Botanica SERBICA 40 (2): (2016) 205-215

Original Scientific Paper

The charophyte flora in a Ramsar Mediterranean wetland (Albufera de València Natural Park, Spain) during the period 2007-2010

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ABSTRACT: The Albufera de València Natural Park (AVNP) is an internationally recognised coastal region. With an area of 21000 ha, it is composed of a large lagoon surrounded by marshlands devoted to rice crops, a web of irrigation channels connecting the rice fields to the lagoon, small freshwater-to-brackish ponds patchily scattered throughout an area of sand dunes separating the lagoon from the sea, a set of springs and newly created artificial wetlands. In the '60s and '70s, the area was seriously affected by urbanisation, development of agriculture, industry, etc., and many of the indicated water bodies were destroyed. At present, managers have restored some of these aquatic ecosystems. Between 2007 and 2010 we visited 32 sites (six rice fields, 10 ponds, eight springs, four channels and four sites in two artificial wetlands) and studied the richness of charophyte species. In addition to macroalgae, we sampled sediments as well (searching for charophyte oospores and gyrogonites). Fifteen charophyte taxa were identified (*Chara aspera, Ch. braunii, Ch. canescens, Ch. globularis, Ch. hispida* var. *baltica, Ch. hispida* var. *hispida, Ch. imperfecta, Ch.vulgaris* var. *contraria*, *Ch. vulgaris* var. *inconnexa, Ch. vulgaris* var. *longibracteata, Ch. vulgaris* var. *vulgaris, Lamprothamnium papulosum, Nitella hyalina, Tolypella glomerata* and *T. prolifera*), 14 of them as growing specimens. *Chara vulgaris* was the most abundant taxon. Rice fields were one of the systems with the highest charophyte richness. Approximately 30% of the Iberian charophyte flora (46 taxa) and 58% of that in the province of Valencia (26 taxa) are represented within the AVNP. Eleven taxa of the genus *Chara* are present on the Iberian Peninsula, and seven of them were found within the limits of the AVNP. A comparison with charophyte richness in other West Mediterranean wetlands is also provided.

Keywords: Albufera de València Natural Park, *Characeae*, species richness, anthropogenic disturbances, rice fields, springs, interdunal ponds

Received: 26 April 2016 Revision accepted: 24 June 2016

UDC: 582.263.3(460)
DOI: 10.5281/zenodo.162222

INTRODUCTION

The Iberian Peninsula is not an area with many large lakes, but it contains a large variety of water bodies with different hydromorphological and ecological patterns (Casado & Montes 1995). These kinds of environments usually exhibit considerable biodiversity (Alonso 1998). The aquatic flora is one of the best sources of information about the current and potential conservation status of every aquatic body (García-Murillo *et al.* 2006; Cirujano *et al.* 2007; Cirujano *et al.* 2008). Environmental events such intensive agricultural practices (with the indiscriminate use of pesticides and fertilisers), tourism, groundwater over-exploitation, exotic species invasions, global warming, etc., which can negatively affect vegetation richness, create the need to update information on macrophytes, particularly charophytes (Ortega *et al.* 2004). Inasmuch as a large number of different types of small water bodies exist

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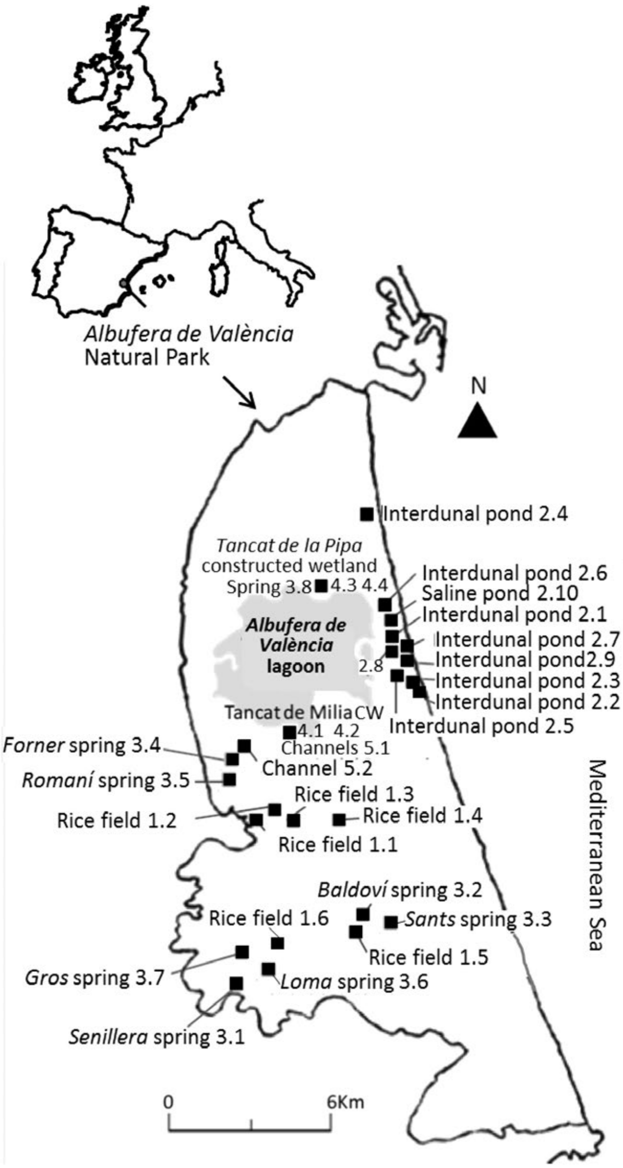
on Spanish territory, it is paradoxical that publications which integrate knowledge on submerged vegetation, particularly charophytes, are scarce (Cirujano *et al.* 2008; Flor-Arnau & Cambra 2015). This is striking given the relevant role that these organisms play in maintenance of the clear-water state in aquatic environments (Van den Berg *et al.* 1997; Rodrigo *et al.* 2007; Rodrigo & Alonso-Guillén 2008; Blindow *et al.* 2014).

Declared a protected area in 1986, the Albufera de València Natural Park (AVNP hereafter) is a large coastal wetland located on the Mediterranean coast. The park is a Special Protection Area in the European and international sphere: it has been included in the Ramsar list of important wetlands since 1990 and considered a relevant habitat under terms of the EU Bird Directive (79/409/CEE) since 1991, in addition to which it possesses species and habitats treated in the EU Habitats Directive (92/43/CEE). The AVNP consists of the largest coastal lagoon on the Iberian Peninsula, the Albufera de València, surrounded by fields devoted to rice crops. It is fed by a large number of channels and gullies associated with agricultural uses, as well as by springs located either within the lagoon (in the past, Roselló 1976) or in the surrounding marshland. The lagoon is separated from the sea by a sand bar with different lines of sand dunes, with a pine forest in the inner one, and scattered interdunal ponds. At one time, the Albufera de València possessed rich communities of submerged vegetation, both vascular plants and charophytes (Prósper 1910; Arévalo 1916; Pardo 1942; Rodrigo *et al.* 2009; Rodrigo *et al.* 2010). The earliest published study on charophytes in the current AVNP was by Cavanilles (1795), a famous 18th century botanist. Later, Prósper (1910) also mentioned charophytes within the limits of the AVNP. However, since then few publications have been published on charophytes of this wetland (Pardo 1942; Corillon 1962; Batalla 1975; Benet-Granell 1983; Boira & Carretero 1985; Carretero 1986; Pedrola & Acuña 1986; Olivares 1998).

Unfortunately, since the 1960s, sewage water from industrial sources (as a result of industrialisation of the neighbouring areas), agricultural sources (extensive agricultural land uses) and urban sources (due primarily to demographic expansion of the neighbouring villages) was discharged directly into the lagoon without any type of treatment, causing massive eutrophication (Dafauce 1975). The submerged vegetation in the lagoon was lost many years ago and it is now hypertrophic. During the 70s, the sand bar was also subjected to a huge private urban development plan. Both semi-mobile and fixed dunes were almost totally destroyed during implementation of the plan. Most of the interdunal ponds were covered by sand to provide suitable land to build on. Also, due to the development of agriculture, most former spring basins were either reduced to a pipe (Soria 1990) or else totally covered with rubble and other debris (Roselló i Verger 1995). Fortunately, due to social pressure, the urbanisation plan was stopped and the public administration several years later restored some springs and recreated the interdunal ponds. A few years ago (2007 and 2009), several constructed wetlands were created on former rice fields near the main lagoon, which, based on phytodepuration principles, aimed at improving the quality of water flowing into the main lagoon (Rodrigo *et al.* 2013a; Rodrigo *et al.* 2013 b). All these environments represent new sites for the development of charophytes within the natural park. Accordingly, the aim of this study was to describe the biodiversity (species richness) of charophytes in the different types of water bodies within current limits of the AVNP during the period 2007-2010. Here it was considered that the obtained results would provide a useful tool for further restoration of this wetland's vegetation in particular and for its management in general. A brief comparison with charophyte species richness in other wetlands, mainly ones from the western part of the Mediterranean basin, is also provided.

MATERIAL AND METHODS

Currently there are five types of water bodies that can host charophytes within the AVNP: (i) interdunal ponds, (ii) springs, (iii) rice fields, (iv) channels and (v) constructed wetlands. Between May 2007 and August 2010, a total of 32 water bodies were visited, at least once, within the AVNP (Fig. 1). The interdunal ponds are formed on the one hand by accumulation of rainfall (due to the existence of a several-decimetre grey silt layer which confers impermeability) during the wet season, and on the other by the outcrop of subsurficial water (due to hydrostatic pressure when freshwater and saline aquifers meet), giving rise to brackish waters. Some of these interdunal ponds maintain the water column during wet periods but decrease in depth during dry periods, while some even dry out during the summer (Soria 1997). Thanks to the continuous efforts of the Devesa-Albufera Technical Office-Valencia City Council from the beginning of the 80s, when the urbanisation plan was stopped, and an appropriate contribution from the European Commission, which funded two LIFE Nature projects (LIFE 2000/Nat/E/7339 and LIFE 2004/Nat/ES/44), the interdunal ponds have been reconstructed. During the first project, a dune ecosystem area of 13.5 ha was partially restored, mainly by the elimination of infrastructures. The restoration continued during the second project (2004-2008). The dunes and interdunal ponds currently represent priority habitats under terms of the EU Habitats Directive (92/43/CEE), with important species such as *Juniperus oxycedrus* subsp. *macrocarpa* (Sm.) Ball and endemic cyprinodontid fish (*Lebiasibera* Valenciennes, 1846; *Valencia hispanica* Valenciennes, 1846). In our study, we chose nine of the interdunal ponds. Moreover, we also visited one sea-connected artificial saline pond created during realisation of the urbanisation plan.



		UTM coordinates (30S+)	
		X	Y
Rice fields	**1.1**	727305	4350982
	1.2	727708	4351172
	1.3	728537	4351029
	1.4	730254	4351235
	1.5	731303	4347211
	1.6	727120	4345978
Interdunal ponds	**2.1**	731694	4357999
	2.2	732558	4356514
	2.3	732405	4356587
	2.4	730217	4362722
	2.5	731869	4356938
	2.6	731161	4359239
	2.7	732146	4357490
	2.8	731701	4357578
	2.9	732083	4357433
	2.10	731437	4358670
Springs	**3.1**	726971	4344706
	3.2	731467	4347794
	3.3	731814	4347387
	3.4	725085	4352650
	3.5	724795	4352488
	3.6	727548	4345302
	3.7	727170	4345954
	3.8	728371	4360744
Construct. wetlands	**4.1**	727933	4354200
	4.2	727898	4354495
	4.3	728614	4360118
	4.4	728805	4360515
Channels		728343	4354431
	5.1	728068	4354468
		727893	4354105
	5.2	724822	4353681

Fig. 1. Sites in the AVNP investigated for charophyte species richness. UTM coordinates are provided.

Springs were abundant in the past (Soria 1997). Their basins differed in form (circular, elongated, etc.), and they were mostly fed by freshwater. The Regional Government restored some of the most notable ones (the Baldoví and Senillera springs). We visited eight of these springs.

Seventy per cent of the AVNP consists of rice fields (OGTPNA 2002), which make up an agrarian landscape with great historical significance in Valencian society. These irrigated lands, with dry-flood cycles, were shown in the past to be potential sites for charophytes (Carretero 1986). Moreover, the whole of the AVNP is divided by an extensive network of channels and gullies with different water qualities (Soria 1997). We visited six rice fields and four channels.

Since 2009, we have been monitoring one of two former rice fields transformed into constructed wetlands (Tancat de la Pipa, Rodrigo *et al.* 2013b; Rodrigo *et al.* 2015) and collected valuable data concerning charophyte development at this site. The 40-ha wetland in question consisted of two small shallow lagoons, an artificial spring and several surface-flow areas planted with emergent vegetation for phytodepuration purposes. The other constructed wetland, Tancat de Milia, was designed to receive the outflow from a sewage treatment plant before discharging it into the Albufera de València lagoon (ACUAMED 2008). It consists of a subsurface-flow sector, several surface-flow sectors and a final small lagoon. We sampled two sites in this constructed wetland.

The different sites were visited during the warm season in order to find fructified specimens for easier identification. This criterion meant that some temporary interdunal ponds were dry at the time of sampling, and we therefore had to sample the sediments (the first 5 cm) to search for oospores. Depending on the type of water body, charophytes were directly collected from the shore by hand or with the help of a hook; elsewhere, we either wore waders or used a boat. The collected charophytes were transported to the lab in plastic bags in an insulated container. Around 15 g of wet sediment was sifted through sieves with pore sizes of 1000, 500 and 250 µm to isolate the oospores. The bibliographic source used for identification and classification of charophytes was Cirujano *et al.* (2008), whereas for oospore identification Soulié-Märsche (1989) was mainly used [see Alonso-Guillén (2011) for more details]. *In situ* pH and conductivity-salinity measurements were carried out using Multiline F/Set-3 (WTW) equipment.

RESULTS AND DISCUSSION

Charophytes in the AVNP. Fifteen charophyte taxa were identified at the sites visited (Table 1). Fourteen of them were found as specimens growing in the water, with their sexual propagules in most cases being found in the sediments. The taxa identified were: *Chara aspera* Dethard. ex Willd., *Chara braunii* CC.Gmelin, *Chara canescens* Desv. and Loisel., *Chara globularis* Thuill., *Chara hispida* var. *baltica* (Bruzelius) RD.Wood, *Chara hispida* var. *hispida* L, *Chara imperfecta* A.Braun, *Chara vulgaris* var. *contraria* (A Braun ex Kütz.) Moore, *Chara vulgaris* var. *inconexa* (TF.Allen) RD.Wood, *Chara vulgaris* var. *longibracteata* (Kütz.) J Groves and Bull., *Chara vulgaris* var. *vulgaris* L., *Lamprothamnium papulosum* (Wallr.) J.Groves, *Nitella hyalina* (DC) C.Agardh and *Tolypella glomerata* (Desv.) Leonhardi. For one taxon, *Tolypella prolifera* (Ziz ex A. Braun) Leonhardi, only oospores in the sediment were found.

Among the sampled water bodies, the rice fields were among the ecosystems with highest species richness, with up to six out of 15 taxa identified in the AVNP, although only from the genus *Chara* (Table 1). In one of the springs, four taxa were identified. In the interdunal ponds which contained water when sampled, five taxa were identified; in those ponds which were dry when sampled, oospores assigned to five taxa were isolated and identified, suggesting the existence of both freshwater and oligohaline waters in these interdunal ponds. One of the reconstructed interdunal ponds (2.3 in Table 1) contained four species of charophytes, and in 2013 the free-floating plant *Utricularia australis* R. Br., which is cited in the catalogue of threatened Valencian flora species (Aguilella *et al*. 2009) as an endangered species, appeared in the pond (Calero *et al*. 2015). In the studied period, the springs did not exhibit high charophyte species richness. In some of them, in which environmental conditions had been improved as a result of restoration work (such as the Baldoví spring), only *Nitella hyalina* was found, but it was sparsely represented together with the angiosperm *Myriophyllum spicatum* L. In another survey (Biological Network Monitoring, TECNOMA 2010), other macrophytes were detected (*Ranunculus* sp., *Potamogeton nodosus* Poir. and *Myriophyllum verticillatum* L.), but no charophytes were found. Other springs contained vascular macrophytes but no charophytes, and in three of them no submerged vegetation was found. Most of the springs were surrounded by agricultural fields and continued to receive inputs of nutrients that negatively affected the water quality, and consequently the submerged vegetation. One exception is the artificial spring in Tancat de la Pipa (Rodrigo *et al.* 2015), excavated in 2007 with the aim of recreating past environments of the AVNP. Six taxa of charophytes were detected growing in the water of this spring, although *Ch. hispida* largely dominated. In its surficial sediments, oospores of 11 taxa were identified. These fructifications, although currently located close to the water-sediment interface, came from deeper sediments that were brought up due to excavation work in the basin. The given oospores were formed in the past, when this area was a rice field (this would explain the presence of *Ch. braunii,* for example) and even in older times, when the area formed part of the Albufera de València lagoon and the presence of *L. papulosum* fructifications corresponded to the saline period of the lagoon's history (Rodrigo *et al.* 2010; Rodrigo & Alonso-Guillén 2013). A particular *Chara* gyrogonite morphotype whose features did not exactly fit any known charophyte species was also found. Gyrogonites appear as two types, smooth specimens mixed with ornamented specimens displaying tubercles on the lime spirals. This morphotype was previously found in Albufera de València sediments and was described in Rodrigo *et al.* (2010) in open nomenclature as *Chara* sp. With regard to the constructed wetlands, only two varieties of *Ch. vulgaris* were found in the phytodepuration ponds of Tancat de Milia. In the small shallow lagoons of Tancat de la Pipa, taxon richness was higher, taking into account those growing in the water and fructifications found in the sediments (Rodrigo *et al.* 2013b). Only *Ch. vulgaris* was found in the studied channels. One method of charophyte dispersal might be zoochory, although dispersal by waterfowl (in this park the bird density is very high) and hydrochory (using the extensive network of channels) are also possible. We therefore stress the importance of maintaining good quality water in these channels, and including them in future environmental conservation plans as an aquatic habitat for growing charophytes and as a vector of propagation.

Forty-six taxa of charophytes are described by Cirujano *et al.* (2008) in their monograph on charophytes (Iberian Flora Collection) of the Iberian Peninsula, 26 of which have been cited in the province of Valencia. These

Table 1. Taxa of charophytes and other macrophytes found in the AVNP in **1**: rice fields, **2**: interdunal ponds, **3**: springs, **4**: constructed wetlands, **5**: channels.
• = presence in the water; ••= presence in the water and also oospores in the sediment; •*: only oospores found in the sediment; d: the waterbody was dry when sampled.•^{1}: species planted by the managers. -: no data available.
$^{+}$: *Ranunculus* sp., *Potamogeton nodosus* and *Myriophyllum verticillatum* were found in another monitoring for a biological survey (TECNOMA 2010).
$^{++}$: only gyrogonites of *Chara* sp. according to Rodrigo *et al.* 2010.

	Rice fields						Interdunal ponds										Springs								Constructed wetlands				Channels	
	1.1	**1.2**	**1.3**	**1.4**	**1.5**	**1.6**	**2.1**	**2.2**	**2.3**	**2.4**	**2.5**	**2.6**	**2.7**	**2.8**	**2.9**	**2.10**	**3.1**	**3.2^{+}**	**3.3**	**3.4**	**3.5**	**3.6**	**3.7**	**3.8**	**4.1**	**4.2**	**4.3**	**4.4**	**5.1**	**5.2**
Sampling (month and year)	4/08	8/10			7/10		5/07	5/09	6/09			7/10				7/10	6/07				7/10			09-11	7/10		09-11		7/10	
Salinity (g/l)	-	-	-	-	0.5	0.5	0.8	4	1.7	1.3	d	d	d	d	d	49	0.5	1.8	1.0	0.5	-	-	-	2	3.0	3.0	1.0	1.2	1.2	0.3
pH	-	-	-	-	7.6	8.0	9.2	7.6	7.4	7.8	d	d	d	d	d	7.9	7.9	7.4	7.4	7.8	-	-	-	7.7	7.6	7.6	8.2	8.3	7.8	8.2
Chara aspera							•		•			•*												••			••	••		
C. braunii	•	•																						•*			•*			
C. canescens								•																						
C. globularis	•	•				•				•*														•*			•*	•*		
C. hispida var. *baltica*							•	•	•															•*			•*	•*		
C. hispida var. *hispida*																								••			•	•		
C. imperfecta	•			•																										
C. vulgaris									•	•*	•*	•*		•*	•*															
C. vulgaris var. *contraria*				•																					•					
C. vulgaris var. *inconnexa*					•																									
C. vulgaris var. *longibracteata*	•	•	•			•																		••			••	••	•	•
C. vulgaris var. *vulgaris*																	•							••		•	•	•	•	
Chara sp.$^{++}$																								•*			•*	•*		
Lamprothamnium papulosum												•*	•*			•								•*			•*	•*		
Nitella hyalina									•									•									•	•*		
Tolypella glomerata										•*		•*												••			••	••		
T.prolifera																								•*			•*			
Ceratophyllum sp.																						•	•							
Myriophyllum spicatum																		•				•	•				•^{1}	•^{1}		
Nymphaea alba																						•								
Potamogeton pectinatus									•																	•				
Zannichellia peltata																											•^{1}	•^{1}	•	
Cladophora sp.																		•				•	•							

Waterbodies with toponymical name: 2.1: Mallada Nova del Fang; 2.3: Llacuna Nova del Canyar; 2.4: Mallada del Quarter; 2.5: Mallada de la Torre; 2.6: Mallada llarga; 2.10: Estany del Pujol; 3.1: Ullal de Senillera; 3.2: Ullal de Baldoví; 3.3: Ullal dels Sants; 3.4: Ullal del Forner (Vell i Nou); 3.5: Ullal del Romaní (Rajolar); Ullal de la Loma (Mula); 3.7: Ullal Gros; 3.8: Ullal Tancat Pipa; 4.1: Balsa sector BW (Tancat de Mília); 4.2: Balsa sector B2W (T. Mília); 4.3: Laguna Educativa (Tancat de la Pipa); 4.4: Laguna de Reserva (T. Tipa); 5.1: Three channels in T. Mília.

authors already at that time concluded that the floristic richness of Iberian charophytes was currently lower than that described when the first monographs on this family were published in the first half of the 20th century. In the present survey, 15 taxa were detected in the AVNP. This means that approximately 30% of the Iberian charophyte flora is represented within the limits of the AVNP, and that more than 50% of the province's taxa can be found there. Charophytes in the AVNP were found living in water pH ranging from neutral to slightly alkaline (Table 1). Thanks to the wide range of salinity in the investigated water bodies, both freshwater and saline species were found. *Chara canescens, Ch. hispida* var. *baltica* and *L. papulosum* grew in the more saline environments, particularly the last-named taxon, which is considered to be a hypersaline species able to live in up to 125 g/l of dissolved salt. This was the case of *L. papulosum* growing in an artificial pond constructed during early execution of the urban plan, which was connected to the sea and possessed high salinity (49 g/l). Out of 11 taxa of the genus *Chara* described in Cirujano *et al.* (2008), seven were found in the present study, which is a high representation. Of the nine varieties of the *Ch. vulgaris* complex cited in the same monograph, four were detected here. *Chara vulgaris* was one of the most heavily represented taxa in the AVNP, presumably because it tolerates pollution well. It is also a typical pioneer species, often found in small ecosystems with alternation of flood/drought periods. However, the genus *Nitella* was poorly represented, with just one species. Most of the water bodies we visited in this study were rich in calcium (> 100 mg/l; see, for example, Calero *et al.* 2016). Species from the genus *Nitella* usually grow in calcium-poor or moderately rich waters (Doege *et al.* 2016). Moreover, Cirujano *et al.* (2008) described how *Nitella* species are more sensitive to alterations in the environment.

The AVNP also contained forms of special interest or vulnerable taxa such as *L. papulosum, Ch. imperfecta, Ch. vulgaris* var. *inconnexa* and *T. prolifera*. As Blaženčić *et al.* (2006) stated, by conserving their habitats, the existence of charophytes will be assured. It would therefore be desirable to create habitats where species in danger of extinction, such as *Ch. tomentosa* L., 1753 and *N. obtusa* (Cirujano *et al.* 2008), could live. In the past, *Ch. tomentosa* could be found in the Albufera de València lagoon, as demonstrated by study of oospores contained in the lagoon's sediments (Rodrigo *et al.* 2009; Rodrigo *et al.* 2010). It was recently shown that surficial sediments, supposedly polluted by the uncontrolled dumping of waste water from different sources over many years, can sustain both vegetative growth and the germination of charophyte species (Rodrigo & Alonso-Guillén 2013). This fact, together with adoption of a proper water policy for the AVNP, opens up a window of hope for the renaissance of charophytes in the main lagoon. Moreover, the presence of charophytes, currently restricted to isolated sites, has been favoured by the creation of constructed wetlands that in the course of time will be transformed into quasi-natural systems optimal for the attraction of other species, ones which were common in the past but now can no longer be found (for example, certain waterfowl species).

Comparison with other ecosystems. Comparisons of charophyte species richness among different sites are not easy to draw due to differences in the methodology used, strength of sampling efforts, number of visits, degree of specialisation of researchers engaged in sampling and identification, classification keys used, aims of the study, etc. Despite these difficulties, we here present a brief comparison of charophyte species richness in the AVNP with that at other peninsular sites and within the framework of the Mediterranean region, mainly its western part (Table 2). One of the littoral wetlands on the Iberian Peninsula where charophyte richness has been studied is the Llobregat Delta, where only six taxa were found (in the period 1993-1995; Seguí 1995). In the Albufera de Adra (Almería), Ortega *et al.* (2004) cited four species. In the Albufera de Mallorca, on the other hand, Martínez-Taberner & Pericàs (1988) and Martínez-Taberner & Moyà (1991) cited 11 species (which represent 69% of *Chara* species and 37% of the charophyte flora of the Iberian Peninsula). These authors considered such diversity high, given the small surface area of this environment. They attributed this high species richness to the broken-up structure of the flooded areas, which constituted different habitats colonised by different species, although owing to alterations suffered by this wetland the populations of some species such as *Nitellopsis obtusa, Ch. hispida, Ch. canescens, Ch. galioides, Ch. connivens* and *T. glomerata* had low abundance and were discontinuous in time. In the Doñana National Park, García Murillo *et al.* (2006) cited 19 charophyte taxa in a survey that took into account previous references since the time of Corillion. In East Andalucía (the provinces of Málaga, Granada, Jaén, Almería and East Córdoba), Ortega *et al.* (2004) recorded 16 taxa in water bodies such as small ponds, salt crops, river mouths, etc. In inner zones of the Iberian Peninsula, for example in the Alto Guadalquivir wetlands (Jaén province), charophyte richness was up to five taxa (Ortega *et al.* 2007). The small lake called Valdeazores was the one with the highest diversity (three taxa). In the Duero basin wetlands, Flor-Arnau & Cambra (2015) found 10 taxa at 14 out of 71 visited sites, of which 39 possessed water when visited (summer of 2005) (eight taxa belonged to the genus *Chara* and two to the genus *Nitella*). These authors stressed the considerable decline of charophyte species richness in the area evident when comparing this survey with the one carried out by Alonso & Comelles (1987) in the period 1977-86. They considered an increase of anthropogenic disturbances (mainly those related to agriculture and raising of livestock) to be the cause of the indicated

Table 2. Charophyte taxa in some (Iberian) peninsular and non-peninsular Mediterranean wetlands.

Ecosystem	Province/Country	Type of system	Surface (ha)	*Chara aspera*	*C. braunii*	*C. canescens*	*C. connivens*	*C. fragifera*	*C. galioides*	*C. globularis*	*C. hispida* var. *hispida*	*C. imperfecta*	*C. major*	*C. polyacantha*	*C. vulgaris*	*C. vulgaris* var. *contraria*	*C. vulgaris* var. *crassicaulis*	*C. vulgaris* var. *longibracteata*	*C. vulgaris* var. *oedophylla*	*C. vulgaris* var. *vulgaris*	*Chara hispida*	*Lamprothamnium papulosum*	*Nitella capillaris*	*N. confervacea*	*N. flexilis*	*N. gracilis*	*N. hyalina*	*N. mucronata*	*N. opaca*	*N. tenuissima*	*N. translucens*	*Nitellopsis obtusa*	*Tolypella glomerata*	*T. hispanica*	*T. intricata*	*T. prolifera*	*T. salina*	Reference
Llobregat delta	Barcelona	Small lakes, channels, flooded areas	923	•	•					•								•		•																•		Seguí 1995
Albufera Adra	Almería	Lagoon	13			•				•								•			•																	Ortega et al. 2004
S'Albufera de Mallorca	Balearic Islands	Lagoon	1687	•		•	•		•	•			•		•						•	•										•	•					Martínez-Taberner & Pericàs 1988; Martínez-Taberner & Moyà 1991
Doñana National Park	Huelva Sevilla	Wetlands	54252	•		•	•	•	•	•						•		•	•	•	•	•			•		•			•	•			•		•	•	García Murillo et al. 2006
High Guadalquivir wetlands	Jaén	10 karstic ponds and wetlands		•			•			•								•							•													Ortega et al. 2004
Duero basin	Soria, Burgos Valladolid Zamora Salamanca	Pools, ponds, small lakes		•		•	•			•			•	•		•									•	•												Flor-Arnau & Cambra 2014
Tablas de Daimiel National Park	Ciudad Real	Wetlands	32	•		•	•													•	•									•			•	•				Álvarez-Cobelas et al. 2001
Ruidera Natural Park	Albacete-Ciudad Real	Karstic lakes, wetlands	3772	•							•		•	•	•	•	•					•		•			•						•					Cirujano & Medina 2002
Rice fields	Tarragona Valencia	More than 100 rice fields			•					•										•																		Carretero 1987
Languedoc-Roussillon	France	Ponds								•		•			•														•				•					Soulié-Märsche in Grillas et al. 2004
Zasavica Special Nature Reserve	Serbia	Wetland	1150							•					•	•							•	•				•				•			•	•		Vesić et al. 2011
Sidi Bou Rhaba	Morocco	Saline shallow lake	1700	•																																		
Merja Bokka	Morocco	Freshwater shallow lake	5												•																							
Megene Chitane	Tunisia	Small soft-water lake	250																										•									
Garaet El Ichkeul	Tunisia	Shallow freshwater lake	890000																														•					Ramdani et al. 2001
Korba	Tunisia	Long narrow shallow channel	32																			•																
Nile delta	Egypt	Lakes Edku, Burullus and Manzala	189600																																			

decline. These alterations changed the quantity and quality of water susceptible to hosting charophytes. In the Tablas de Daimiel National Park, eight taxa were cited in the period 1956-1997 (Álvarez-Cobelas *et al.* 2001). In the Ruidera Lakes Natural Park and nearby environments, on the other hand, Cirujano & Medina (2002) found 11 taxa. Carretero (1986) listed the charophyte taxa in rice fields of the Tarragona and Valencia provinces. In the former province only two taxa were cited, while three were cited for Valencian rice fields, *Ch. vulgaris* being the most heavily represented species in both provinces. In the present study, in spite of not being an exhaustive survey of Valencian rice fields, the three taxa listed by Carretero were also found, along with *Ch. imperfecta, Ch. vulgaris* var. *contraria*, *Ch. vulgaris* var. *inconnexa* and *Ch. vulgaris var. longibracteata*. Rice fields have been considered as habitats where certain species can be found (Uwe Selig, University of Rostock, Germany; pers. comm.), but the number of scientific publications treating charophytes in rice fields is small (Soulié-Märsche *et al.* 2013). This kind of environment is subject to great human influence. They are habitats with a variable flooding regime (they are flooded for most of the year, but remain dry for some months), and most of them undergo phytosanitary treatments (with herbicides and algaecides). In fact, research is being developed in some countries to produce specific pesticides to combat charophytes in rice fields (Guha 1991), since they reduce the economical yield. On the other hand, charophytes in rice fields have also been described as important contributors to fertilisation with nitrogen in the soils of these systems through the action of epiphytic N-fixing cyanobacteria, which grow mainly on charophyte nodes (Ariosa *et al.* 2004).

In Mediterranean Europe (Table 2), up to six taxa of charophytes were recorded in temporary lacustrine systems of the French region of Languedoc-Roussillon (Soulié-Märsche in Grillas *et al.* 2004). Some of them were vernal species that have a higher patrimonial value such as *Nitella opaca*, and some were more opportunistic species such as *Ch. vulgaris* and *Ch. globularis.* Vesić *et al.* (2011) recorded nine species (three from the genus *Chara*, four from *Nitella* and one from *Tolypella*) in a protected Serbian wetland included in the Ramsar list (1998-2010). The preferred habitats for charophytes were shallow, often ephemeral, ponds and puddles in diluvial forests and marshy meadow depressions.

Expanding the geographical range of our comparison to the African continent, we note that the charophyte richness cited in Mediterranean zones such as the coastal regions of Morocco and Tunisia was low (CASSARINA project, Ramdani *et al.* 2001). Surprisingly, in four lakes from the Nile Delta included in the project, no charophytes were detected in the survey of aquatic vegetation. This low richness might be related to a weak sampling effort or to strong disturbances (pollution, transformations, etc.) in the surveyed water bodies.

CONCLUSION

In spite of the alterations which aquatic environments of the AVNP suffered in the past, and thanks to some of the transformations carried out on these environments to rectify their status and remove problematic conditions, this natural park can be considered as a site of high charophyte richness in comparison with other wetlands and other water bodies, namely Mediterranean littoral systems on the Iberian Peninsula and elsewhere. Only in the vast Doñana National Park was greater charophyte richness found compared to the AVNP. We therefore stress the relevance of the surveyed water bodies for the future conservation of charophytes in the area. And we also point out the need to preserve these habitats in order to keep the charophyte flora healthy and thriving. We consider the results obtained in the present study to be of interest both to charophytologists who deal with biogeographic distribution and to managers of protected areas.

Acknowledgements — The authors thank Joan Miquel Benavent (Devesa-Albufera Technical Office) and William Colom (University of Uppsala) for their help during some of the samplings. The English was edited by Daniel Sheerin (Online English S.C.).

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Botanica SERBICA

REZIME

Harofite Ramsarskih mediteranskih vlažnih staništa (Albufera de València park prirode, Španija) u periodu 2007-2010

María A. Rodrigo i José L. Alonso-Guillén

Park prirode Albufera de València (AVNP) je međunarodno prepoznata obalna oblast. Sa produžetkom od 21000 ha sastavljena je od velike lagune okružene močvarama koje se koriste za pirinčana polja, mreže kanala za navodnjavanje koji povezuju pirinčana polja sa lagunom, malih jezera sa svežom brakičnom vodom sporadično raspoređenih između peščanih dina koje odvajaju lagunu od mora, seta potoka i novoformiranih veštačkih ostrva. Tokom 60-ih i 70-ih godina ova oblast je bila ozbiljno ugrožena urbanizacijom, razvojem poljoprivrede, industrijom itd., i tada su mnoge od ovih vodenih površina uništene. U poslednje vreme su menadžeri obnovili neke od ovih akvatičnih ekosistema. Između 2007. i 2010. godine smo posetili 32 lokacije (6 pirinčanih polja, 10 jezera, 8 potoka, 4 kanala i 4 lokaliteta na 2 veštačka ostrva) i istraživali na njima bogatstvo harofita. Sakupili smo makroalge kao i sediment (tražeći oospore i girogonite harofita). Identifikovano je 15 vrsta harofita (*Chara aspera, C. braunii, C. canescens, C. globularis, C. hispida* var. *baltica, C. hispida* var. *hispida, C. imperfecta, C.vulgaris* var. *contraria*, *C. vulgaris* var. *inconnexa, C. vulgaris* var. *longibracteata,C. vulgaris* var. *vulgaris, Lamprothamnium papulosum, Nitella hyalina, Tolypella glomerata* i *T. prolifera*), 14 njih kao rastućih uzoraka. *Chara vulgaris* je bila najčešće nađen takson. Najbogatija harofitama su bila pirinčana polja. U ovom parku prirode je prisutno oko 30% iberijske flore harofita (46 taksona) i 58% onih zabeleženih u provinciji Valensija (26 taksona). Jedanaest taksona roda *Chara* je prisutno na Iberijskom poluostrvu, pri čemu je sedam od njih prisutno u ovom parku prirode. Predstavljeno je, takođe, i poređenje bogatstva harofita sa ostalim zapadno mediteranskim vlažnim staništima.

Ključne reči: Albufera de València park prirode, *Characeae*, bogatstvo vrsta, antropogeni poremećaji, pirinčana polja, potoci, međudinska ostrva