ECOLOGICAL LONGITUDINAL GRADIENTS IN LOTIC VEGETATION OF NORTH ALENTEJO, PORTUGAL

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ABSTRACT

The ecological longitudinal gradients of the river vegetation from the hydrographic bassin of Sorraia were studied in a total of 101 site surveys, of 250 m lenght. Maximum values for total richness and cover were found in lower courses, order numbers 4-6. However, high values were also reported in the heads, inserted in highly agricultured, planatic areas. TWINSpan clustering shows the existence of strong ecological gradients other than the upstream-downstream axis, and related to substrat granulometry of river beds, eutrophication and tree shading. The importance of these gradients in the distribution of lotic vegetation communities is discussed.

RESUMO

Com base em 101 inventários foram analisados os gradientes ecológicos dominantes na bacia hidrográfica do rio Sorraia, caracterizada pelo domínio de actividades agrícolas. Embora a variação da cobertura e riqueza evidenciem valores máximos no curso médio (números de ordem 4 a 6), verifica-se um enriquecimento e aumento de cobertura nas cabeceiras, instaladas em zonas planálticas e envolvidas por agricultura de sequeiro e regadio. A utilização da hierarquização divisiva TWINSpan salienta a existência de outros gradientes ecológicos fortes para além do eixo cabeceiras - curso final, associados à granulometria dos substratos do leito, eutrofização e ensombramento arbóreo. É discutida a importância relativa dos vários factores que determinam a estrutura longitudinal das comunidades de macrófitos lóticos.

INTRODUCTION

The river Sorraia is the largest tributary of the portuguese part of the Tagus bassin, with a total area of 7652 km², occupying all the north Alentejo region. Its direct tributaries are the rivers Erra and Sor on the right margin and rivers Raia and Divor on the left margin. The hydrographic bassin of Sorraia presents interesting features when compared to typical rivers of the temperate zone, namely the concentration of 80% of the pluviosity in a period of three winter months, mild winters and high summer temperatures with extended drought, lack of flow during four summer months, hard geological materials in the heads and middle course but with alkaline and erodible characteristics, planaltic heads with soft slopes resulting in local intense agricultural activities similar to the ones along the lower courses.

Only recently the lotic vegetation of this area has been studied, namely

aspects of general distribution, seasonal evolution and management techniques (Ferreira and Moreira, 1989; 1990 a and b). The macrophytic communities present well established populations in all the river course, with general high richness, density and cover. Many reaches are affected by human activities, namely diffuse sources of nutrients from agriculture, discharges from irrigation reservoirs, increased period of summer drought by river water pumping, straightening or channelization of the banks and dragging of river beds. The extent of changes resulting from such aggressions is unknown, however a better knowledge of the system can contribute to establish its resilience and limits.

METHODS

One hundred and one sampling sites of 250 m length were scatterly established in the hydrographic basin of Sorraia, including rivers Erra (15 sites), Sor (36 sites), Divor (30 sites), Raia (6 sites) and Sorraia (14 sites). The largest distance between sites was 7.3 km and average distance was 4.3 km. Sites were visited in the period of 1986-88 during growth season (May-August). All plant species present in the stream way (inner bank, bed and river channel) were identified following Vasconcelos (1969), Tutin *et al.* (1980), Haslam *et al.* (1982), Franco (1971, 1984), Comelles (1985) and Valdes *et al.* (1987).

Species with no connection to the aquatic or wet environment (like ruderals and terrestrial weeds) were not included in data treatment. For the input matrices of vegetation data, the sum of abundance, density and sociability was used (and called species importance, with a range of 0-9). Ecological gradients were studied using the hierarchical divisive cluster analysis TWINSpan, developed by Hill in 1979.

RESULTS

1. Longitudinal evolution of importance

The evolution of the site importance (sum of species importance) against distance to the source is shown in Figure 1. Values found are generally high, even in reaches with eroding substrate. An average of 41 (18-71) species associated with aquatic and wet environments were found per site and the poorest sites presented total covers of at least 60 %, increasing along the summer as water level decreases. A maximum importance occurs in order numbers 4-6, especially in river Raia where a mosaic of pebbles-sand-silt occurs, and decline towards the final course (order number 7). Values found in the heads are scattered and frequently high. The lowest values are found in sites in order numbers 3-4 where tree shading is maximum (more than 80% total cover) and few areas are available for herbaceous colonisation.

A total of 213 aquatic, amphibious and riparian species were found. About 12% show a relative frequency over 60%, that is, are cosmopolites in north-Alentejo region. The most important are *Paspalum paspalodes*, *Lythrum salicaria*, *Cyperus longus*, *Rumex conglomeratus*, *Holcus lanatus*, *Polygonum hydropiper*, *Polygonum lapathifolium*, *Bidens frondosa*, *Sparganium erectum*, *Apium nodiflorum*, *Juncus effusus* and *Typha latifolia*.

2. Vegetation

Groups with a more restrict distribution are associated with specific conditions of river bed granulometry, water velocity and depth, etc. For example, *Ruscus aculeatus*, *Erica arborea* and *Frangula alnus* occur with tree galleries; *Anagallis tenella*, *Fuirena pubescens* and *Hydrocotyle vulgaris* occur in acidic waterlogged stream ways; *Myriophyllum verticillatum*, *Utricularia australis*, *Callitriche lusitanicum* and bryophytes occur on the heads with rocky substrates in river bed; and *Lindernia dubia*, *Ammania coccinea* and *Cyperus fuscus* occur in waterlogged sands of lower courses.

Figure 1. Relationship between each site importance (sum of species importances) and its distance to the river source (km).

3. Dominant gradients in river Erra

The river Erra (with 38 km maximum length and an area of 183.5 km²) has a small hydrographic basin dominated by cenozoic deposits where podzolic soils have evolved. A large part of the basin is used for forestry production, having cork-oak and pinus stands. In the planaltic heads, three small reservoirs irrigate a large area of rice fields, and most head sites are regularised and channelized. The middle course runs through narrow valleys with bigger slopes and has coarser materials in bed (up to 40% pebbles). Most sites never had surrounding agriculture, some of them have small orchards, now abandoned. Total tree cover tends to be dense in these sites and increases towards downstream, where closed galleries can be found. The last part of the basin is highly agricultured and connected to the large irrigated area around the main course of river Sorraia.

The cluster of sites from river Erra in presented in Figure 2, including indicator species. Level I opposes tree shaded sites to moderate or no tree cover. Within this group, the last site T86, bearing high florist resemblance with the Sorraia river, is set apart. The other sites are separated according to land use, including a channelized group of sites and sites with no agriculture surrounded by cork-oak forest.

4. Dominant gradients in river Sor

The hydrographic basin of river Sor has 98.9 km maximum length and 1268.9 km² of total area. The heads and part of the left margin tributaries are included in a large area of hercinic quartzodiorites while the rest of the basin spreads through a mosaic of granites, metavulcanites, cenozoic formations and quaternary alluvial deposits. The heads are used for forest production, with large stands of *Eucalyptus globulus*, *Pinus pinaster* and *Quercus suber*. The tributaries from the right margin present intensive agriculture, namely rice fields. The middle course is characterised by a patchy land use with mixed activities, including orchards, small farms, cattle rearing and small food industries. Extensive agriculture is associated with a 30 km long reservoir downstream followed by 8km of river presenting a small and regulated flow and a stream way almost totally occupied by *Salix salvifolia* and *S. alba*.

Figure 3 shows the cluster of sites obtained with the vegetation data. Level I separates sites where rocky (quartzodiorite) substrates dominate from sites with sandy and mixed substrates existing in the right margin, middle and lower courses. Within sandy sites, a separation is made between site groups with different surrounding use, namely rice fields agriculture in the heads and mixed activities, A group of downstream sites is set apart because of its large tree cover.

LEVELS

Figure 2. Cluster of sites obtained with TWINSpan analysis based on the vegetation data of river Erra. Ti- site numbers. Indicator species are also shown. JEFF-*Juncus effusus*; GPAL-*Galium palustre*; SALV-*Salix salvifolia* ssp. *salvifolia*; AGLU-*Alnus glutinosa*; LORY-*Leerzia oryzoides*; ANOD-*Apium nodiflorum*; CSTA-*Callitriche stagnalis*.

Figure 3. Cluster of sites obtained with TWINSpan analysis based on the vegetation data of river Sor. Ti- site numbers. Indicator species are also shown. SERE-*Sparganium erectum*; OREG-*Osmunda regalis*; MSUA-*Mentha suaveolens*.

Figure 4. Cluster of sites obtained with TWINSpan analysis based on the vegetation data of river Divor. Ti-site numbers. Indicator species are shown. ACAR-*Azolla caroliniana*; PHYD-*Polygonum hydropiper*; HLAN-*Holcus lanatus*; CERA-*Cyperus eragrostis*; LVUL-*Lysimachia vulgaris*; PREP-*Panicum repens*; ASTO-*Agrostis stolonifera*; LEUR-*Lycopus europaeus*; AGLU-*Alnus glutinosa*; JEFF-*Juncus effusus*; MPUL-*Mentha pulegium*; UVUL-*Utricularia vulgaris*; TANG-*Typha angustifolia*.

LEVELS

Figure 5. Cluster of sites obtained with TWINSpan analysis based on the vegetation data of rivers Raia and Sorraia. Ti- site numbers. Indicator species are also shown. PMON- *Polypogon monspeliensis*; LMIN- *Lemna minor*; SPOL- *Spirodela polyrrhyza*; PFLU- *Potamogeton fluitans*; CLON- *Cyperus longus*; MYAQ- *Myriophyllum aquaticum*.

5. Dominant gradients in river Divor

The heads of river Divor (a basin with 73 km maximum length and 1425.4 km² of total area) are spread throughout a planaltic area with mixed lithologic materials, including cenozoic sands, pebbles and clays and siluric series of xists, chalks and metavulcanites. The middle course runs through narrow valleys occupied by cork-oak forests in an area dominated by alkaline hercinic granites resulting in hard substrate dominated river beds. The lower course runs through areas of cenozoic materials and quaternary alluvial deposits resulting in sandy bed substrates. Cereals are extensively cultivated in the heads though a large area of rice fields and other irrigated crops also exist, associated with an eutrophic reservoir. The flood plain of the lower course is occupied with pastures and irrigated crops, especially tomato and maize.

The first level of the cluster analysis (Figure 4) opposes the rocky dominated sites from middle course to the sandy dominated ones in the upper and lower courses. Within the sandy sites, the lower course is separated from the head site group, within which show distinctiveness sites with direct sources of organic pollution and silting (domestic sewage, rice effluents and reservoir discharges), sites with mixed river use (washing, leisure activities, cattle drinking supply, vegetation cuts) and sites with minimum human interference. T1 is affected by reservoir water level fluctuations.

6. Dominant gradients in river Raia and Sorraia

The river Raia together with river Sorraia (78 km maximum length), have an almost rectilinear west-east oriented course up to the Tagus confluence and were

several kilometers) and is mostly occupied by rice fields, though many other irrigated cultures are also common. The valley is dominated by detritic cenozoic and quaternary alluvial deposits. River bed consists mostly in sand materials, although the proportion of pebbles is considerable (up to 40%) in river Raia and fine particulate materials greatly increase in the last 20 km of river Sorraia. Two small regulation reservoirs are installed in river Raia, thus creating half-lentic patterns in some sites.

Figure 5 shows the cluster of sites resulting from vegetation data. Level I separates the group of sites where fine particulate materials are dominant from sites where sand materials dominate. Within this last group there is a division between sites influenced by Raia reservoirs, sites with pebble-sand-silt patterns of substrate and typical sand substrate sites from river Sorraia.

DISCUSSION

A geo-morphological succession is generally recognised between upstream and downstream in many temperate rivers, ranging from hard, rocky, erosion substrates in the heads to fine particulate sedimentation substrates in lowlands (Hawkes, 1975). Following this same pattern, other associated physical and chemical characteristics, as well as communities, also show longitudinal gradients, although recently much discussion have arisen about the form of the succession changes, namely a gradual and overlapping change along a continuum or punctuated gradients with sudden shifts (Wher, 1981; Cushing *et al.*, 1983 a and b; Perry and Schaeffer, 1987).

In all clusters obtained and based on vegetation data, the strongest emergent gradient is bed granulometry and the relative proportion of bed materials, emphasising the importance of the geological background that originated them. In rivers Sor and Raia/Sorraia, the substrate gradient overlaps with the upstream-downstream axis; this is not the case in river Divor where a different substrate sequence exists (and associated physical and chemical characteristics) and in river Erra, with incipient substrate differentiation along the river axis. In fact, mosaics of geological materials, in different forms and stages of alteration and of different age, erodibility and element exportation potential are quite common in the Alentejo region, where ancient eruptive and metamorphic materials contact with cenozoic and quaternary deposits originated in past and present activities of the Tagus and Sado basins. Many types and proportions of bed materials and longitudinal sequences may occur along the river axis which determined the resulting clusters.

Geological background and other associated characteristics as slope and altitude are also related to landscape use, especially the type and intensity of agricultural activities, which in turn secondarily affect river characteristics through human interferences and result in the emergence of strong secondary gradients reflecting river use and approaching site groups with common surrounding activities as the heads and lower course of river Divor. Tree cover is the major gradient in river Erra where no significant geological differences exist within the basin, while secondary gradients still reflect land use and river alterations.

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