and ICM 41150, respectively). Atomic absorption (Shimadzu AA-6200) was used for the determination of Mg. Estimation of Ca, Na and K was carried out by flame photometer (CORNING M410). Molybdenum blue and indo-phenol blue methods were applied for the determination of total P and total N, respectively, using a spectrophotometer (CECIL CE 1021). All these procedures are outlined in APHA/AWWA/WPCF (1985).

2.4. Data analysis

We concentrate on data from the growing season (March 2003 to November 2003). The relationships between density and the morphological parameters (height, diameter, number of leaves and leaf area) were assessed using ANCOVAs. Effects of variation in salinity and fertility along the E–W and N–S transect on the morphological parameters and biomass (shoot dry weight, total above-ground biomass) over time were assessed using repeated measurement ANOVAs. Because of the unbalanced sampling design (see above) two different repeated measures ANOVAs were used. In the first analysis (ANOVA I), we included all the stands from the east and middle basins; by doing so we could evaluate the differences in *P. australis* morphology and biomass between basins (east and middle), sites (north, middle and south) and stand age (young and old) over time (nine sampling dates). In the second analysis (ANOVA II), we included only the old stands from the northern and southern sites of all the three basins. This gave us the