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Effect of two management techniques applied to the reduction of *Juncus maritimus* (Lam.) abundance in a selected temporary wetland

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Abstract

Moderate management of temporary wetlands is one of the most proper methods for their restoration and conservation. The cessation of use may lead to high biomass domination by macrophytes as *Juncus maritimus* (Lam.) that changes plant community structure, threatens species biodiversity, and becomes a danger for their conservation. The experiment was carried out in Sidi Boughaba coastal reserve in Morocco. Two management techniques of wetlands were tested, cutting and uprooting of the rush. Four experimental plots (4.2 × 2.9 m) within the rush belt were set up, with intact plots as a control. Vegetation structure and water levels were monitored on 96 quadrats over two years. The six visits dates, three visits per year (February, April, June), were monitored over two years. The abundance and richness of species were studied, simultaneously with the density of the seed stock in each plot. Results showed that both techniques allowed the opening of the habitat with a significant increase of richness and abundance of species, particularly the restoration of characteristic species of the temporary wetland from the seed bank. The cut technique seems to have less of an effect on the seed stock, total seeds median value was 6.5 in cut plots versus 5 in uprooting plots, being regularly applied given the rapid encroachment of the rush.

Key words: conservation of temporary wetlands, experimental approach, *Juncus maritimus* (Lam.), rush, seed bank, techniques of management

INTRODUCTION

Among the Mediterranean region, temporary wetlands are habitats of high biodiversity interest; particularly because of the rare and endangered species they harbour [BIGGS *et al.* 2005; ERWIN 2009; MEDAIL *et al.* 1998; OERTLI *et al.* 2008; WILLIAMS *et al.* 2004]. In these habitats species can use different strategies to establish [SAHIB 2018]. In Europe, they are recognized as priority areas regarding conservation (Natura Code 3170 [Council Directive 92/43/CCE]), and protection [MIODUSZEWSKI, OKRUSZKO 2012]. The species of plants present in temporary wetlands are dominated by annual species, adapted to the alternation of dry and wet phases, and the huge interannual variation in high and duration of flooding [DE BÉLAIR 2005].

Recently, temporary wetlands have gained significant prominence but yet remain overlooked with inadequate

management [SNODGRASS *et al.* 2000]. Traditional land use practices by local people have always existed with biodiversity conservation, and have been of great benefit for habitats [BEJA, ALCAZAR 2003; GRILLAS, ROCHÉ 1997] by supporting the conservation of threatened species after the habitat opening due to high biomass harvest, that supports rural people's small economic activities [GÓMEZ-BAGGETHUN *et al.* 2010]. Since halophytes (e.g. *Phragmites australis* (Cav.) Trin. ex Steud., *Juncus maritimus* (Lam.)) are harvested for traditional handicraft and (e.g. *Papus* spp.; *Typha* spp.) are used as a source of biomass energy [JONES *et al.* 2016; LISHAWA *et al.* 2015].

The abandonment of moderate traditional land uses have led to a high biomass domination, which consequently changed the plant community structure in many habitats [BIGNAL, MCCracken 1996; KEDDY 2010; MACDONALD *et al.* 2000], as the case in temporary wetlands it leads to

a habitat deterioration by a strong dynamics of macrophytes and woody species [GRILLAS, TAN HAM 1998]. These traditional practices appear to play an important role in conserving the biodiversity [O'ROURKE 2006; PLIENINGER *et al.* 2006], and were reported as management methods of macrophytes and perennials.

Macrophytes succession is usually accompanied by a change in the physical characteristics of the environment [BLOSSFELD *et al.* 2011; BREZINOVÁ, VYMAZAL 2014]. Litter accumulation, and enrichment of the soil with organic matter has an effect on the vegetation dynamics and species recruitment, resulting in the modification of the biological richness. The effect is more pronounced on rare and characteristic species [HOULAHAN, FINDLAY 2004] that life traits (e.g. small size, weak competitiveness) are a disadvantage in highly colonised habitats.

As in temporary wetlands, the conservation of characteristic species involves the opening up of the habitat with the appropriate management of competitive plants [ERVIN, WETZEL 2002]. Cutting and burning have been experimentally tested to restore the biodiversity and richness of wet habitats [ZEDLER 2000], or by a combination of multiple management strategies [MILLER 2016]. The choice of the efficient technique depends strongly on, the physical and the biological properties of the habitat as well as financial cost [MILLER, HOBBS 2007].

In the north-west of Morocco, the temporary wetland of Sidi Boughaba's coastal reserve has always been grazed by cattle, and the rushes *Juncus maritimus* (Lam.) were harvested by the local people for traditional handicrafts. Since the 1980s and after the enclosing of the reserve [AT-BIB 1979–1980; RAMDANI *et al.* 2001], these traditional activities have been abandoned, and a strong dynamic of rushes has been observed. The reserve is undergoing rushes domination (Fig. 1).

The main assumptions of this work are:

- cutting and uprooting increase the abundance and richness of species, by reducing competition and allowing the establishment of seeds from the undisturbed vertical stratification of seeds stock; the efficient method is cutting, and the expected increase is greater for annual species more than perennials, and also greater for characteristic species of a temporary wetland than for terrestrials;
- uprooting the rushes reduces the density and the richness of seed stock, because of the disturbance of the soil's vertical stratification by roots removal;
- interannual dynamic of vegetation is greater when uprooting, more than when cutting with a leading role of hydrology.

The main hypothesis for this work is that the spreading and condensation of rushes *Juncus maritimus* (Lam.) leads to a regression of abundance and richness of herbaceous species particularly the characteristic species of temporary wetlands. Restoration treatments are necessary to reduce the high biomass of macrophytes and consequently allow characteristic species to become established from seed stocks. Furthermore, to suggest adequate management methods for a general model which could be related to temporary wetlands, the aim of the current study is to con-

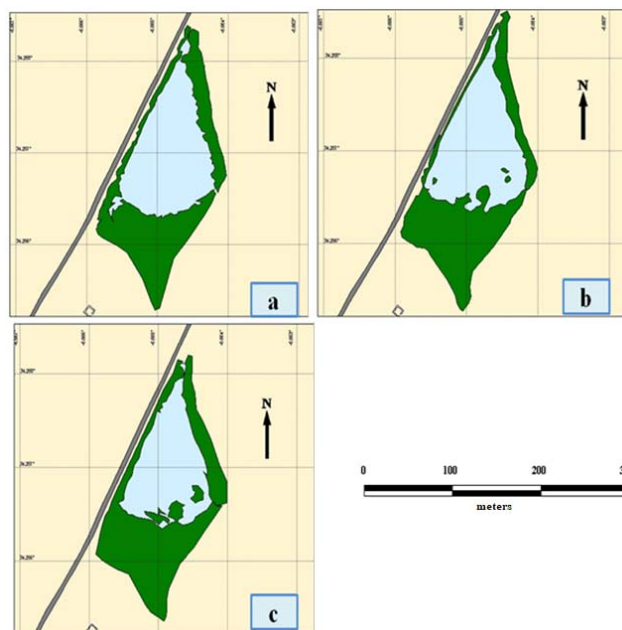


Fig. 1. Dynamic of the rush *Juncus maritimus* (green belt) around the studied temporary wetland; a) twenty years before the enclosing, b) twenty years after the enclosing, c) thirty years after the enclosing; source: own elaboration based on the aerial photographs of the Mapping Service and the Google Earth environment for visualizing images software was used for image analysis

duct a test in a (cutting vs. uprooting) experiment, to explore the possibility of restoring characteristic species of temporary wetlands being colonised by rushes *Juncus maritimus* (Lam.). For this reason, the study combined a test of (cutting vs. uprooting) clearance in the field with seed stock germination.

MATERIALS AND METHODS

STUDY AREA

Experimental management of rushes *Juncus maritimus* (Lam.) (cutting vs. uprooting) for the restoration of the biodiversity, particularly characteristic species of one selected temporary wetlands were set up simultaneously with a seed bank study. The experiment was carried out in the temporary wetland located at the upper northern side of the wet complex of Sidi Boughaba (34°12' N; 6°42' E), located in the North-West coast of Morocco (Fig. 2) by the estuary of the Sebou River. The wet complex puts together:

- a permanent shallow lake (<3 m deep) extending to a ~6 km long depression, that separates on the east side coastal mobile dunes (20–30 m high) and fossilised dunes (~50 m high);
- a small seasonal wetland, adjacent to the lake, that the surface water flows down into the lake during heavy floods;
- a temporary wetland, that fills with water during the rainy season and dries out during the summer.

The 650 ha depression, including the temporary wetland, the seasonal wetland and the permanent lake, was established as a National Nature Reserve in 1975 and des-

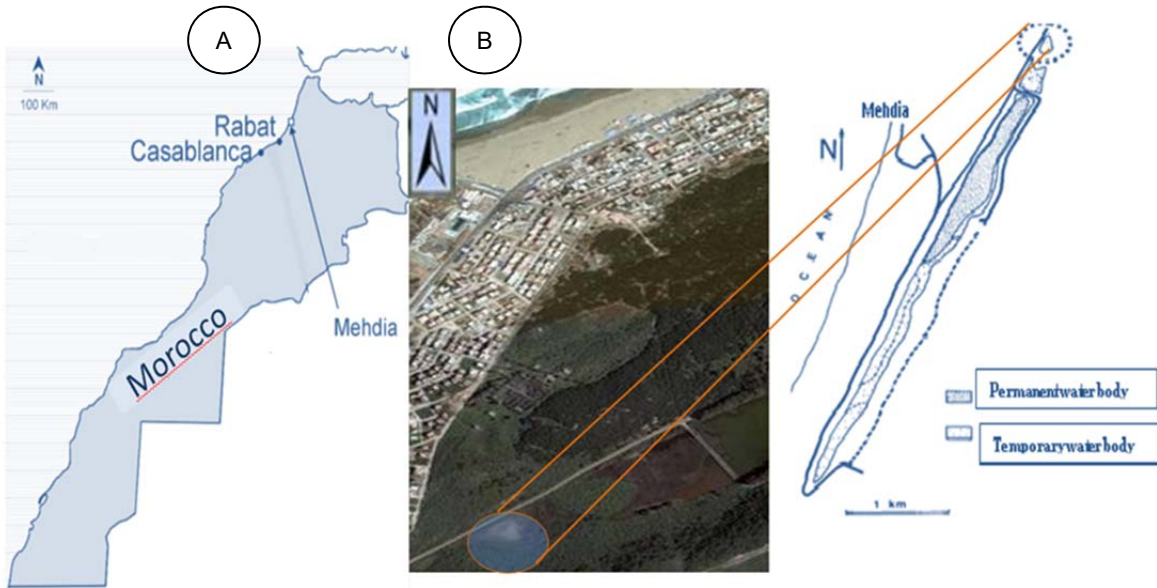


Fig. 2. Map of the wet complex of the reserve of Sidi Boughaba located by the estuary of the Sebou River near the Mehdia (North-West Morocco); dotted circle = the temporary wetland of the reserve (the study site); source: a) ATBIB 1983, B) aerial photography of the study site by Google Earth

ignated as a site of international importance by the Ramsar convention in 1980.

Sidi Boughaba reserve is subject to a Mediterranean climate with Atlantic influence ensuring yearly rainfall of between 500–600 mm. The Mediterranean climate is characterized by dry summers, mild winters and a very variable amount of rainfall from year to year. The Mediterranean climate is influenced by the Atlantic Ocean that produces a sub-humid Mediterranean climate with mild, moist winters from October until March/April, and hot, dry summers from May until September. The annual average temperature is of 18.4°C. The average of the annual precipitation reaches 570 mm [ZAIDI *et al.* 2016].

EXPERIMENTAL (CUTTING VS. UPROOTING) SET UP

Randomly within the rushes belt, four pairs of homogenous and neighbouring plots with two treatments were set up. A total of eight plots were assigned (4.20 × 2.90 m) plots were 2 m apart, to one of the three treatments (control, cutting, or uprooting) (Fig. 3). Vegetation was monitored on (30 × 30 cm) quadrats along the three permanent and parallel transects/plots (Fig. 3). Transects were 1 m apart. The number of quadrats per plot was 12, spread over the three transects, with a total of 96 quadrats for the experiment. Cutting treatment: consisted of cutting the whole rushes stems at the sediment surface using a brush cutter,

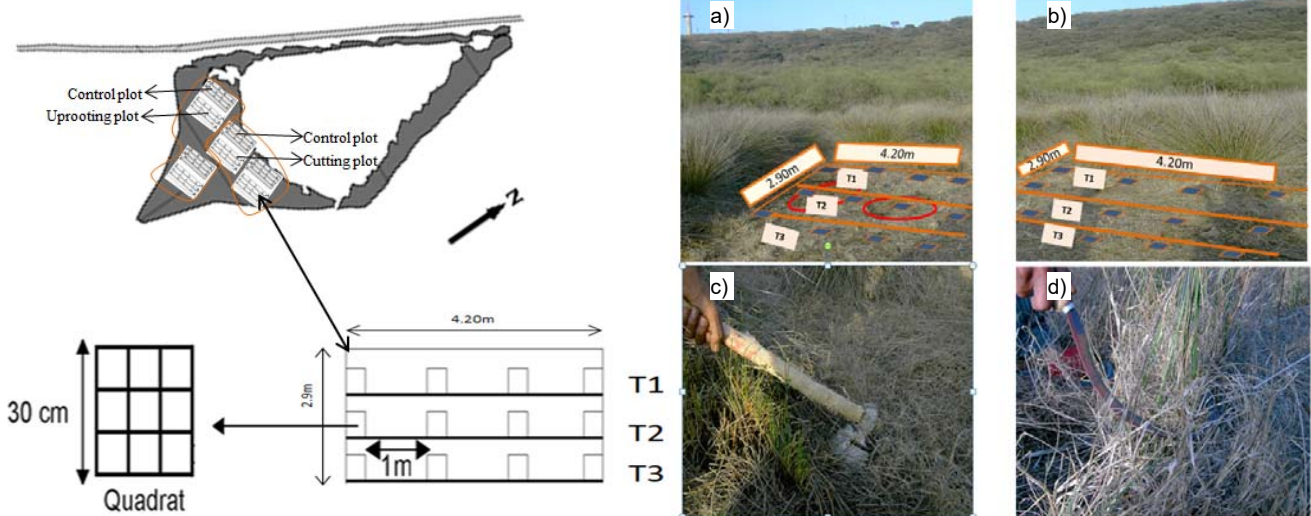


Fig. 3. Spatial distribution of the plots in the rush belt *Juncus maritimus* L. of the temporary wetland; four zones (2 treatments per zone with 4.20 × 2.90 m), vegetation was monitored on 30 × 30 cm quadrats placed along permanent and parallel transects (T1, T2, T3) with a total of 96 quadrats; photos: a) uprooting plot, b) cutting plot, c) the proceeding of uprooting treatment after cutting of the rush stems followed by hand removal of all roots from the sediment red circles are showing created micro-cavities which remained flooded longer after root removal, d) the cutting treatment with brush cutter; source: own elaboration

then removing biomass and all litter outside the plots. Uprooting treatment: consisted firstly of cutting off the rushes stems followed by hand removal of all roots from the sediment. Both treatments were applied at the start of the experiment (December 2011).

On each quadrat, the cover of each species was noted according to the Braun–Blanquet scale [KENT, COKER 1992]. Water depth (when present) was measured in each quadrat at each date over two years (2012 and 2013), with three visit dates per year (February, April, June). The quadrats were not flooded during the first year but were under maximum water heights of between 10 and 30 cm during the second year. Maximum water depths in quadrats in the 1st year experiment, did not differ significantly between the four control zones ($p > 0.05$), but differed significantly between the three treatments (control, cutting, uprooting) ($\chi^2 = 14.40$; $df = 2$, $p = 0.0007$), with greater water heights in the uprooting and cutting treatments than in the control.

The abundance of each species was calculated at each monthly date (February, April, June) as was the frequency of that species in each quadrat. The abundance value used in data analysis was accumulated and a sum obtained across the different dates for each year. The species richness per plot was calculated as the accumulated sum of the species found across dates separately for each year. The annual or perennial trait (Tab. 1) was attributed for each species, following “Flora of North Africa” [MAIRE 1952–1987] consisting of sixteen volumes, and “Flora of Morocco” [FENNANE *et al.* 1999; 2007; 2014] consisting of three. The characteristic species of temporary wetlands (been defined as aquatic plants and amphibious ones), as well as the opportunistic species (been defined as terrestrial plants generally frequent in the surroundings) both have been identified following “Flora of North Africa” [MAIRE 1952–1987] and “Flora of Morocco” [FENNANE *et al.* 1999; 2007; 2014].

STUDY OF SEED BANK/SPORE

Within each of the 96 quadrats where vegetation was monitored, a (4 × 4 cm) soil core targeting viable seeds [BONIS, LEPART 1994; LAVOREL *et al.* 1993] were sampled the first year of the experiment, after cutting and uprooting the rushes. In the laboratory, samples were weighed, soaked in water, and spread out on a layer of synthetic absorbent tissue on top of a 1 cm layer of washed and sterilized sand. The samples were arranged at random and watered daily. Once the seedlings emerged, they were identified, counted, and removed. Monitoring was performed weekly for the first four months, then monthly. After being kept dry for five months, the same samples were again submitted to the same germination conditions. For each sample, the seed density (total number of germinations per 1 g of sediment) was calculated.

DATA ANALYSIS

Differences in species richness (total, annuals, perennials and characteristic species) and species abundance

(total, annuals, perennials and characteristic species) and differences in density and species richness in the seed stock (total, annuals, perennials and characteristic species) between treatments (control, cutting, uprooting) were analysed separately for each year using non-parametric Kruskal–Wallis tests. Comparisons by pair of treatments were performed. Difference in maximum water depths per quadrat between the four control zones, as well as between the three treatments (control, cut, uprooting), was studied by a nonparametric variance analysis Kruskal–Wallis. Correlation between the abundance of species (total, annuals, perennials, terrestrials and characteristic species) in vegetation and their abundance in the seed stock was tested by linear regressions performed separately for each treatment and each species group (JMP™ software).

A correspondence analysis (CA) was performed on the overall vegetation data during the two years of monitoring, taking into account (for each year, and each species) the maximum value of frequency (the frequency of each species was the maximum value found in sampling dates) recorded per quadrat. The CA was conducted with 39 species, excluding those found in less than four quadrats over the two years (<0.5% of the total number of quadrats). The centroids of the distribution of the quadrants of each year were positioned on the 1/2 biplot (Statistica 7.0).

RESULTS

SPECIES RICHNESS AND ABUNDANCE RESPONSE TO CUTTING AND UPROOTING

During the two cumulative years, 54 species were recorded in all quadrats, including 43 annuals (80% of the total) and 11 perennials (20%). A total of 41 species (33 annuals, 8 perennials) were found for control, 45 (37 annuals, 8 perennials) for the uprooting and 48 (39 annuals and 9 perennials) for the cutting (Tab. 1). The maximum water depth did not differ significantly between the four control zones ($p > 0.05$), but it was significantly different between the three treatments (control, cutting, uprooting) ($\chi^2 = 14.40$; $df = 2$, $p = 0.0007$); higher water was recorded in (uprooting and cutting) treatments than in the control one (Fig. 4).

Species richness. Total species richness per quadrat and annual species richness was significantly greater in the treated plots than in control area over the two years of the experiment (Tab. 2). Both richness of total and annual species were not significantly different ($p > 0.05$) in the first year between the two treatments (cutting and uprooting), the second year more species were recorded (total and annual) in the uprooting treatment than in the cutting (Tab. 2). Perennials richness was significantly different between the three treatments, showing lower values in the control plots the first year (Tab. 2). However, the richness of perennials did not show any significant difference between control and both treatments over the second year (Tab. 2).

Characteristic species richness increased significantly ($p < 0.05$) in cutting and uprooting plots compared to control areas for both years (Tab. 2, Fig. 5A). This richness was not significantly different between cutting and uproot-

Table 1. List of recorded species during the experiment within each treatment over two years monitoring

Species	Code	Annuals (A)/ Perennial (V)	Characteristic species (m)/ Terrestrials (t)	Treatment		
				control	cutting	uprooting
<i>Agrostis pourretii</i> Willd.	Ag.sal	A	m	x	x	x
<i>Ammi majus</i> L.	Am.maj	A	t	x	n	x
<i>Anagallis arvensis</i> L.	An.arv	A	t	x	x	n
<i>Atriplex prostrata</i> Boucher.	At.pro	A	m	n	x	x
<i>Bellis annua</i> L.	Be.ann	A	t	x	x	n
<i>Bolboschoenus maritimus</i> L.	Sc.mar	V	m	x	x	x
<i>Briza minor</i> L.	Br.min	A	t	x	x	x
<i>Calendula arvensis</i> L.	Ca.alg	A	t	x	x	x
<i>Chara canescens</i> Desv. & Lois.	Chara	A	m	n	x	x
<i>Chenopodium chenopodioides</i> (L.) Aellen.	Ch.che	A	m	x	x	x
<i>Cynodon dactylon</i> L.	Cy.dac	V	t	n	x	x
<i>Daucus crinitus</i> Desf.	Da.cri	V	t	x	x	x
<i>Diplotaxis catholica</i> (L.) DC.	Di.cat	A	t	x	x	x
<i>Echium plantagineum</i> L.	Ec.pla	V	t	x	x	x
<i>Erodium cicutarium</i> L.	Er.cic	A	t	x	x	n
<i>Euphorbia exigua</i> L.	Eu.exi	A	t	x	x	n
<i>Exaculum pusillum</i> (Lam.) Caruel.	Ex.pus	A	m	n	n	x
<i>Filago gallica</i> L.	Fi.gal	A	t	n	x	x
<i>Frankenia laevis</i> L.	Fr.lae	V	m	x	x	x
<i>Fumaria agraria</i> Lag.	Fu.agr	A	t	x	x	x
<i>Gaudinia fragilis</i> (L.) P.Beauv.	Ga.fra	A	t	x	x	x
<i>Geranium molle</i> L.	Ge.mol	A	t	x	x	x
<i>Glyceria fluitans</i> (L.) R.Br.	Gl.flu	V	m	x	x	x
<i>Hedypnois cretica</i> (L.) Dum. Cours.	Hy.cre	A	t	x	x	x
<i>Hordeum maritimum</i> Hudson.	Ho.mar	A	m	x	x	x
<i>Isolepis cernua</i> (Vahl) Roem. & Schult.	Is.cer	A	m	n	x	n
<i>Juncus bufonius</i> L.	Ju.buf	A	m	x	x	x
<i>Juncus maritimus</i> L.	Ju.mar	V	m	x	x	n
<i>Juncus pygmaeus</i> Richard	Ju.pyg	A	m	n	x	x
<i>Leontodon taraxacoides</i> (Vill.) Merat.	Le.tar	V	t	n	x	x
<i>Lolium rigidum</i> Gaudin.	Lo.rig	A	t	x	x	x
<i>Lotus hispidus</i> DC.s	Lo.his	A	m	x	x	x
<i>Lythrum junceum</i> Banks & Solander	Ly.jun	V	m	x	x	x
<i>Malva hispanica</i> L.	Ma.his	A	t	n	x	x
<i>Medicago polymorpha</i> L.	Me.pol	A	t	x	x	x
<i>Mercurialis annua</i> L.	Me.ann	A	t	x	x	x
<i>Nitella opaca</i> Ag.	Nitella	A	m	x	x	x
<i>Cladanthus mixtus</i> (L.) Chevall.	An.mix	A	t	x	x	n
<i>Plantago coronopus</i> L.	Pl.cor	A	t	n	n	x
<i>Polypogon monspeliensis</i> (L.) Desf.	Po.mon	A	m	x	x	x
<i>Ranunculus baudotii</i> Schrank.	Ra.bau	A	m	x	x	x
<i>Ranunculus sardous</i> Crantz.	Ra.sa	A	m	x	x	x
<i>Rubia peregrina</i> L.	Ru.per	V	t	x	n	n
<i>Rumex crispus</i> L.	Ru.cri	V	m	n	x	x
<i>Rumex pulcher</i> L.	Ru.pul	V	m	n	x	n
<i>Salicornia herbacea</i> L.	Sa.her	A	m	x	x	x
<i>Sanguisorba minor</i> Scop.	Sa.min	V	t	x	n	x
<i>Spergularia salina</i> J. Presl & C. Presl.	Sp.sal	A	m	x	n	x
<i>Stellaria media</i> (L.) Vill.	St.med	A	t	x	x	x
<i>Tolpis barbata</i> (L.) Gaertn.	To.bar	A	t	x	x	x
<i>Trifolium michelianum</i> L.	Tr.mic	A	t	x	x	x
<i>Trifolium repens</i> L.	Tr.rep	A	t	x	x	x
<i>Urospermum picroides</i> (L.) Scop.	Ur.pic	A	t	x	x	x
<i>Urtica dioica</i> L.	Ur.dio	A	t	n	x	x
Total number of species	54			41	48	45

Explanations: x = recorded, n = not-recorded.

Source: own study, the identification of species was based on MAIRE [1952–1987] and FENNANE *et al.* [1999; 2007; 2014].

Table 2. Kruskal–Wallis results comparing the abundance and species richness (total, annuals, perennials, characteristics and terrestrials) between treatments (control: T; cutting: C; uprooting: E) over the 1st and 2nd monitoring year (df = 2)

Monitoring years	Description	Richness				Abundance			
		χ^2	<i>p</i>	median value	comparison	χ^2	<i>p</i>	median values	comparison
1 st year	total	50.69	<0.001	10.5 ^a ; 9 ^a ; 2 ^b	E ^a C ^a T ^b	38.03	<0.001	27 ^a ; 25.5 ^a ; 9 ^b	C ^a E ^a T ^b
	annuals	50.09	<0.001	8.5 ^a ; 6.5 ^a ; 1 ^b	E ^a C ^a T ^b	51.10	<0.001	22.5 ^a ; 22 ^a ; 10.5 ^b	E ^a C ^a T ^b
	perennials	6.36	<0.01	2 ^a ; 2 ^a ; 1 ^b	C ^a E ^a T ^b	6.71	<0.01	9 ^a ; 8 ^a ; 6 ^b	T ^a C ^a E ^b
	characteristics	28.93	<0.001	4 ^a ; 4 ^a ; 2.9 ^b	E ^a C ^a T ^b	21.16	<0.001	14 ^a ; 12.25 ^a ; 6.5 ^b	E ^a C ^a T ^b
	terrestrials	30.51	<0.001	3.5 ^a ; 3 ^a ; 3 ^b	C ^a E ^a T ^b	19.70	<0.001	19 ^a ; 15 ^a ; 10 ^b	C ^a E ^a T ^b
2 nd year	total	70.00	<0.001	13 ^a ; 12.5 ^b ; 6 ^c	E ^a C ^b T ^c	64.75	<0.001	33.5 ^a ; 32 ^b ; 11 ^c	E ^a C ^b T ^c
	annuals	71.50	<0.001	10 ^a ; 9 ^b ; 4 ^c	E ^a C ^b T ^c	71.30	<0.001	26.5 ^a ; 22 ^b ; 7 ^c	E ^a C ^b T ^c
	perennials	1.87	0.47	3 ^a ; 3 ^a ; 3 ^a	T ^a C ^a E ^a	14.56	<0.001	11 ^a ; 8.5 ^b ; 8.5 ^b	T ^a C ^b E ^b
	characteristics	40.94	<0.001	6 ^a ; 5 ^b ; 3 ^c	E ^a C ^b T ^c	20.69	<0.001	19 ^a ; 13.5 ^b ; 10 ^c	E ^a C ^b T ^c
	terrestrials	78.65	<0.001	7.5 ^a ; 6.5 ^a ; 1 ^b	E ^a C ^a T ^b	77.85	<0.001	20 ^a ; 18.5 ^b ; 16 ^b	E ^a C ^a T ^b

Explanations: different letters on median values and their comparison represent significant difference between treatments (*p* < 0.05). Source: own study.

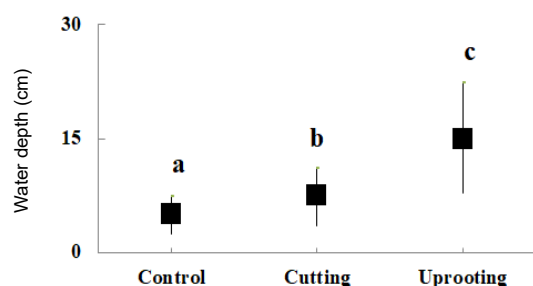


Fig. 4. Comparison of water depth recorded between treatments (control, cutting and uprooting) over the second year monitoring; on the graphs are represented the medians the minimum and maximum for each treatment; the different letters on the graph indicate a significant difference between treatments (*p* < 0.05); source: own study

ing during the first year but increased significantly in the second year (Tab. 2). The terrestrial richness was significantly greater in the cutting and uprooting plots compared to controls over the two years of monitoring (Tab. 2). Terrestrials' richness did not show a significant difference between cutting and uprooting (*p* > 0.05) over the two years (Tab. 2). Total richness per quadrat was correlated to the maximum depth of water in the second year ($r^2 = 0.30$, $p < 0.0001$, $n = 96$). This correlation was greater for the richness of characteristics ($r^2 = 0.40$, $p < 0.0001$, $n = 96$) compared to terrestrial richness ($r^2 = 0.10$, $p = 0.01$, $n = 96$).

Species abundance. Total species abundance per quadrat and annuals abundance were significantly greater in the treated plots than in control during the two years experiment (Tab. 2). Their abundance had significantly increased in uprooting plots during the second year (Tab. 2). The abundance of perennials was significantly lower in the uprooting plots than in the cutting and control plots during the first year. Cutting and control plots did not show any significant change (Tab. 2) in the second year. The abundance of perennials was significantly lower both in the uprooting and cut plots, compared to control, with a small difference between cutting and uprooting (Tab. 2). The abundance and richness of characteristic species had increased more and significantly both in experimental and control plots during the two years experiment (Tab. 2; Fig 5A, 5B). Their abundance was not significantly different between the cut and uprooting in the first year but had increased significantly the following year in uprooting (Tab. 2). The abundance of terrestrial species was significantly higher in the experimental plots than in the controls during the two-year experiment (Tab. 2), but with no significant difference between cutting and uprooting treatments (Tab. 2). The total vegetation abundance was significantly correlated with the maximum water depth ($r^2 = 0.32$, $p < 0.0001$, $n = 96$). This correlation was greater for the abundance of characteristic species ($r^2 = 0.35$, $p < 0.0001$, $n = 96$) compared to the abundance of terrestrials ($r^2 = 0.1$; $p = 0.01$; $n = 96$).

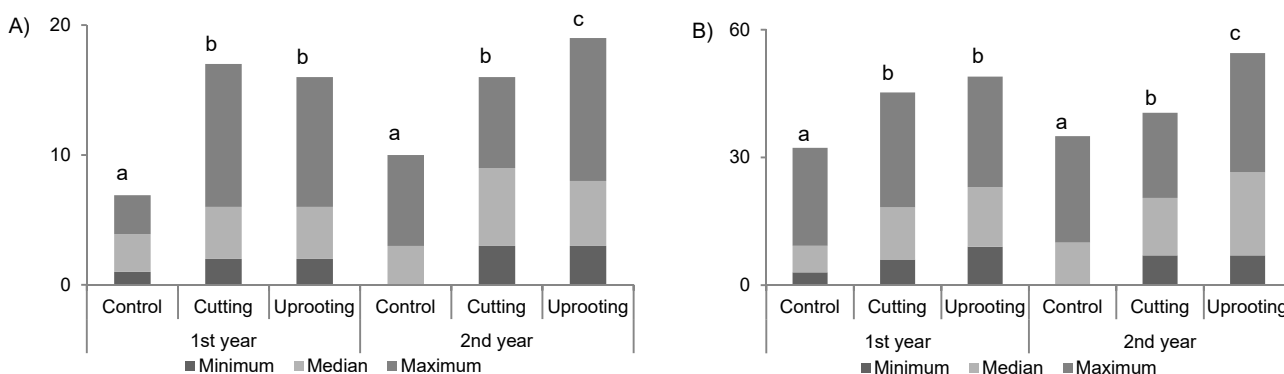


Fig. 5. Comparison of characteristic species richness (A) and abundance (B) between treatments (control, cutting and uprooting), separately for each year monitoring; on the graphs are represented the minimum, the medians and maximum for each treatment; the different letters on the graph indicate a significant difference between treatments (*p* < 0.05); source: own study

EFFECT OF CUTTING AND UPROOTING ON SEED STOCK DENSITY AND RICHNESS

During the germination trial of soil samples cored from the quadrats, a total number of 8876 germinations occurred (1621 established in cutting treatment, 1923 in uprooting and 5232 in control). 27 species were identified (24 annuals and 3 perennials) a number of 17 species occurred in the uprooting treatment (14 annuals and 3 perennials) 21 species in the cutting treatment (17 annuals and 4 perennials) and 25 species occurred in the control (19 annuals and perennials). The seed bank was mainly dominated by *Juncus maritimus* (Lam.) (34% of total seedlings), *Polypogon monspeliensis* (L.) Desf (25% of total seedling), *Anagallis arvensis* (L.) (11% of total seedling), *Juncus pygmaeus* (Rich.) (10% of total seedling) and *Chenopodium chenopodioides* (L.) Aellen. (4% of total seedling).

Seed stock density and richness. The density of the seed stock (total, annuals and terrestrials) was significantly higher in the control area, but showed no difference between cutting and uprooting treatments. On the other hand, no significant difference of the density of perennials was recorded (Tab. 3). While seed density of characteristic species was significantly different between the three treatments, but remained higher in control (Tab. 3). The total richness of seed stock, as well as annuals richness, was significantly different ($p < 0.05$) between control, uprooting and cutting. They were higher for the control but greater in the cutting treatment (Tab. 3), perennials showed no significant difference between treatments (Tab. 3).

Correlation between vegetation/seed stock within treatments.

During the two years of monitoring, the correlation between vegetation and seed stock ranged between treat-

ments with an r^2 value ranging from 0.03 to 0.96 (Tab. 4). Seeds/vegetation correlation was not significant for the total species among control as well as annuals, characteristics and terrestrials but significant for perennials (Tab. 4). The cutting treatment showed the same correlation seed/vegetation for perennials. Concerning the uprooting treatment, the correlation between vegetation and seed stock was significant for the total number of species, the annuals, the characteristics, and terrestrials, but not significant for the perennials (Tab. 4).

Post-treatment temporal community dynamic. The first two axes of correspondence analysis (CA) account for 54.16% of the total variance (Fig. 6A). F₁ axis (39.47% of variance) opposes characteristics of temporary considered as aquatic species *Ranunculus baudotii* Schrank., *Glyceria fluitans* (L.) R.Br., and terrestrial species *Anagallis arvensis* L., *Hordeum maritimum* Hudson. F₂ axis (14.69% of variance) opposes treatments (cutting and uprooting) with low abundance of vegetation and control areas with high abundance. The coordinates of centroids of quadrats on F₁ axis were correlated with the maximum depth of water ($r^2 = 0.97, p = 0.004, n = 96$). The coordinates of vegetation quadrats on the F₂ axis of the CA were significantly correlated (Fig. 6A). With the total abundance of species per quadrat ($r^2 = 0.93, p = 0.0016, n = 96$).

The annual centroids displacement of treatments (control, cutting, uprooting) on the 1/2 biplot of the CA was more important for uprooting treatment compared to cutting. While it was lower for the control (Fig. 6B), the displacement was along the F₂ axis for the uprooting and the cutting, reflecting an increase in vegetation abundance during the two years monitoring, but along the F₁ axis for the control treatment reflecting an increase in the number of terrestrial species (Fig. 6B).

Table 3. Kruskal–Wallis results comparing seed stock density and richness (total, annuals, perennials, characteristics and terrestrials) between treatments (df = 2)

Description	Density				Richness			
	χ^2	p	median value	comparison	χ^2	p	median value	comparison
Total	16.98	<0.001	1.32 ^a ; 0.88 ^b ; 0.75 ^b	T ^a E ^b C ^b	9.15	<0.01	7 ^a ; 6.5 ^b ; 5 ^c	T ^a C ^b E ^c
Annuals	16.89	<0.001	1.32 ^a ; 0.88 ^b ; 0.75 ^b	T ^a E ^b C ^b	9.71	<0.001	7 ^a ; 6.5 ^b ; 5 ^c	T ^a C ^b E ^c
Perennials	1.87	0.39	0 ^a ; 0 ^a ; 0 ^a	T ^a E ^a C ^a	1.87	0.39	0 ^a ; 0 ^a ; 0 ^a	T ^a C ^a E ^a
Characteristics	14.98	<0.001	0.91 ^a ; 0.61 ^b ; 0.42 ^b	T ^a E ^b C ^b	5.87	<0.01	4 ^a ; 4 ^a ; 3 ^b	T ^a C ^a E ^b
Terrestrials	9.10	<0.01	0.45 ^a ; 0.3 ^b ; 0.23 ^b	T ^a C ^b E ^b	6.74	<0.01	3 ^a ; 2 ^b ; 2 ^b	T ^a C ^b E ^b

Explanations: T = control, C = cutting, E = uprooting; different letters on median values and their comparison represent significant difference between treatments ($p < 0.05$).
Source: own study.

Table 4. Correlation between the abundance of species (total, annuals, perennials, characteristics and terrestrials) in the aboveground vegetation and seed stock density for the three treatments (control, cutting, uprooting)

Treatment	Total abundance			Annuals abundance			Perennials abundance			Characteristics abundance			Terrestrials abundance		
	r^2	p	n	r^2	p	n	r^2	p	n	r^2	p	n	r^2	p	n
Control	0.20	0.08	43	0.06	0.85	35	0.82	0.009	8	0.03	0.2	19	0.13	0.2	24
Cutting	0.17	0.17	46	0.16	0.35	37	0.96	0.0001	9	0.16	0.3	21	0.11	0.4	25
Uprooting	0.37	0.009	52	0.35	0.01	42	0.44	0.32	10	0.21	0.008	22	0.57	0.006	30

Explanations: r^2 = determination coefficient, n = total number of observations of species abundance.
Source: own study.

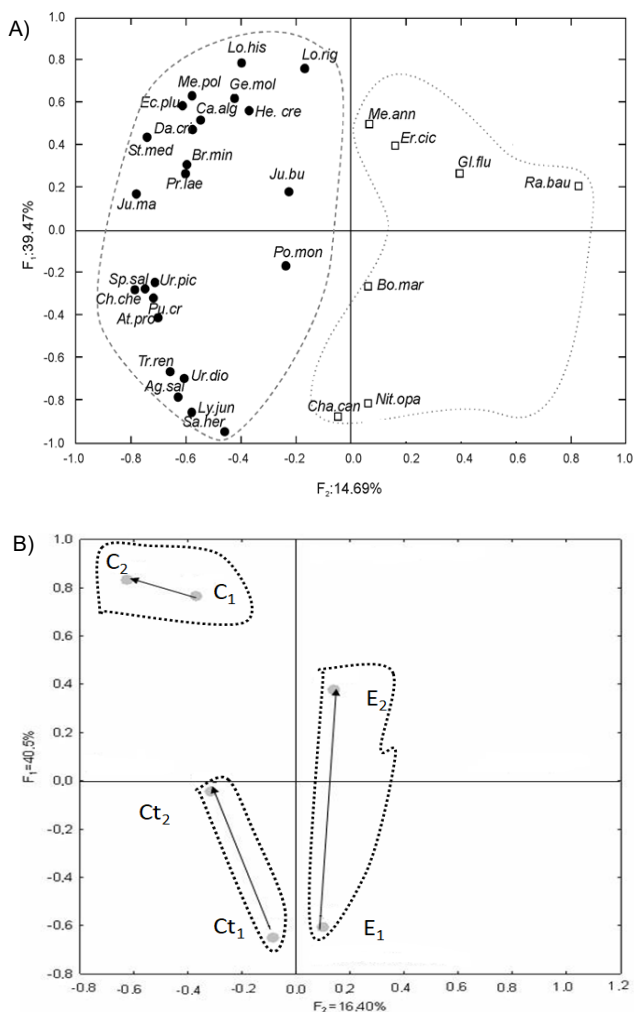


Fig. 6. Plot 1/2 of the CA with the positioning of centroids of vegetation axis 1 opposes characteristics and terrestrials; axis 2 opposes high abundance and low abundance (species code in Table 1) (A) and plot 1/2 of the CA over the two years monitoring with the positioning of centroids of each year; C₁, Ct₁, E₁: control, cutting, uprooting first year post treatment respectively and C₂, Ct₂, E₂: control, cutting, second year post treatment uprooting respectively axis 1 opposes characteristics and terrestrials axis 2 opposes high abundance and low abundance (B); source: own study

DISCUSSION

Both the cutting and uprooting the rushes *Juncus maritimus* (Lam.) had significantly increased the richness and abundance of the species (total, annuals, and characteristics). Since the first year experiment, showing that the reduction of heavy biomasses of high competitors favours the recruitment and installation of fewer competitor species [BARBARO *et al.* 2001; ERWIN, WETZEL 2002; KAHMEN *et al.* 2002]. Cutting followed by biomass removal was found in other ecosystems in Europe such as montane fen meadow [BILLETTER *et al.* 2007] and grassland [WAHLMAN, MILBERG 2002], as an efficient technique for restoring and conserving the biodiversity.

Over the second-year experiment, this increase was greater in the uprooted plots than in cut ones (Tab. 2), probably as a result of the maximum water depth that was

significantly higher in the uprooted plots than in the cut ones (Fig. 4). This could be explained by the creation of micro-cavities during root removal that remained flooded longer, favouring the establishment of many species [JANSEN, ROELOFS 1996] particularly characteristic species of the temporary wetlands (e.g. *Chara canescens* Desv. & Lois., *Juncus pygmaeus* (Rich.), *Exaculum pusillum* (Lam.) Caruel.). The significant correlations found between species richness/maximum water depth on the one hand, and species abundance/maximum water depth, on the other hand, could confirm this hypothesis. Compared to terrestrials ($r^2 = 0.10$), characteristic species were more favoured by these hydrological conditions ($r^2 = 0.35$). The result joins many studies that highlight the importance of environmental variables, particularly hydrology, in the restoration of communities in wetlands [KERCHER, ZEDLER 2004; ZEDLER 2000].

Furthermore the long-term study conducted by KOLOS and BANASZAK [2013] emphasizes that cutting must be accompanied by appropriate hydrological conditions, among which flooding is of great importance, otherwise cutting cannot be adequate to suppress rushes and ensure the restoration of species richness on wetlands meadows. Species recruitment would be mainly linked to some release of the local seed stock; while the role of colonisation from neighbouring sites would be reduced given the limitation of particular mechanisms for dispersal. The increase of species richness and abundance of the characteristic species of the temporary wetlands after cutting and uprooting rushes *Juncus maritimus* (Lam.) is an indicator of the success of their restoration. This result, obtained over a two-year monitoring period is likely to change over the short periods of time because of the rapid development of macrophytes. To cope with the problem, a repeated annual monitoring of the use of the land will be required, as it would reduce rushes dominance [LISHAWA *et al.* 2015]. Indeed, GÜSEWELL *et al.* [2000] had shown the main role of both frequency and timing of mowing for the success of restoration; this is due to tolerance of macrophytes to mechanical handling [DEER 2008]. The increase of mowing frequency can be counterproductive leading to a decrease in the number of targeted species, reducing flowering and fructification [FYNN *et al.* 2004].

EFFECT OF CUTTING AND UPROOTING ON THE SEED STOCK

It has been proven that the seed stock needs an investigation period before any restoration intervention; the seed stock of the temporary wetland is dominated by typical wetlands species (*Juncus pygmaeus* (Rich.) Fourr., *Polygonum monspeliensis* (L.) Desf., *Juncus maritimus* (Lam.), *Chenopodium chenopodioides* (L.) Aellen.) representing 73% of the total stock. Terrestrial species were poorly represented. Indeed, in unpredictable habitats such as temporary wetlands, the characteristic species are adapted to the fluctuating conditions of the hydrology by producing sustainable buried seeds [BROCK, CROSSLÉ 2002]. Seed stock buffers the effect of repeated establishment failure during dry years [BONIS 1993]. The availability of a high density of seeds of the characteristic species of the temporary wet-

lands eases the restoration of characteristic communities. Indeed, the importance of seed availability for wetland restoration has been highlighted in many studies as a key element of its success [BISCHOFF 2002; ERVIN, WETZEL 2002; LINDIG-CISNEROS, ZEDLER 2002; UNGAR 2001; ZEDLER 2000]. Seed stock also plays an important role in the resilience of temporary wetlands [BROCK 1998]. Our study shows that both the density and richness of the seed stock were three times greater in the control plots than in the cutting and uprooting plots (Tab. 3). Both treatments (uprooting and cutting) reduced significantly the density and total richness of the seed stock. In the case of uprooting this is probably linked to root removal (root were 50 to 60 cm deep), whereas for cutting it is probably due to the above ground biomass cleaning after the cut. Both methods had a simultaneous seed stock decrease as side effect. However, the expected result was a non-significant effect of rushes cutting on total seed density. The obtained effect (Tab. 3) would probably be related to the deep cleaning of experimental plots (removal of all litter above ground after cutting), which would have eliminated many seeds out of the plots. Although, the cut did not affect the richness of characteristic species of the temporary wetlands in seed stock, their richness was not different in cut plots compared to control (Tab. 3) On the other hand, uprooting had significantly reduced their richness probably in relation with the deep disturbance of the soil stratification and the bottom-up movement of the seed layers.

SEED STOCK/VEGETATION CORRELATION

Poor seed stock conditions suggest, poor vegetation re-introduction, it is likely to potentially block species recovery in temporary wetland community. Correlation between vegetation and seed stock over the two years in the plots was studied by linear regressions carried out separately on each group of species. Results showed that in the uprooted plots the abundance of all species (total, annuals, characteristics and terrestrials) in the vegetation was significantly correlated to their density in the seed stock. This correlation would be favoured by the elimination of the competition previously exerted by rushes, plus the flooding of quadrants after uprooting. These two factors combined would have allowed the expression of a good fraction of the seeds, increasing the correlation (vegetation/seeds stock) with r^2 value ranging between 0.25 and 0.60. However, within the cutting and the control plots, the established species did not show any correlation to the seed stock except for perennials. This is probably due to their fast regrowth (perennials abundance did not differ from the reference state) particularly the rushes *Juncus maritimus* (Lam.) preventing light penetration as light reduction is the principal mechanism through which characteristic species of temporary wetlands are excluded from *Juncus maritimus* (Lam.) invaded habitats (Tab. 2). Anticipated expectation over the near future is that faster recovery of *Juncus maritimus* (Lam.) biomass would be accompanied by rapid litter accumulation and the concomitant exclusion of characteristic species diversity [LARKIN *et al.* 2012].

VEGETATION DYNAMIC

Inter annual dynamic of vegetation differed between the three treatments, with stronger dynamic in cut and uprooted plots. This reflects changes in vegetation composition, in which hydrology (Axis 1 of the CA) and plant abundance (Axis 2 of the CA) play a major role (Fig. 4). Indeed, these two factors (i.e. biotic and abiotic) together account for 54.16% of the total variance of vegetation composition in experimental plots. Within the control, the inter annual dynamic was low with high plant abundance due to dominance of *Juncus maritimus* (Lam.) associated with terrestrials *Cynodon dactylon* L., *Daucus crinitus* Desf., *Echium plantagineum* L., *Hordeum maritimum* Hudson., *Lolium rigidum* Gaudin., *Medicago polymorpha* L. High species abundance by rushes and perennial grasses is often accompanied by a modification of the soils, with an increase in litter and organic matter, which have a strong effect on the dynamic of the vegetation and their recruitment [FACELLI, PICKETT 1991]. Litter accumulation inhibits the characteristic species of temporary wetland that would contribute to a greater dynamic over the two years.

Within the cut plots, the interannual vegetation dynamic was greater compared to control (Fig. 6A, 6B). The centroids moved from characteristic species of temporary wetlands with low-abundance species such as, *Spergularia salina* J. Presl & C. Presl., *Lythrum junceum* Banks & Solander, *Agrostis pourretii* Willd., *Chara canescens* Desv. & Lois., towards high abundance species with *Juncus maritimus* (Lam.) across species of the flooded phase *Polypogon monspeliensis* (L.) Desf., *Juncus bufonius* L. coexisting with terrestrials *Daucus crinitus* Desf., *Anagallis arvensis* L., *Echium plantagineum* L. (Fig. 6A, 6B). The dynamic shows a convergence towards a plant group similar to the control plots group composition, marked by a dominance of rushes. The resumption of the rushes, which was cut only once at the beginning of the experiment, and his significant increase within years in the abundance of perennials (Fig. 6A, 6B), would limit considerably the recruitment of characteristic species of temporary wetlands in the short term.

In the case of the uprooted plots, the interannual vegetation dynamic was much stronger compared to cut plots. This was achieved by an increase in the abundance of species, especially the aquatic characteristics of temporary ponds (Fig 5A, 5B), since the first year with less water demanding species such as *Spergularia salina* J. Presl & C. Presl., *Juncus bufonius* L., *Juncus pygmaeus* (Rich.) Fourr., *Agrostis pourretii* Willd., *Frankenia laevis* L., *Isolepis cernua* (Vahl) Roem. & Schult., and *Rumex pulcher* L. In the second year, it is mainly the aquatics *Nitella opaca* Ag., *Chara canescens* Desv. & Lois., *Ranunculus baudotii* Schrank., and *Glyceria fluitans* (L.) R. Br. With the emergence of the clonal perennial, *Bolboschoenus maritimus* L., which had invaded some of the plots from the neighbouring area this establishment was probably favoured by: the opening of the gaps after rushes extermination and the longer submersions from the deepening of the plots due to root removal. The appearance of high competitor bulrush *Bolboschoenus maritimus* L. is likely to have

similar impact of rushes on herbaceous characteristic communities of these habitats in the short term. Recent study revealed this problem [MENICHINO *et al.* 2016]; as expected rapid regrowth of the dominant species limits the efficiency of cutting, leading to contrasting expected results. Therefore, relevant well-studied choice of the most advantageous mowing frequency will allow sustained control in rushes belt. Modified traditional land use practices have led to major changes in the vegetation in many types of habitats [HALADA *et al.* 2011], mainly due to the installation of macrophytes influencing their conservation value. The appropriate management of habitats, along with long-term continuation of moderate land use practices could increase biodiversity [PLIENINGER *et al.* 2006].

The experiment gave the possibility to test the impact of two techniques (cutting and uprooting) on the restoration of the characteristic species of temporary wetlands. Results show that both techniques allow for the opening of the habitat and the significant increase of species richness and abundance, particularly annuals and characteristic species of temporary wetlands (Fig. 5) from the seed stock, with abundance and richness increasing over two years in relation with the hydrology conditions.

Nevertheless, the uprooting significantly reduced the density and the richness of the seed stock after the root removal and created micro-cavities which remained submerged longer, favouring the installation of other macrophytes *Bolboschoenus maritimus* apt to have the same effect as the rushes. The cutting technique, followed by the export of the shallow litter, seems to have had less effect on the seed stock, but needs to be regularly maintained with optimum frequency to control the rapid regrowth of the rushes. The technique has also been adopted in many herbaceous restoration trials [BARBARO *et al.* 2001; BILLETTER *et al.* 2007; DEER 2008; DUTOIT *et al.* 2001; FYNN *et al.* 2004; GRYSSELS 1989; LAVERGNE, MOLOFSKY 2006; MENICHINO *et al.* 2016].

While a resumption of traditional manual cutting activities on the site, together with controlled grazing, is recommended, these activities could guarantee maintenance of the specific characteristic species, which is the main conservation issue for these habitats after the preservation.

CONCLUSIONS

The initial hypothesis for this study is a reduction of the characteristic species of the temporary wetlands by rushes via competitive exclusion. In order to test the most efficient restoration methods of these species this experiment was carried out. Our results show that both chosen techniques allow the opening of the surrounding belt of the rushes. We recorded a significant increase in the richness and abundance of the species, particularly the restoration success of the characteristic species of the temporary wetland from the seed stock. The cut technique seems to have less effect on the seed stock, but needs to be regularly carried out given the rapid encroachment of the rushes *Juncus maritimus* (Lam.). Traditional activities held previously by local people, especially the regular cut of rushes in the site is strongly recommended. It could guarantee management

of the characteristic species of temporary wetland which constitutes the major stake of conservation in these habitats, along with low cost for managers, adding to these a high implication of local population.

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Wpływ dwóch technik gospodarowania stosowanych do ograniczenia obfitości *Juncus maritimus* (Lam.) w wybranych okresowych środowiskach podmokłych

STRESZCZENIE

Umiarkowane zarządzanie okresowymi środowiskami podmokłymi jest jedną z najbardziej właściwych metod ich odtwarzania i ochrony. Zaniechanie użytkowania może prowadzić do znaczącej dominacji biomasy makrofitów, takich jak *Juncus maritimus*, która zmienia strukturę zespołu roślinnego, ogranicza różnorodność gatunkową i stanowi zagrożenie dla ochrony siedlisk. Eksperyment prowadzono w przybrzeżnym rezerwacie Sidi Boughaba w Maroku. Testowano dwie techniki gospodarowania – cięcie i wykorzenianie sitowia. Założono cztery poletka doświadczalne (4.2 × 2.9 m) w pasie sitowia, stosując poletka bez jakichkolwiek zabiegów jako kontrolę. Strukturę roślinności i poziom wody monitorowano

sześciokrotnie na 96 kwadratach w ciągu dwóch lat, trzykrotnie w ciągu roku (w lutym, kwietniu i czerwcu). Badano obfitość i bogactwo gatunkowe oraz zagęszczenie banku nasion w każdym poletku. Wyniki dowodzą, że obie techniki umożliwiają otwarcie siedlisk ze znaczącym wzrostem bogactwa i obfitości gatunków, szczególnie przywracanie z banku nasion gatunków charakterystycznych dla siedlisk podmokłych. Technika wycinania skutkuje, jak się wydaje, słabszym wpływem na bank nasion, stosowana regularnie ułatwia gwałtowny rozrost sitowia.

Słowa kluczowe: *bank nasion, Juncus maritimus (Lam.), ochrona okresowych środowisk podmokłych, podejście doświadczalne, sitowie, techniki zarządzania*