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POND CONSERVATION

Ten-year dynamics of vegetation in a Mediterranean temporary pool in western Morocco

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Abstract The aim of this work was to test the hypotheses that the species composition of the vegetation of one pool in Morocco change continuously along with rainfall fluctuations, that among the vegetation can be recognized Pool species and Opportunistic species with distinct dynamics in time. We expected the Pool species to show lower inter-annual variation than the Opportunistic species. This hypothesis was tested in a 10-year study of the species composition of the vegetation along two permanent transects. The results showed high cumulative species richness (95 species) with large differences between years and a predominance of annual species (77). The proportion of Pool species during these 10 years was low (39%) when compared to opportunists (61%). In dry years the Opportunistic species were dominant and declined during wet years. The number of Pool species was correlated with the amount of rainfall. A large number of these species revealed a preference for wet years. No negative interaction between annuals/perennials and pools/non-pools species was found, suggesting that competition was not a major process during the survey. The intensity of the drought and flood stress, related to climate fluctuations, seems to be the main factors controlling the species composition of the vegetation of this unstable habitat. However, beyond the inter-annual fluctuation of the species composition of the vegetation a directional change was noticed. This directional change could result from a recovery process of the vegetation during the first years of the study after a severe flood which extirpated most of the Opportunistic species of the pool. In the last years this directional change of the species composition of the vegetation is less clear and random recruitment of the Opportunistic species from the surrounding forested habitats could contribute to explain inter-annual changes. The data collected over

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these 10 years led to the speculation of hypotheses on the consequences of climate change. The expected reduction of humid years and of rainfall regionally may lead to important changes in the species composition of the vegetation of the temporary pools in Morocco.

Keywords Temporary pools · Inter-annual dynamics · Plant community · Hydrology · Climate change · Morocco

Introduction

Temporary aquatic habitats are varied ecosystems extensively widespread on a world scale (Deil, 2005; Williams, 2006). They play an important role in the landscape such as controlling flooding, refilling aquifers, retaining toxic products, and recycling nutrients (Keddy, 2000; Williams, 2006). They also have an important use for the population (Williams et al., 2004; Biggs et al., 2005) and constitute a remarkable habitat for unique flora and fauna contributing to regional biodiversity (Williams et al., 2004; Biggs et al., 2005; Oertli et al., 2008).

Among these temporary humid habitats, special attention should be given to Mediterranean temporary pools that are present in the five regions of the world with Mediterranean climate (Europe: Braun-Blanquet, 1936; Barbéro et al., 1982; Quézel, 1998; Grillas et al. 2004; Australia: Jacobs & Brock, 1993; California: Barbour & Major, 1977; Zedler, 1987; Keeley & Zedler, 1998; South America: Bliss & Zedler, 1998; South Africa: Been et al., 1993; North Africa: Chevassut & Quézel, 1956; Nègre, 1956; Rhazi et al., 2006). Mediterranean temporary pools are very important habitats for biodiversity in particular for plants (Médail et al., 1998; Grillas et al., 2004; Rhazi et al., 2006), invertebrates (Thiéry, 1991; Waterkeyn et al., 2008), and amphibians (Jacob et al., 2003). They are extensively recognized as important zones in terms of conservation, because of their fast disappearance due to human activity in North Africa (urbanization, infilling, agriculture, etc.; Grillas et al., 2004; Saber, 2006).

Often occupying endoreic depressions, temporary pools show a high diversity of size, depth, shape, landscape context, use, and habitat characteristics (substrate, salinity, etc.; Grillas et al., 2004; Rhazi et al., 2006). In spite of this diversity, temporary pools share important common features related to the hydrologic cycle and to adaptations to the alternation of flooded and dry phases. These conditions encourage the abundance of short cycle species, adapted to the unpredictability of this habitat in terms of water regime (Thiéry, 1991; Médail et al., 1998; Grillas et al., 2004).

Temporary pools are sensitive habitats to environmental changes, in particular those affecting their hydrological functioning (e.g., Zedler, 1987; Keeley & Zedler, 1998). The local climate conditions, the topography, and the catchment size influence their hydrology (Brooks & Hayashi, 2002; Bauder, 2005; Brooks, 2005). The large intra- and inter-annual rainfall variability of the Mediterranean climate led to important differences between years in terms of water volume and the periods of setting in water (Metge, 1986) thus determining the specific composition of the communities (Bonis, 1993; Grillas & Battedou, 1998; Waterkeyn et al., 2008). The temporary flooded pools are the main habitat for some species including rare ones (e.g., *Pilularia minuta*, *Elatine brochonii*, and *Marsilea strigosa*). The pools also host more Opportunistic species which find their main habitat in the surrounding landscape. Due to their small size and simple community structure, temporary pools are often considered as early warning systems of the effects of the long-term changes to larger aquatic systems (for example, changes in the hydroperiod due to the global change; De Meester et al., 2005; Pyke, 2005; Hulsmans et al., 2008).

The climate changes for the Mediterranean region foresee a decrease of the rainfall, an increase in the evapotranspiration, and a higher frequency of severe droughts in the south of the Mediterranean basin (Bates et al., 2008; Elouali, 2008) as well as the amplification of the variance of the monthly and annual rainfall (Alibou, 2002). The consequences of climate changes could strongly influence the dynamics and the specific composition of plant communities due to the strong sensitivity of the pools to the variations of the hydrologic balance. The species with the highest requirements in terms of height, duration, and phenology of flooding could be negatively affected. In contrast, the terrestrial species would be favored as well as those with short and flexible life cycles (Thomas et al., 2004). Strong human pressure on the pools (drainage, infilling, agriculture, etc.) and its use as a freshwater source constitute supplementary effects that could accelerate these changes.

The aim of this work was to study the inter-annual dynamics of vegetation in relation to the rainfall during a 10-year period in a temporary pool in Morocco, while distinguishing the characteristic species of the pools from the opportunist ones and the annual species from the perennials. The initial hypotheses were the following:

(1) every year, only a fraction of the total richness of vegetation expresses itself and its expression is dependent on hydrologic conditions;
(2) the Opportunistic species of the pools constitute an important fraction of their biodiversity, and vary significantly according to hydrology cycles; and
(3) the characteristic species of temporary pools are more stable in time than Opportunistic species because the former have large permanent seed banks; in contrast, the Opportunistic species should not have well established populations, their presence putatively resulting from successful establishment from the seed rain from surrounding habitats during the short favorable periods of drought.

Materials and methods

The study site is in the province of Benslimane (western Morocco), located between Rabat and Casablanca. This region has a semi-arid Mediterranean climate, with a mean annual rainfall of 450 mm and large inter-annual fluctuations (range: 142–803 mm for the period of 1961–2006). This province has a remarkably high density of temporary pools (670) covering a total surface area of 1,994 ha, about 0.8% of the total surface of the area (Saber, 2006). These pools are very diverse in terms of size, depth, shape, landscape features, and use (Rhazi et al., 2006). They are grazed extensively by cattle and sheep; at the regional scale the pools outside forested areas are submitted to high human pressure mostly by urbanization and agriculture (Rhazi et al., 2001a; Saber, 2006).

Within this system of temporary pools, only one site (N 33°38,497′, W 007°05,242′; elevation: 259 m; area: 0.4 ha) located in the Benslimane cork oak forest, was selected for an inter-annual vegetation survey (Rhazi et al., 2001b). This pool is located on an underlying quartzitic sandstone rock and a silty-clayey, acidic soil (Rhazi et al., 2001b) and is representative of the forest pools of the area (Rhazi et al., 2001a).

The vegetation of this pool was studied from 1997 to 2006 with two sampling dates per year (March–April and June) in 79 permanent quadrats (0.3 × 0.3 m, divided into nine squares of 0.1 × 0.1 m) regularly distributed (every 2 m) along two permanent orthogonal transects ($T1 = 80$ m and $T2 = 74$ m) starting near the trees of cork oak and passing through the deepest part of the pool. The species frequency was measured in each quadrat in each visit as the number of squares in which it was found (0–9). The data of the two sampling date for each year were integrated into single annual values: the frequency of each species was the maximum value found in the two sampling dates, the species richness per quadrat was the cumulated number of species found at the two dates.

The water level was measured at each quadrat at the same date of the vegetation survey (March–April and June) and also at January when the pools are usually at maximum flooding conditions. Two groups of species were distinguished, i.e., (1) Pool species: aquatic and amphibious species (sensu lato), identified as characteristic species of Mediterranean temporary pools by Nègre (1956) and Médail et al. (1998) or more generally of wetlands and (2) Opportunistic: terrestrial species typically found outside wetlands. The annual or perennial trait was attributed following the flora of North Africa (Maire, 1952–1987) and Morocco (Fennane et al., 1999, 2007). The total richness and the richness of the specific groups (annuals, perennials, Pool, and Opportunistic) were calculated for each year. A correspondence analysis (CA; ADE-4 software) was performed on the 10-year data vegetation, considering for each species and each year the maximum value of frequency observed by quadrat. The CA was carried out with 78 species, excluding those that found in less than four quadrats (<0.5% of the total number of quadrats) over the 10 years. The barycenters of the distribution of the quadrats of each year were positioned on the ½ biplot. Variations in time of the total species richness, measured as the total number of species listed per year in all of the quadrats, as well as of its components ("Characteristic"/"Opportunistic", "Annual"/"Perennial") were studied by nonparametric correlations of Spearman. The difference in frequencies for each species between dry and wet years was tested by nonparametric variance analysis (Kruskal–Wallis). The species tested were those present in at least three out of the 10 years. The statistical analyses were conducted using JMP™ software.

Results

The period in study (1997–2006) was characterized by significant inter-annual rainfall fluctuations with four wet (1997, 2003, 2004, and 2006) and six dry years (1998, 1999, 2000, 2001, 2002, and 2005) (Fig. 1). The maximum levels of water recorded in the pool varied between 40 and 54 cm in the wet years against 5–17 cm in the dry years. The duration of the flooding periods ranged between 3 and 23 weeks. The average rainfall during the 10 years (439 mm) was slightly lower than that of the 45-year period (458 mm), but without significant difference ($P > 0.05$). The January (maximum) water levels were strongly correlated with the annual rainfall ($r^2 = 0.97$; $P < 0.0001$; $n = 10$).

A total of 95 species was found in the pool during the study period and, the annual richness varied between 28 (1997) and 68 species (2003). Of this total, 18 species occurred only 1 year, conversely 13 species were present every year. A total of 37 Pool species were found (39% of the total richness) and 58 were listed as Opportunistic (61%). The annuals (77 species) represented 81% of the accumulated total richness over the 10 years (perennials = 19%).

The cumulated frequency of species over the 10 years was significantly higher for the Pool species than for the Opportunistic species (nonparametric test of Wilcoxon, one-way test, $\chi^2 = 25.38$; $P < 0.001$). However, some Opportunistic species occurred at high frequencies (found in 9 years out of 10), notably *Leontodon saxatilis* (218), *Narcissus viridiflorus* (189), *Scilla autumnalis* (177), and *Filago gallica* (154) (Supplementary material—Annex 1).

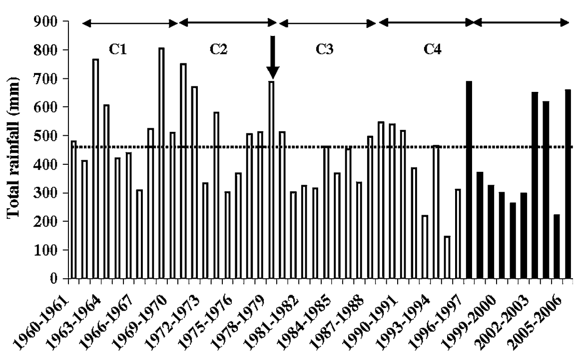

Fig. 1 Total rainfall during annual hydrological cycles (September–August) between 1960 and 2006 at Benslimane (in *black* are the years studied; *broken line*: average of 1961–2006; C1, C2, C3, and C4 correspond to cycles similar to the survey period)

Temporal dynamics of the vegetation

Axis 1 (32% of variance) of the CA (Fig. 2) opposes terrestrial (*Sanguisorba minor*, *Cistus salviifolius*, *Lolium rigidum*…) and aquatic species (*Myriophyllum alterniflorum*, *Callitriche brutia*, *Ranunculus peltatus*…). Axis 2 (26% of total variance) opposes the forest terrestrial species (*Gaudinia fragilis*, *Stachys arvensis*, *Anagallis arvensis*…) and amphibious characteristic pool species (*Pilularia minuta*, *Damasonium stellatum*, *Exaculum pusillum*, *Elatine brochonii*, etc.).

The annual barycenter of the quadrats shows an important displacement on the ½ biplot of the CA (Fig. 2). The coordinates on axis 1 of the annual barycenter were significantly correlated with the maximum depth of water ($r^2 = 0.84$; $P < 0.001$; $n = 10$). This axis 1 opposes the wet (1997, 2003, 2004, and 2006) and the dry years (1998, 1999, 2000, 2001, 2002, and 2005). The coordinates on axis 2 of the barycenter of the distribution of the quadrats for each year, increased significantly with time (Spearman $\rho = 0.91$; $P < 0.001$) and they are also significantly correlated with the total species richness (linear regression, $r^2 = 0.68$; $P < 0.01$; $n = 10$).

Species richness

The total number of species found each year in the pool was the lowest (28) in 1997 (Fig. 3); it significantly increased during the survey period (Spearman $\rho = 0.91$; $P < 0.001$) reaching 68 species in 2003 (142% increase) and then fluctuated around 60 species for the following years. The number of Pool species found each year fluctuated between

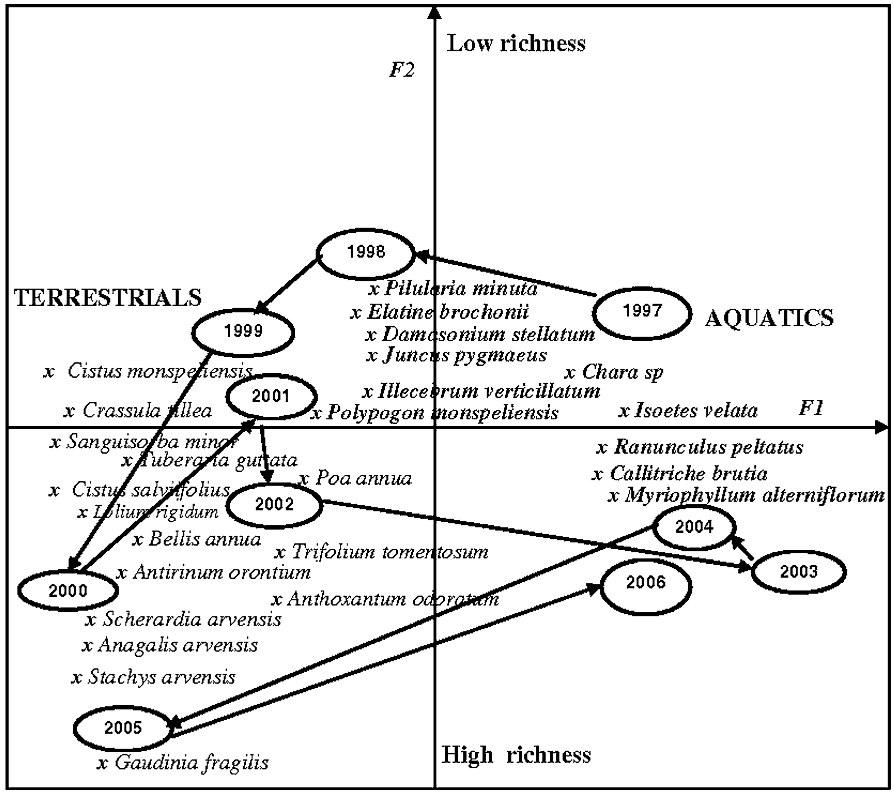

Fig. 2 Plot ½ of the CA vegetation (1997–2006) with positioning of the barycenters of the years (in *bold* characteristic pool species and in *non-bold* terrestrial species)

years between 20 and 35 species. The Pool species contributed only to 39% of the total species richness during the 10 years; they were, however, more frequent than the Opportunistic species. The Opportunistic species were numerous (58 species: 61% of the total number of species found in the pool), but generally less frequent over the 10 years. Some Opportunistic species were however found every year (*Cynodon dactylon*) or absent for only 1 year (Supplementary material—Annex 1). Among these two annual (*Leontodon saxatilis* and *Filago gallica*) and perennial species (*Narcissus viridiflorus* and *Scilla autumnalis*) (Supplementary material—Annex 1) were found 9 years out of 10 each of them occupying a cumulated number of quadrats higher than 150 (close to 20% or more of the maximum possible).

The number of Pool species was significantly correlated with rainfall ($r^2 = 0.61$; $P < 0.01$) and did not show a significant trend in time (Spearman $\rho = 0.34$; $P = 0.34$). In contrast, the annual number of Opportunistic species, was not correlated with rainfall ($r^2 = 0.21$; $P = 0.17$) and significantly increased during the survey period (Spearman $\rho = 0.66$; $P < 0.05$) from a very low value (three species) in 1997 to 39 in 2005. This increase showed two phases: until 2001, the number of Opportunistic species steadily increased from 3 to 32 species; from 2001 to 2006 it fluctuated around 30 species (Fig. 3). The contribution of the Opportunistic species to the flora of the pool increased from 10% of flora in 1997 to about 50% from 2003 to 2006 (Fig. 3).

The numbers of perennial and annual species were similar during the first year (1997) with, respectively, 11 and 17 species. The number of perennials significantly increased during the survey period (Spearman $\rho = 0.88$; $P < 0.001$) reaching a maximum value of 18 species in 2003, 2004, and 2006. The number of annuals also increased significantly (Spearman $\rho = 0.89$; $P < 0.001$) reaching a maximum value of 50 in 2003. The increase of the annual species showed two distinct phases: a fast increase until 2001 reaching 39 followed by inter-annual fluctuations around a mean value of 41 species. Over the 10 years of survey the contribution of the annual species to the total flora of the pool rose from 60 to

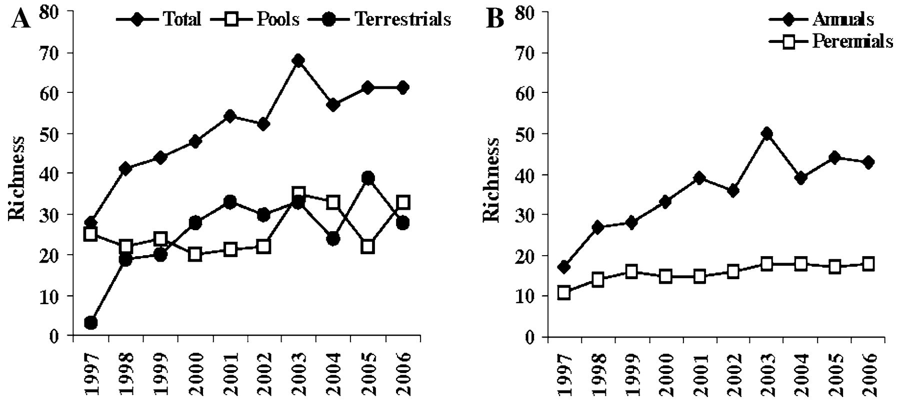

Fig. 3 Inter-annual variations of the number of species: **A** characteristic pool species, terrestrials, and total; **B** perennial and annual species

70%. There was no significant correlations between the numbers of annual and perennial species found every year ($P > 0.05$).

Among the 37 Pool species, 14 were significantly more frequent during the wet years and two during the dry years (*Polypogon monspeliensis* and *Hypericum tomentosum*) (Table 1). The annual number of Pool species did not show a significant correlation with the number of the Opportunistic species ($P > 0.05$).

Discussion

Species composition of the vegetation of the pool

The vegetation of the studied pool is representative of the oligotrophic Mediterranean temporary pools of Morocco (Rhazi et al., 2001a) with notably high richness in annual species (>65% of the total). The abundance of annual species, often with very short life cycles, is characteristic of the Mediterranean temporary pools of the Old-World (e.g., Nègre, 1956; Boutin et al., 1982; Médail et al., 1998) and of the vernal pools of California (Zedler, 1987) where it is usually interpreted as an adaptive strategy to the unpredictability of the environmental conditions (e.g., Keeley & Zedler, 1998; Deil, 2005; Grillas et al., 2004), notably the hydrology.

Two groups of species have been distinguished in this study: Pool species and Opportunistic species. The Pool species group includes the species usually found in the plant communities of the Isoeto-Nanojuncetea class (*Isoetes velata*, *Isoetes histrix*, *Juncus bufonius*, *Juncus pygmaeus*, *Juncus capitatus*, etc.) which is considered as a characteristic of Mediterranean temporary pools (Deil, 2005). More generally it contains species which are most generally found in wetland habitats such as *Ranunculus baudotii*, *Bolboschoenus maritimus* (Supplementary material—Annex 1). In this group, six species were rare or threatened in Morocco (*Elatine brochonii*, *Pilularia minuta*, *Lythrum thymifolia*, *Myriophyllum alterniflorum*, *Isoetes velata*, and *Exaculum pusillum*) (Fennane & Ibn Tattou, 1998). The Opportunistic species group is made of terrestrial species encompassing both forests species (e.g., *Cistus monspeliensis*) and species found in a wide range of habitats (e.g., *Trifolium campestre*, *Cynodon dactylon*). The Pool species contributed only to 39% of the total species richness during the 10 years and the majority of the species encountered in the pool were Opportunistic species. In each given year, the numbers of Opportunistic and Pool species were similar except in the first years when Pool species dominated. This large contribution of non-Pool species to about half of the total species richness is striking suggesting that the pool receives a significant seed or propagule rain from the surrounding habitats. These Opportunistic, terrestrial, species found in the pool a suitable habitat during the dry phases (Keeley & Zedler, 1998) where their establishment is probably further favored by the generally low cover of vegetation. At the edge of the pool, flooding occurs only during wet years and the terrestrial vegetation, including perennial species, such as *Cistus* spp., intolerant to flooding can develop during several years (e.g., five dry years after 1997 flood). The invasibility of the plant communities of the vernal pool vegetation has been highlighted in California by the encroachment of exogenous invasive species (Gerhardt & Collinge, 2003).

Table 1 Results of the tests for significant differences in the occurrence of species between wet (4) and dry years (6); each species is characterized as Pool/Non-Pool (P/NP), with the number of years the species was present during the 10 years (Total), during the four wet years (Wet) and the six dry years (Dry), the preference for dry or wet years, the value of χ^2 (Kruskall–Wallis) and the probability [* $P < 0.05$; ** $P < 0.01$; (*) P is very near to 0.05]

Species	Pool/Non-Pool	Occurrence (years)			Test		
		Total	Wet	Dry	Preference	χ^2	P
Damasonium stellatum	P	4	4	0	Wet	8.37	**
*Elatine brochonii**	P	4	4	0	Wet	8.37	**
*Pilularia minuta**	P	4	4	0	Wet	8.3	**
*Lythrum thymifolium**	P	5	4	1	Wet	6.93	**
Lythrum hyssopifolium	P	8	4	4	Wet	6.75	**
Eleocharis palustris	P	10	4	6	Wet	6.62	**
Heliotropium supinum	P	9	4	5	Wet	6.62	**
Scirpus pseudocetaceus	P	3	3	0	Wet	5.62	*
Juncus capitatus	P	3	3	0	Wet	5.62	*
Lythrum borysthenicum	P	6	4	2	Wet	5.36	*
*Exaculum pusillum**	P	6	4	2	Wet	4.39	*
Cerastium glomeratum	NP	4	3	1	Wet	4.3	*
Mentha pulegium	P	8	4	4	Wet	3.79	*
*Isoetes velata**	P	10	4	6	Wet	4.12	*
Spergula arvense	NP	9	3	6	Dry	5.36	*
Polypogon monspeliensis	P	9	3	6	Dry	4.15	*
Scilla autumnalis	NP	9	3	6	Dry	5.07	*
Hypericum tomentosum	P	10	4	6	Dry	4.6	*
Anthirinum orontium	NP	4	0	4	Dry	3.8	(*)

For the pools of California, Keeley & Zedler (1998) distinguished different patterns of plant dynamics between endemic Pool-obligate species and cosmopolitan wetland species. Our approach here, and thus the way the groups were made, differs in the sense that our focus was on the understanding of the dynamics of communities considering the processes rather than the biogeographical issues. More detailed groups could have been used such as the seven functional groups identified by Brock & Casanova (1997); however, the needed information was not available for most species. Furthermore, the lower number of species that would have resulted from more groups would have limited the statistical power of the analyses although it would have probably also resulted in lower intra-group variance.

The results of the CA are consistent with the grouping of the species, the two groups being well separated on axis 1. This axis separates the terrestrial species (*Cistus* spp., *Sanguisorba minor*, etc.) from those found in the center of the pool (*Myriophyllum alterniflorum*, *Callitriche brutia*, *Ranunculus peltatus*). The most characteristic species of the Mediterranean temporary pool are found in the center of the graphs which results from both their intermediate position in the depth gradient and their frequency throughout the pool.

Inter-annual fluctuations of the vegetation

The survey period (1997–2006) was characterized by an alternation of contrasted dry and humid years. The first year (1997) was exceptionally wet with maximum water levels recorded in the pool (54 cm). Four analogous rainfall cycles (mostly dry years with the exceptional extremely wet years) characterized the climate between 1962 and 1995 in the region of Benslimane (Fig. 1). The rain distribution pattern for the survey period (10 years) is representative of the last 45 years, with similar average rainfall (439 mm against 458 mm), but very dry years (<321 mm) which are more frequent (five in 10 years against 13 in 45). This 45-year rainfall pattern can be divided into two successive phases, with a transition toward drier conditions from the beginning of the 1980s. Eleven of the 13 driest year of the period 1960–2006 occurred after 1980. The rainfall pattern (Fig. 1) is consistent with the predictions for climatic changes (Bates et al., 2008), i.e., an increase in temperature, a reduction of the annual rainfall leading to an increase in the frequency and intensity of droughts, and the occurrence of unusually humid years (Jalil, 2001; Elouali, 2008).

The species composition of the vegetation in the pool differed from 1 year to the next with large difference in species richness. In any given year could be found only 30–70% of the total number of species found during the 10 years of survey (Fig. 3). The variations of the total species richness showed an inter-annual dynamic that followed two distinct patterns: (1) an alternation between dry and humid years and (2) a directional dynamic accompanied by an increase of the specific richness. These variations clearly showed that the specific composition of the pool vegetation is not steady and varies over time according to rainfall conditions (Jeffries, 2008).

The number of Pool species was correlated with the amount of rainfall, but did not show any significant trend over the 10 years. Within this ecological group, there was however, a large variation in the frequency of the different species corresponding to different life strategies more particularly at the establishment phase (Brock & Casanova, 1997):

– Some species, such as *Damasonium stellatum*, *Elatine brochonii**, *Pilularia minuta**, *Scirpus pseudocetaceus*, and *Juncus capitatus*, were solely present in the wet years (Table 1). These species, of which two are rare and of high patrimonial interest for Morocco (*), are restricted to the edges of the pool. The survival of these species implies the adoption of adaptive strategies related to the germination/reproduction and spatial displacements in search of favorable niches. These species are considered as more threatened by increasing drought as it is likely to decrease the frequency of reproductive success and therefore increase stochastic extinction risk.
– Species, such as *Isoetes velata**, *Exaculum pusillum**, *Lythrum thymifolium**, *Lythrum hyssopifolium*, *Lythrum borysthenicum*, *Eleocharis palustris*, and *Heliotropium supinum*, of which three are rare (*), were present in both dry and wet years, but showed a preference for the latter (Table 1). These species are likely to be threatened by climatic change similarly as the previous group.
– The remaining species, which include *Polypogon monspeliensis* and *Hypericum tomentosum,* were present in both wet and dry years, but showed a preference for the latter (Table 1). Unlike the others, these species could be, on one hand, favored by climate changes due to the rise in drought frequency and intensity.

10 years dynamics of communities: hydrological control, resilience, or drift?

Beyond inter-annual fluctuations, a directional process (Holland & Jain, 1981) has been identified over the 10 years. The high water levels in 1997 probably explain the very low frequency of Opportunistic (terrestrial) species (in particular perennials). A fast re-colonization of the edges of the pool by Opportunistic species was observed during the five following years which were dry (Fig. 1). The number of Opportunistic species increased until it reached a plateau at about 30 species (Fig. 3) from 2001. This phase appears as a recovery phase after a major disturbance. It was only in 2004 that the number of Opportunistic species showed a clear decline after two successive wet years. The inter-annual dynamics of the vegetation from 2004 seems to enter into a new inter-annual dynamics with opposite changes in the respective patterns of Pool and Opportunistic species apparently driven by rainfall and flooding conditions. Both perennial and annual species richness increased significantly over time, but the increase of the annual species richness was more accentuated (Fig. 3B).

The number of Pool species showed lower inter-annual variations than the Opportunistic species suggesting the former species constitute rather stable components of the communities, while Opportunistic species are temporary colonizers during the dry years (Keeley & Zedler, 1998). No negative interaction was found between the groups of species (Annual/Perennial and Pool/Opportunistic) suggesting that competition was not a major factor influencing the richness of the plant communities. The stress intensity, resulting from the climate fluctuations, seems to be the main factor controlling the species richness of the vegetation (Jeffries, 2008). However, the lack of correlation could be the result of the large increase of the number of Opportunistic species during the first years of survey. After a recovery stage, when species richness returns to high values, competitive interactions are expected in the community (Rhazi et al., 2001b).

The dynamics of the vegetation in the studied temporarily flooded pool provide clues for the consequences of climatic changes in Morocco. The results show large variations in the species composition of the vegetation with two groups of species contrasting in their dynamics: Pool species and terrestrial Opportunistic species. These two groups may separate "niche" structured communities while the second could be the result of stochastic processes. The former group constitutes the core of the plant communities adapted to the harsh environmental conditions met in temporary pools. The latter group contains species randomly recruited from surrounding habitats. Because of the contrast between the vegetation of the pool and the vegetation of surrounding dry habitats, temporary pool are probably valuable habitats for the identification of the pattern controlling the dynamics of communities (De Meester et al., 2005). These preliminary results obtained on one single pool should be confirmed with more sites. Large changes in the species composition are common in temporary flooded pools. Increasing drought may lead to important changes in the species composition of the plant communities. Long-term monitoring of the vegetation and water levels in the pool as well as a detailed analysis of the different border and center communities, with possible spatial displacements of the species along the topographic gradient, would lead to a better understanding of the climate change phenomena and of the species responses.

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