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Primary Productivity of Restored Wetland – Dragoman Marsh, Bulgaria

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Abstract: *Restoration activities of a drained wetland – Dragoman marsh - have started since the end of the 1990s and by 2007 the marsh regained its pre drainage period looks of typical eutrophic water body. Productivity and composition of the wetland macrophyte community were assessed ten years after its restoration. Only a half of the reported in the past species have reappeared in the wetland, both by natural means and intended reintroduction. An invasive species (Elodea nuttallii) was found in the sinkhole in the north part of the marsh. Above-ground biomass of the emergent macrophytes in Dragoman marsh is two to three times lower than the cited in the literature for similar habitats in the country. This is due to the early stages of formation of the emergent vegetation after its restoration and to the constant influence by factors such as fluctuation of the water table, mowing and burning of the biomass.*

Keywords: *Aquatic vegetation, biomass, ecosystem function, reedbeds, wetland restoration.*

1. Introduction

Throughout the XXth century wetlands in Bulgaria have been altered, degraded or lost through a wide range of human activities. The degradation and loss of wetlands is more rapid than rates for other ecosystems [1]. These trends have primarily been driven by land conversion and infrastructure development, water abstraction, eutrophication, pollution and over-exploitation. In the same time wetlands are among the most important natural resources on earth as they deliver a wide range of services, including food, fiber, biodiversity, water supply, water purification, regulation of water flows, coast protection, carbon storage, regulation of sediment, tourism, recreation and cultural services.

Restoration of wetlands and re-establishment of their hydrology and vegetation restores their functions in time and space [2], [3]. One of those functions is the productivity of a wetland macrophyte community, which reflects the general health and its trophic status [4].

There is an increasing number of restored wetlands in the EU since the 70^{s}. In Bulgaria one of the latest examples is the restoration of Dragoman marsh. The goal of this study was to assess the primary productivity of a wetland, ten years after its restoration.

2. Materials and Methods

2.1. Site Description

The Dragoman marsh is the biggest karst wetland in Bulgaria (A= 331 ha, 702 m.a.s.l.), situated 30km northwest of Sofia. It is an endoreic basin characterized with mean alkalinity (4.1µeq/l) levels. Information about the geology, description of the flora and vegetation in the region, as well as on the anthropogenic influences are presented in [5]-[8]. The marsh has been partly drained in the 1930^{s}, with a complete transition to arable land in the 1950s. The drainage canals remained the only permanent waters in the region, and acted as a refuge for the remaining flora and fauna. Restoration actions have started since the end of the 1990s as a result of the work of Balkani Wildlife Society [9] and so far it is one of the few restored wetlands in Bulgaria. Natural fluctuations in groundwater tables and summer precipitations lead to high natural water level fluctuations and occasional dry out of big portions of the wetland. This favours the development of emergent macrophytes community. By 2007 the wetland regained its pre drainage period looks of typical eutrophic water body. At present the marsh is one of the few natural lakes in Bulgaria to be classified as “Natural eutrophic lake with Magnopotamion and Hydrocharition type of vegetation” – code 3150, according to Directive 92/43/EEC [10].

The western part of the wetland is contaminated by regular discharge of sewage and wastewaters from the town of Dragoman, as well as by infiltration from surrounding arable land.

In 2011 the Ministry of Environment and Water established a new site – “Dragoman Marsh Karst Complex” to the National List of Wetlands of International Importance (Ramsar sites). The wetland is currently a habitat for a number of rare and protected plant and animal species. Approximately 61% of the Bulgarian avifauna (256 species) have been recorded so far in the area, 9 species of amphibians, 11 species of reptiles, 43 mammals and 180 vascular plants (aquatic and terrestrial), including endemic species for the country and the Balkan Peninsula.

2.2. Biomass Estimates

Above-ground standing crop (above-ground biomass, AGB) of *Phragmites australis* (Cav.) Trin. ex Steud., *Typha latifolia* L.; *Typha angustifolia* L., *Scirpus lacustris* L. and *Carex* spp. was estimated by harvesting the biomass in 0.5 m^2 experimental plots in the corresponding associations. Collections were made during a two-week period at the end of the growing season in mid September 2008 and at the beginning of September 2011. Plants were sorted by species, placed in labelled paper bags and transported to the lab. At each sampling, the above-ground biomass of green shoots was determined, 30 stems were cut, oven-dried at 85 ^oC for 48h to constant mass and weighed. The average shoot biomass was calculated by dividing the total weight of the shoots to the shoot number. The product of the average shoot number and average shoot biomass per square meter is taken to be the estimated AGB. The biomass of the submerged macrophyte species, mostly *Ceratophyllum submersum* L., was determined as a bulk value without distinguishing between the productivity of different species by applying the principal method. We take the average carbon content (C) of plant material to be 46% as recommended by [11].

3. Results and Discussion

3.1. Composition of Aquatic Vegetation

Reestablishment of emergent vegetation proceeded rapidly in the first years after the restoration, when it colonized nearly 50% of the wetland. After the initial rapid colonization the cover of emergent vegetation increased slowly in the deeper regions (> 0.7m) to approximately 65%. During the first years after the drainage stopped the species composition of submerged vegetation also changed as remnants of the original community spread out of the drainage canals and new species reappeared, both intentionally reintroduced and carried by birds.

The major species in the shallow portions of the wetland are *Phragmites australis, Typha latifolia, Typa angustifolia, Scirpus lacustris, Carex gracilis* Curtis. In parallel, several hydrophyte and helophyte species are found among the emergent vegetation, such as *Ranunculus trichophyllus* Chaix, *Gratiola officinalis* L., *Polygonum amphibium* L., *Oenanthe aquatica* (L.) Poir., *Alopecurus aequalis* Sobol., *Alisma plantago-aquatica* L. *Butomus umbellatus* L., *Epilobium parviflorum* Schreb., *Lythrum salicaria* L., *Carex melanostachya* M.Bieb. ex Willd, *Iris pseudacorus* L., etc.

In the deeper zones of the wetland, where submerged vegetation predominated the species composition includes *Myriophyllum spicatum* L., *Polygonum amphibium* L., *Zannichellia palustris* L., *Ceratophyllum submersum, Utricularia vulgaris* L., etc.

A project conducted by Balkani Wildlife Society, aimed at and successfully reintroduced previously common species *Nymphaea alba* L. and *Aldrovanda vesiculosa* L. The reintroduction of *Caldesia parnassifolia* (L.) Parl. is still in its preliminary stage, whereas *Hydrocharis morsus-ranae* L. was unintentionally introduced and at present is well established in the marsh.

Following emergent marsh colonization, duckweed (*Lemna minor* L., *Lemna trisulca* L. and *Spirodela polyrhiza* (L.) Schleid.) and small floating aquatic plants, also became established and spread through the wetland, often under the emergent marsh canopy and in low quantities.

In 2010 the invasive species *Elodea nuttallii* (Planch.) H.St.John was found in the sinkhole “Ponora” located in the north part of the marsh. The appearance of *Elodea nuttallii*, a species with rapid vegetative reproduction [12], [13], poses a major risk for the restored marsh as it is capable of significant disruption of aquatic ecosystems.

For ten years after the restoration of the wetland only half of the reported 60 species [6] reappeared in the wetland.

3.2. Biomass Estimates

The assessment of the vegetation in a newly created wetland through the measurement of AGB – and not only the estimation of plant structure such as diversity and cover – provides essential data on the functional capacity of a site.

The producers in the Dragoman marsh could be divided into two main groups: emergent and submergent vegetation (Table 1). The emergent vegetation is the most important, with dominant associations of *Phragmites australis*, *Typha angustifolia* / *Typha latifolia* and *Scirpus lacustris*, among others.

In September, the AGB of *Phragmites australis* averaged 970 ± 92 g DM/m^2. Net aerial primary productivity of reeds in the littoral zone is estimated to be 417 tones organic matter annually. The estimated AGB of reed beds is ≈ 60% lower, compared to the estimates of [14] for “Srebarna” reserve, as well as to a swamp close to Batin village [15], [16] as well as to a western Polish lake [17]. The highest differences are observed in comparison to Aldomirovtsi swamp, a mature wetland located close to Dragoman site, where [18] estimated reeds AGB at 3665 g DM/m^2. These differences are due to the early stages of formation of the reeds in Dragoman marsh after its restoration, as well as to the altitudinal difference between the investigated areas.

Table1. *Area covered and shoot biomass production at peak standing stock in Dragoman marsh.*

Species	Area (ha)	Above-ground biomass estimates*	
		gDM ± SD	NAPP (tones)
Phragmites australis	43	970 ± 92	418
Typha spp.	69	1096 ± 303	756
Scirpus lacustris	60	1245 ± 36	748
Carex spp.	42	608 ± 14	255
Submerged vegetation	117	502 ± 154	587
* average values for 2008 and 2011			

The associations of *Typha latifolia* and *Typha angustifolia* have similar productivity to the beds of *Phragmites australis* – the above ground biomass is on average 1096 g DM/m^2. The net aerial primary productivity of cattail is 756 tones organic matter annually. The results are approximately a third of the annual productivity of Aldomirovtsi swamp [15], [18] and halve of the given for the Polish lake [17]. Taking into account the short time passed after the restoration of the swamp, we suppose that these figures are an adequate representation of the average *Typha* sp. productivity.

The area of Dragoman marsh overgrown by *Scirpus lacustris* is assessed at approximately 60 ha, with average AGB of 1245 g DM/m^2. The annual net aerial primary productivity of club-rush is 747 tones organic matter. These figures are comparable to the sited ones by [15] for the Aldomirovtsi swamp.

The area of Dragoman marsh overgrown by different species of *Carex* spp. is approximately 42 ha, with annual production of 608 g DM/m^2. The net aerial primary productivity of the sedges is 255 tones organic matter annually. The annual production is by 40% lower compared to a lake in western Poland [17] and 2.5 times lower than the sited by [15] for the Aldomirovtsi swamp.

The production of the submerged aquatic vegetation plays a secondary role to the production of the emergent vegetation. Despite this fact, the small depth of the water in the swamp and the favorable light regime promote the development of dense submerged macrophyte beds. The area of the marsh occupied by the submerged aquatic vegetation is 117 ha, with AGB of 502 ± 154 g DM/m^2. The net aerial primary productivity of submerged macrophytes is assessed at 587 tones. [16] report an AGB of 770 g DM/m^2 for a *Potamogeton natans* association in land slide lakes in south Rhodope Mountains, while [18] give a value of 505 g DM/m^2 for a mixed submerged community in Aldomirovtsi swamp.

In order to take into account the relative magnitude of the different associations to the overall productivity of the Dragoman marsh, a normalized productivity, expressed as a percentage fraction of the lakes area, was calculated (Table 2).

The average primary productivity of Dragoman marsh was assessed at approximately 380 g organic carbon per square meter or 1261 tones for the whole area of the wetland. Because biomass estimates from *Typha* spp. and *Scirpus lacustris* were greater than inputs from the rest of the studied vegetation components, they dominated C inputs to the wetland.

Table2. *Primary productivity of the different components expressed as average values and as a normalized to the lake area values.*

Species	Average values gC/m^2	Normalized value gC/m^2
Phragmites australis	442	58
Typha spp.	500	104
Scirpus lacustris	568	103
Carex spp.	277	35
Submerged vegetation	229	81
Sum	---	**381**

AGB measurements can underestimate net primary production because they do not include seasonal biomass lost to leaf and shoot mortality prior to sampling, or growth occurring afterwards [19] – [22]. This unmeasured production can be substantial, especially in regions with long growing seasons [23]. These losses can be taken into account by estimates of the annual biomass turnover of the species. [4] did not find any significant difference between the turnover rates of the emergent species in experimental wetlands, and estimated an average annual turnover of emergent marsh vegetation in wetlands of 2.0 ± 1.0 times mid season standing live biomass. This estimate is comparable to biomass turnover measurements in other emergent marshes, [20], [24] – [27]. Therefore, the analysis of the AGB in Dragoman marsh could be up to a half of the total annual biomass production. We can expect this as a number of studies [20], [25] show higher turnover rates at locations with greater nutrient availability, such as the discharge of sewage to the Dragoman marsh.

Our results show that above-ground biomass of Dragoman marsh is still lower than the observed one in similar habitats in the country. The relatively short time after the restoration affects the standing biomass of aquatic plants, which varies between 5 and 12.5 t/ha, depending on the species. For most of the studied components the AGB estimates is two to three times lower than the cited in the literature. This is due to the early stages of formation of the emergent vegetation in Dragoman marsh after its restoration and to the constant influence by factors such as fluctuation of the water table, mowing and burning of the biomass. Our results confirm to the findings of [28], who observed gradual increase of both density and biomass of aquatic macrophytes by two to ten times in five years in lakes formed in abandoned sandpit extraction sites. The authors also point out that the autumnal burning and gathering of the biomass reduce the productivity of the wetlands.

The lower productivity of the Dragoman marsh is also related to the history of its restoration. Although the draining was stopped at the end of the ‘90s, increase of the water level in the marsh was gradual and maximum water level was reached by the end of 2005. Thus, the first habitats to be restored are the deepest portions with submerged vegetations, while the shallower zones were flooded subsequently. This pattern is well reflected by the macrophyte productivity, which is close to the average values in the open water regions of the lake and still lower in the littoral regions.

4. CONCLUSION

The results show that a vegetative community rapidly develops and colonizes the shallow wetland regions, which is important to potential carbon storage as emergent marsh vegetation is more productive, and less labile, than submerged and floating vegetation. This emphasizes the fact that restored wetlands act as carbon sinks. In this study we demonstrated the potential of restored wetlands to re-establish themselves and the ecosystem services, such as providing habitat for a variety of species, improved water quality, floodwater storage, carbon sequestration and recreation.

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