Aquatic Botany 103 (2012) 115–121

Contents lists available at SciVerse ScienceDirect

Aquatic Botany

journal homepage: www.elsevier.com/locate/aquabot

Do effects of landscape factors on coastal pond macrophyte communities depend on species traits?

Ana Silvia Rolon[a,b], Odete Rocha[a], Leonardo Maltchik[b,*]

[a] Federal University of São Carlos, São Carlos, Brazil
[b] University of Vale do Rio dos Sinos, São Leopoldo, Brazil

ARTICLE INFO

Article history:
Received 15 September 2011
Received in revised form 12 July 2012
Accepted 13 July 2012
Available online 23 July 2012

Keywords:
Conservation
Growth form
Non-fragmented wetland
Spatial dynamics
Subtropical region

ABSTRACT

We investigated the richness and composition of aquatic macrophyte communities of non-fragmented ponds in a matrix of coastal dunes in Southern Brazil. We tested three hypotheses on natural wetlands: (1) area, diversity of habitats and hydroperiod increase the total macrophyte richness; (2) isolation among ponds decreases the total macrophyte richness; and (3) the influence of environmental factors on macrophyte richness and composition change among macrophyte groups with different degrees of tolerance to hydrological variation. Our results showed that area was not a determining factor for macrophyte richness in coastal dune ponds. Diversity of habitats positively influenced total macrophyte richness, both hydrophyte and emergent species. Total richness of macrophytes declined with the increase in distance from source areas. However, this pattern varied among the study macrophyte groups with different degree of tolerance to hydrological variations. Whereas richness of hydrophyte and emergent species richness were related with isolation, the richness of amphibious species was not. Species composition was determined by the combination of the following environmental factors: isolation, diversity of habitats and hydroperiod. The current process of fragmentation taking place in Southern Brazil will increase the isolation among wetlands, and will influence the aquatic macrophyte species. The isolation effects may be most severe for hydrophytes.

1. Introduction

Island biogeography and metapopulation theories have been used to characterize the spatial dynamics of communities in continental ecosystems, such as forests (Harris, 1984) and wetlands (Oertli et al., 2002; Murphy and Lovett-Doust, 2004; Hall et al., 2004; Beltman et al., 2011). Such theories postulate that the presence and absence of species results from the balance between population colonization and extinction rates, where species colonization and extinction are strongly determined by the area and degree of island isolation. The size of ecosystems and the distance among islands have been used widely in programs of biodiversity conservation as indicators of ecosystem richness (Margules, 1989).

The increase of richness with the increase of area may be related to the greater capacity of colonization by individuals – the potential of an area to be colonized increases with its size (area per se) (Ricklefs and Lovette, 1999). Furthermore, area can influence the number of species due to a greater diversity of habitats – larger areas tend to have more complex structure than smaller ones (Ricklefs and Lovette, 1999; Rolon et al., 2008). The influence of isolation on biological communities may be directly associated with the differential dispersal ability of organisms (Murphy and Lovett-Doust, 2004). It is, thus, likely that species with low dispersal ability have lower chances of colonization and higher chances of extinction than species with high dispersal ability. Furthermore, the degree of permeability of the matrix may increase or reduce the effect of isolation on species richness since some plant species respond differently to gradients of resource and there is no clear distinction between habitat and matrix (Murphy and Lovett-Doust, 2004).

Wetlands are appropriate systems to test the influence of area and isolation on species richness (de Meester et al., 2005). The positive relationship between area and species richness of aquatic plants has been widely described in the literature (Oertli et al., 2002; Jones et al., 2003; Dahlgren and Ehrlén, 2005). However, the effects of isolation on macrophyte richness have received less attention. While some studies found no effect of isolation (Brose, 2001), others identify a negative relation between macrophyte richness and isolation (Lopez and Fennessy, 2002; Matthews et al., 2005). This contrast may be related to different survival strategies among macrophyte species and to the matrix quality (Brose, 2001; Bossuyt et al., 2003; Boughton et al., 2010; Beltman et al., 2011).

* Corresponding author at: Ecology and Conservation of Aquatic Ecosystems, University of Vale do Rio dos Sinos, UNISINOS, São Leopoldo, Rio Grande do Sul 93022-000, Brazil.
E-mail address: maltchik@unisinos.br (L. Maltchik).

0304-3770/$ – see front matter © 2012 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.aquabot.2012.07.004

Studies relating landscape effects on species richness have been encouraged by the increase of wetland fragmentation, however, species distribution patterns in non-fragmented wetlands are still little known. Even though size and isolation may not be related in non-fragmented areas, in areas subject to fragmentation such variables can be strongly associated. Hydroperiod and hydrological variation are also important attributes for macrophyte richness and composition in wetland systems (Brose, 2001; Schott et al., 2005; van der Valk, 2005; Maltchik et al., 2007). Brose (2001) found that hydroperiod was more important than area to determine macrophyte richness in intermittent wetlands. Variation between periods with and without surface water in wetland systems would increase environmental heterogeneity, thus favoring the coexistence of species with higher and lower degrees of tolerance to water stress (Maltchik et al., 2007). Landscape structure may affect aquatic plant richness and composition in fragmented wetlands (Rolon et al., 2008). Furthermore, the community of aquatic macrophytes comprises a heterogeneous group of species with different adaptations to flooding and soil saturation, and different degrees of tolerance to hydrological variations (Cronk and Fennessy, 2001). This study tested three hypotheses on natural wetlands: (1) area, diversity of habitats and hydroperiod increase the total macrophyte richness; (2) isolation among ponds decreases the total macrophyte richness; and (3) the influence of environmental factors on macrophyte richness and composition change among species groups with different degrees of tolerance to hydrological variations.

2. Methods

2.1. Study area

The Coastal Plain (State of Rio Grande do Sul) is one of the regions in Southern Brazil with the highest concentration of wetlands (Maltchik, 2003) and with high aquatic macrophyte diversity (Rolon et al., 2010). The area of study is located at Lagoa do Peixe National Park in Southern Brazil (Fig. 1). This conservation unit, created in 1986, was designated as a Ramsar site and Biosphere Reserve due to high species richness. Lagoa do Peixe National Park (LPNP) has 34,400 ha and protects estuarine and freshwater habitats as well as terrestrial habitats (e.g. dune, grassland and shrubs).

The region has a moist subtropical climate with a mean annual temperature of 17.5 °C, and an annual average ranging from 13 °C in winter to 24 °C in summer. The mean annual rainfall ranges between 1200 and 1500 mm/year (Tagliani, 1995). The prevailing wind directions are northeast (5 m/s) – from September to April – and southwest (8 m/s) – from May to October (Klein, 1998).

2.2. Data collection

This study was performed on the coastal fringe of the park (distance less than 400 m from the sea). This area is characterized by small ponds distributed over a sand dune matrix with herbaceous vegetation typical of dunes. The ponds were identified using satellite imagery. Sixteen ponds were randomly selected and were considered as islands (Fig. 1). Two extensive wetlands were selected in the boundaries of Lagoa do Peixe National park and assumed to be the main sources of propagules (Fig. 1). These areas were selected because they are: (1) permanent freshwater systems; (2) larger areas; (3) near the ponds; (4) located in the same marine regression (same geologic age), and (5) had high richness and abundance of aquatic macrophytes over the year. In addition, these two wetlands had different species composition. The Lagoa do Peixe (another large wetland, Fig. 1) was not considered a source area because it has a regular connection with the sea, and its community consists of species typical of brackish waters. All ponds were considered freshwater systems, since water salinity changed from 0 to 0.1 over the study.

Six collections were carried out bimonthly from October 2007 to August 2008. The locations were determined using a GPS receiver (Garmin, GPS III Plus). The area of each pond was measured from a *Quikbird* image extracted with the software Google Earth Pro 4.2.1 (June/2008, WGS 84, RGB, 0.6 meters resolution). Pond area was measured during the greatest inundation period (winter). Habitat diversity for aquatic plants was assessed in each pond based on two environmental variables: water depth and substrate characteristics. Water depth was quantified in 30-readings along three random transects (10 per transect, separated by ± 1 m). Each reading was classified in one habitat type: (1) without surface water or saturated soil; (2) water depth between zero and 40 cm; (3) water depth between 40 and 80 cm; (4) water depth over 80 cm. The number of habitats related to water depth in a pond system was the cumulative number of habitat types observed in the 30-readings analyzed and changed from 1 to 4. One substrate sample was collected in the middle of each random transect ($n = 3$) using a core (7.5 diameter) inserted into 10 cm depth. The substrate samples were classified in one habitat type: (1) organic – consisted of a large amount of organic material (e.g. vegetal detritus); (2) sand – mainly composed by mineral particles larger than 0.05 mm; (3) silt – predominantly formed by mineral particles smaller than 0.05 mm. The number of habitat types related to substrate characteristics in a pond system was the cumulative number of habitats observed in the three transects analyzed and changed from 1 to 3. The habitat diversity represented the combination between the number of habitats related to water depth and substrate characteristics in a pond system and changed from 1 to 12 (4 possible depths $\times$ 3 substrate types). For each pond we quantified: (a) the mean distance of each pond to the two source wetlands and (b) the mean distance of each pond to the nearest three ponds (permanent or intermittent). The metrics of isolation were based on the minimum distance between ponds and source wetlands (edge-to-edge). We used two isolation metrics (distance to source wetlands and nearest ponds) because we did not exclude the possibility that the nearest small pond might have contributed with the entry of plant propagules. We measured the length of hydroperiod of each wetland as the number of months with surface water (1–12). According to hydroperiod, ponds were classified as permanent (that presented surface water over the year) and intermittent (those that dried out at least during one month).

Aquatic vegetation surveys were carried out visually, i.e. macrophyte species were intensively surveyed (walk-through over total pond area to document the presence of species) until no new species was found. The maximum inundation area was surveyed also during dry periods. To ensure an exhaustive survey, macrophyte presence was evaluated by non-linear transects based on time (3 min each transect). For each of the apparently different vegetation stands present in the ponds (e.g. banks of submerged, floating or emergent plants), sampling was finished when no new species was found after 6 min (two transects) in each given vegetation stand. The number of transects ranged from 6 to 15 and the survey area of each transect varied from 10 to 100 m^2, depending on the abundance and size of plants. All plants were identified to species level – some species were taken to the laboratory for identification. We used a broad definition of aquatic macrophyte, which included submerged, floating-leave and emergent plants (herbs, shrubs and trees) and covered a wide taxonomic range (Charophytes, Bryophytes, Pteridophytes, and Spermatophytes; Cronk and Fennessy, 2001). The macrophyte collection complied with Brazilian current laws (IBAMA – 02001.001148/2007-61). The aquatic macrophyte species were grouped into three growth forms according to their tolerance to hydrological variations (herein considered traits): hydrophyte, emergent and amphibious species.