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Wetland and landscape indices for assessing the condition of semiarid Mediterranean saline wetlands under agricultural hydrological pressures

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ABSTRACT

During last decades semiarid Mediterranean saline wetlands have undergone several hydrological and biological changes as a consequence of increased water inputs from agricultural areas. Specific indices are needed in order to assess the condition of these unique ecosystems in relation to major hydrological disturbances at watershed level. Through the long-term study of selected plant taxa in a set of representative wetlands in Murcia province (SE Spain), together with the characterization of their watershed agricultural land uses, plant indicators of wetland condition were sought and then combined into a wetland condition index. Percentages of land cover classes of interest were weighted taking into account land cover arrangement and receiving wetland size. Characteristic perennial plant taxa were sampled in 1989 and 2008 and significant taxa frequency changes at each wetland site were determined. Regression analysis was used to relate wetland plant taxa frequency and watershed condition during the study period. *Limonium* spp., *Arthrocnemum glaucum*, *Phragmites australis*, *Tamarix canariensis* and *Atriplex halimus* showed significant relationships with watershed condition. Indicator taxa were thus identified and their frequencies were combined into an integrated index of wetland condition, which showed a robust relationship with watershed hydrological condition.

1. Introduction

Wetlands naturally act as sinks of surface and subsurface drainage effluents due to their relative low position in the landscape, thus reflecting upland occurring processes. In last decades, specially in coastal plain areas, there has been a flourishing growth of agricultural irrigated land areas in many semiarid Mediterranean regions (Herrero and Snyder, 1997; Levin et al., 2009; Martínez-Fernández et al., 2005). More specifically, in Murcia province the opening of the Tagus-Segura river water transfer in 1979 promoted the conversion of most dry farmed lands into irrigated land areas. The current expansion of agricultural irrigated lands at watershed scale has led to significant hydrological imbalances that alter wetland ecosystems, thus threatening its conservation (Casta neda and Herrero, 2008a; Esteve et al., 2008; Ortega et al., 2004).

Monitoring actions applied to management and conservation of wetlands require precise indicators in order to obtain accurate information about ecosystem state and functioning and provide an effective early warning system (Fancy et al., 2009). Although much effort has been applied towards protection of wetlands, the preservation of surrounding areas in which they are embedded has been ignored (Houlahan and Findlay, 2004). Assessment of watershed hydrological condition plays therefore a vital role in wetland management (Mack, 2006; Turner et al., 2003; Wigand et al., 1999).

The European Water Framework Directive (European Commission, 2000) seeks the development of indicators of ecological status for freshwater ecosystems, specifically including wetlands (European Commission, 2003). However, most indicators established for aquatic ecosystems are not suitable for semiarid Mediterranean saline wetlands, also called crypto-wetlands (Carre no et al., 2008; Innis et al., 2000; Williams, 1999). These are semi-terrestrial environments between steppes and standing water ecosystems (Vidal-Abarca et al., 2003; Casta neda and Herrero, 2008b).

The development and selection of ecological indicators is a complex process for which different approaches can be used (Carignan and Villard, 2002; Niemeijer and Groot, 2008). Physico-chemical indicators of wetland habitat condition can be very labor intensive and may not necessarily be biologically relevant (Gergel et al., 2002). However, biotic indicators, and specifically plants, may integrate changes in wetland condition over time, may be easy to identify and may provide information on the type of pressures if

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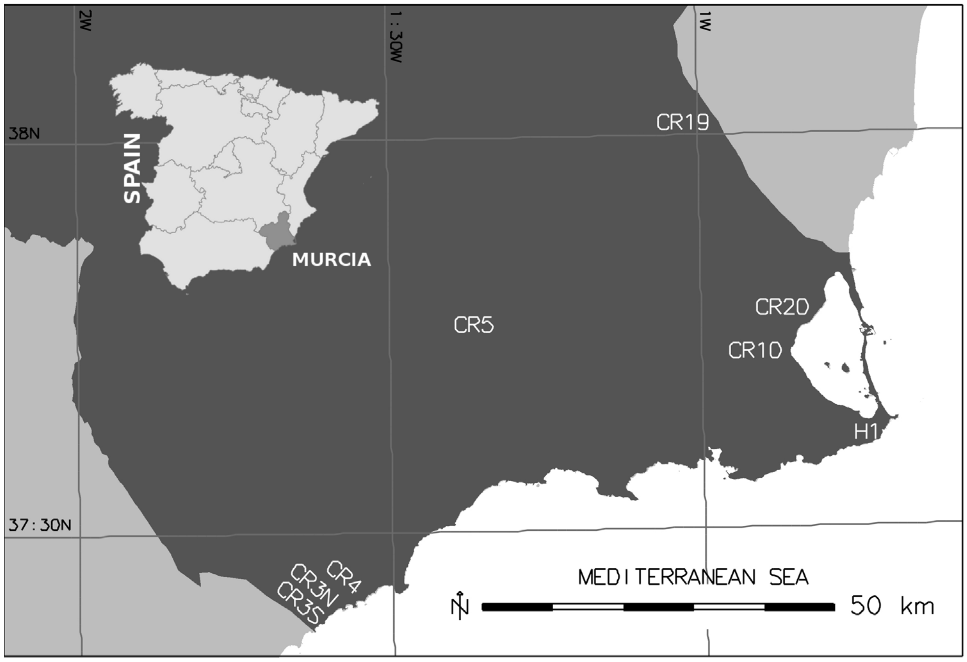

Fig. 1. Location map of the study wetlands in Murcia province. Wetland keys: Cañada Brusca North (CR3N) and South (CR3S), Alcanara (CR5), Marina del Carmolí (CR10), Playa de la Hita (CR20), Matalentisco (CR4), Boquera de Tabala (CR19) and Salinas del Rasall (H1).

their ecological tolerances are known (Cronk and Fennessy, 2001; Mitsch and Gosselink, 2007).

Plant species diversity of semiarid saline wetlands is relatively low and it is differentiated according to the plants' individual tolerance of salinity, fluctuating water table levels and anoxic substrate. The establishment of plants as ecological indicators comprises the study of species responses to a known range of a given environmental stressor (Allan, 2004; Niemi and McDonald, 2004). In this regard, results arising from the study of wetland plant species and surrounding land uses at single dates may not be representative of the whole range of species responses and environmental gradients. It has been suggested, for example, that there is a delayed response of the biota to certain landscape environmental variables (Carre no et al., 2008; Harding et al., 1998). Besides, species might still occur in wetlands long after the conditions that promoted their presence have vanished. Therefore, interpretation of site and date specific data needs to be conducted within the larger spatial and temporal perspective (Álvarez-Rogel et al., 2006; Dale and Beyeler, 2001).

Although several indices based on plant species and communities have previously been used as a tool for wetland condition assessment in the USA (Johnston et al., 2009; López and Fennessy, 2002; Miller et al., 2006), such indices are lacking for semiarid Mediterranean saline wetlands and are needed in order to fulfill the European Water Framework. In the context of a proposal for monitoring semiarid Mediterranean saline wetlands, the main aim of this study was to investigate plant taxa as an ecosystem attribute that reflects long-term changes in wetland hydrological conditions.

More specifically, the objectives were (1) to assess major changes in wetland plant taxa composition and in their associated watershed land cover classes in a set of representative semiarid saline wetlands over a 20 years period, (2) to characterize watershed hydrological condition for each wetland in relation to agricultural hydrological pressures, (3) to establish relationships between wetland plant taxa and watershed hydrological condition, and (4) to develop and validate a wetland condition index based on the resulting indicator plant taxa. To accomplish this, historical fieldwork sampling, remote sensing and hydrological modeling techniques were combined.

2. Methods

2.1. Study wetlands

Murcia province (SE Spain: 37° N, 1° W) has a semiarid Mediterranean climate with a mean annual temperature of 16 °C and a mean annual precipitation of 339 mm (Esteve et al., 2006). Eight representative wetlands from which we had plant records in 1989 and 2008 were selected, *i.e.* 6 coastal and 2 inland wetlands (Fig. 1 and Table 1). Selected sites are included in the regional inventory of wetlands (Vidal-Abarca et al., 2003) and their protection status ranges from regional, national to international level due to their high ecological values (Ramsar Site, Special Protection Area for Birds, Site of Community Importance and Special Protection Area for the Mediterranean), except for Matalentisco and Boquera de Tabala wetlands, which do not benefit from any protection status. Marina del Carmolí and Playa de la Hita wetlands are in a lowland coastal plain, called Campo de Cartagena, associated with the internal shore of the Mar Menor coastal lagoon, which comprises 12,700 ha (Conesa, 1990; Conesa and Jiménez-Cárceles, 2007). The lagoon and its associated wetlands are all RAMSAR sites, containing

Table 1
Characterization of wetlands and their associated watersheds.

Name	Wetland size (ha)	Watershed size (ha)	Location	Reference site
Salinas del Rasall	26.3	236	Coastal	Yes
Cañada Brusca South	3.8	69.5	Coastal	Yes
Cañada Brusca North	17.4	360	coastal	No
Marina del Carmolí	314	16,923	Coastal	No
Playa de la Hita	34.4	2052.8	Coastal	No
Matalentisco	10.4	907.6	Coastal	No
Boquera de Tabala	36.9	5819.2	Inland	No
Alcanara	199	6508	Inland	No