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RIPARIAN SPECIES AND FLOW REGIME: ECOLOGICAL STUDIES FOR APPLICATION IN ENVIRONMENTAL FLOW ASSESSMENTS AND RIVER RESTORATION (MIJARES RIVER, SPAIN)

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ABSTRACT

Currently, environmental flow assessment is taking place in the Júcar River Basin (Eastern Spain). In the Mijares River, the riparian vegetation was studied in relation to flow regime, in order to incorporate more ecological criteria in water management and river restoration.

The study sites were located in three different reaches (water bodies), where the river is regulated by a large dam and several hydropower plants. An ecological study and a hydraulic simulation were conducted for each site and the time-series of flow and water level were calculated for the period 1990-2007. The discharge-level curves were calculated in the channel cross-sections, based on field data (low flows) and hydraulic simulation of large floods. Geo-referenced data of six target species of riparian vegetation were aquired in such cross-section. We identified some differences in species' distribution in terms of distance and elevation above the channel thalweg.

The hydraulic simulation also allowed us to estimate the discharge required to cover most of the riparian forest area and to spread the seeds in the dissemination period. As a result, we recommended a suitable flood frequency to maintain morphology maintenance and improve the riparian conditions.

The recommendations of this study can be used by the water administration for technical studies of environmental flow regime taking place in the Júcar River Basin. The results could also be applied in river restoration projects involving the design of plantation plots and management of riparian zones.

Key words: Mijares River, riparian vegetation, environmental flow, recruitment.

1. INTRODUCTION

In Spain, different types of environmental flow studies (EFS) have been carried out, which took into account hydrological analysis and also fish habitat simulation. Others studies have shown the effects of altered flow regime on zoobenthos, macrophytes and riparian communities but with low applicability in EFS. These studies are very interesting due to the high number of large dams existing in Spain (García de Jalón, 1987), one of the countries with more dams per citizen in the world.

The relation between riparian species and stream hydrology has been largely studied (Stromberg, 1993; Shafroth et al., 1998; Mahoney and Rood, 1998). But despite their importance for the water management, eco-hydraulic studies relating riparian species and flow regime are just starting to be developed in the context of Mediterranean rivers, where the riparian vegetation is highly influenced by factors such as flow regime, soil moisture and groundwater availability (Tabacchi et al., 1996).

In coherence with these ideas, the general aim of this study was apply some concepts and techniques to study riparian vegetation and flow regime in the Mijares River, in order to address these questions:

1. Which are the distribution patterns of the most relevant riparian species in terms of distance and elevation above the channel thalweg?
2. Is the flow regime suitable for the recruitment of the riparian forest (main plant species)?

2. GENERAL SETTING

The Mijares River is one of the most important rivers of the Júcar River basin (Eastern Spain), which is one of the pilot basins for the implementation of the WFD. The catchment area is approximately 4028 km^2, and the main stem has a total length of 156 km. The altitude in the study area is in the range of 172-418 m a.s.l. and average temperature is between 22.7 and 23.4ºC. The mean annual precipitation is 400-600 mm, with maximum in autumn (Roselló, 1994). There are 3 water bodies in the study area, upstream flow is regulated by Arenós large dam, and along the river there are two hydropower plants (Cirat and Vallat plants). Upstream from each plant there is a small dam (Cirat and Vallat dams) which stores water for electricity production and irrigation.

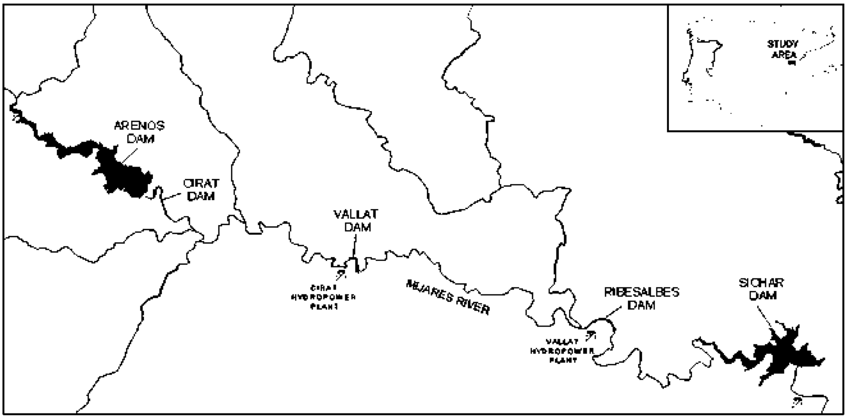

Figure 1 – General view of the study area in Spain, and detail of the Mijares River, where the position of dams and hydropower plants is indicated.

Cirat dam stores all the water released from Arenós dam, and from there it is lead to some irrigation channels and to the hydropower plant. Immediately downstream of Cirat dam the flow is reduced to 0.1 m^3/s (minimum flow). Flow begins to increase downstream thanks to several springs and sporadic flows of a tributary (Montán river). For this reason, the flow regime in the study area is quite similar throughout the year; it is only conditioned by the constant contribution of springs and temporary flows from tributaries. The area where the study was carried out does not suffer hydro-peaking effects because most of the water is diverted.

3. METHODS

The first part of this study was an inventory of the riparian plant species, therefore trees and shrubs were recorded in the study area. Every plant was identified with an abundance rank (1-5) according to its cover (Braun-Blanquet, 1979). A general characterization was made using the following methods: Ferreira and Aguiar (2005), QBR index (Muneé et al., 1998) for the riparian ecological status, and the IHF index (Pardo et al., 2002) for river habitats quality.

In the second part of this study different tasks were carried out, including an eco-hydraulic analysis. Data were collected in 3 reaches 200 meters long, with different valley morphology, valley width and mean annual flow.

3.1 Hydraulic simulation (1dim)

Cross sections were surveyed in the three sites of the study area. Discharge-elevation curves for each cross section were calculated with an hydraulic model calibrated with the program RHYHABSIM (Jowett, 1997), based on field data (low flows) and water elevation cartography (50, 100 and 500 years floods).

Time series of flow were translated into water elevation series, for the period 1990-2007, based on the transects rating curves. At the time of the study, flow data were obtained from the programme AQUATOOL (Andreu et al., 1996); this DSS manages monthly averages, which were converted to water surface elevation in each cross section.

3.2 Geo-referenced survey of the plants related to water level

Among the species present, six target species were selected to study the relation between vegetation and flow regime. These were:

1. Black poplar (*Populus nigra* L.)
2. Large gray willow (*Salix atrocinerea* Brot.)
3. Rosemary willow (*Salix eleagnos* Scop.)
4. Purple willow (*Salix purpurea* L.)
5. Oleander (*Nerium oleander* L.)
6. Tamarisk (*Tamarix* spp.)

Geo-referenced data of these plants were obtained in the selected cross-section using survey level, total station and GPS. The vegetation sampling using linear transects (cross sections) has been described by other authors as the “line intercept method” (FIREMON, 2003). In each transect, every vegetation unit intercepted was surveyed, formed by an individual plant or by a shrub, at the start and the end of the vertical projection of the whole plant on the cross section. The vegetation data (X, Y, Z) and the rating curves of the hydraulic model were adjusted to the same geographic datum. Subsequently, the water level time-series (deduced from the rating curves) above the lower point (start/end) of every plant on the transect was analyzed.

3.3 Diameter-age (growth) curves

Core samples of the target species were collected with pruning shears and a Pressler drill, in order to count the annual rings and to estimate the age. Also the height and DBH were measured in the same plants. The samples were sanded down and dyed to increase the visibility of the growing rings. They were dyed using fluoroglucine in 96% alcohol and clorhidric acid (HCl) as developer. Finally, diameter-age (growth) curves for each species were calculated and were used to assign an age to every plant sampled, in order to analyse the water level during each plant life-time.

3.4 Distance and elevation above the thalweg

The position of the target species in the riparian area was characterized in terms of distance and elevation above the channel thalweg, variables that were selected to represent a ranking of the plant’s tolerance to inundation. The comparative analyses by species were carried out by grouping the results of all the cross sections.

3.5 Considerations about the regulated flow regime and recruitment

April and May are the months when dispersion of the seeds happens. The poplar seeds quickly lose their germination capacity, although this depends on temperature and environmental humidity. In normal conditions, the willow seeds can not be preserved for more than 2-4 weeks (McLeod and McPherson, 1973; Kapustka, 1972). The period with maximum probability of poplar and willow germination in this study was estimated to be between the 1st and 30th of May. In such period, the profile of the hydrograph was observed, in order to evaluate the general trends of the flow during the seedling establishment period (from May to September).

4. RESULTS AND DISCUSSION

4.1 Location of the plants related to water level

The results indicated that poplar and oleander were distributed in stripes near the average water level. The tamarisk covers a slightly higher range of elevation, although there is clear overlap among the three species (poplar, oleander and tamarisk). These results are coherent with those obtained in terms of distance from the thalweg, as these three species are farther from the water than the other ones.

Salix purpurea is the species most exposed to the flow. It had a small sampling size but it was always in the same strip of the floodplain, next to the mean water level. This situation was also confirmed in the analysis of the distance from the thalweg. In general, the three *Salix* species had a similar median, but *Salix atrocinerea* was usually at lower elevations and inundated for longer periods than the other two species.

4.2 Diameter-age (growth) curves

Growth curves were obtained for each target species: *Populus nigra* (N=27), *Salix atrocinerea* (N=13), *Salix eleagnos* (N=26), *Salix purpurea* (N=11), *Nerium oleander* (N=24) and *Tamarix* spp. (N=9). The curves were calculated counting the annual rings (ages) of each core sample and finding the mathematical relation with the diameter (cm) of each sample. These relationships were applied to each plant surveyed in order to estimate their age. Fig.2 and 3 show the growth curve for the large gray willow and the oleander.

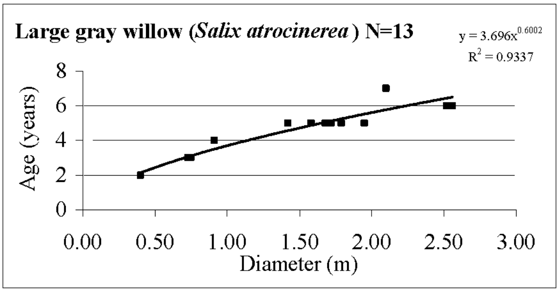

Figure 2 – Diameter-age curve for the large gray willow *(Salix atrocinerea)*.

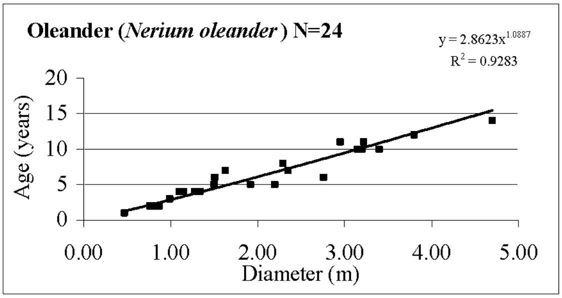

Figure 3 – Diameter-age curve for the oleander *(Nerium oleander)*.

4.3 Distance and elevation above the thalweg

Populus nigra and *Salix eleagnos* showed a similar distance and elevation above the thalweg. They were usually found at a higher level than other willows. In previous studies, *Salix* species have been described as obligate phreatophytes that require permanently available shallow groundwater (Busch et al., 1992; Horton et al., 2001), whereas *Populus* trees could be able to tolerate deeper and more fluctuating water tables than *Salix* (Snyder and Williams, 2000). *Nerium oleander* was located farther from the bank than willows and poplars. *Tamarix* spp. was very similar to the oleander but the data range was wider.

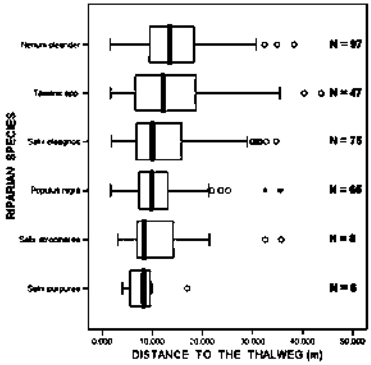

Figure 4 – Box-plots of the distance from the channel thalweg of each species (N=sampling size of each species).

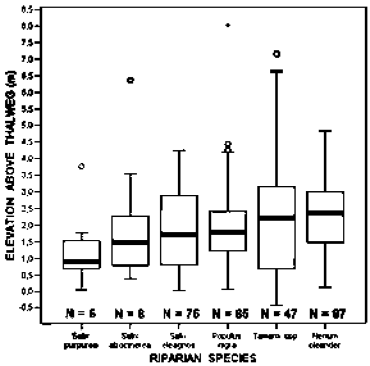

Figure 5 – Box-plots of the elevation above the channel thalweg of each species.

Figure4 and figure 5 show similar results for each species respect to the distance and elevation above the thalweg. The three willows species showed similar location, usually closer to the thalweg (average elevation between 0.5 a 1 m) and to the water, so that the roots are most of the time in the saturated zone (Busch et al., 1992; Horton et al., 2001). *Salix purpurea* was the willow which appeared at lower elevations and *Salix eleagnos* had a wider range of elevations (up to 4 m above the thalweg). This fact makes us think that *Salix eleagnos* can live in a wide range of soil moisture in the floodplain. *Nerium oleander* and *Tamarix* spp. were usually at higher elevations with respect to the thalweg (2 m average), being the tamarisk the species with larger range of variability, reaching a distance of 7 m in some cases.

Salix purpurea and *Salix atrocinerea* did not give confident results due to the low sample size, but we have shown their results as a reference of the position of the main species respect to the river channel. These species seemed to localize in the first line exposed to flow.

These differences between species can be applied to design plantation modules when it is necessary to combine species with similar characteristics in rehabilitation projects taking place in the studied area.

Considering the outlayers, we have verified that the vast majority of them appear in a band defined between 30 and 40 m of distance from the thalweg. Probably their presence at that distance is associated to a side channel present in two of the three sites, where water is flowing only during short periods.

4.4 Considerations about regulated flow regime and recruitment

It is important to remark that the maximum viability period of the seeds occurs only in the first month after they are dispersed, so if the soil and the flow are not suitable in May, when the flow decreases (usually September-October) most of the seeds have lost their viability.

The stable flow regime below the Arenós dam, due to flow reduction in magnitude and timing (for irrigation and hydropower use) and the constant contribution of some springs, has reduced the available area for seedlings establishment (because no banks erosion occurs) and does not favour the creation of new areas for the forest regeneration.

The comparison of aerial photographs taken before dam construction (1976) and today indicated a great reduction in the river dynamism and the proportion of gravel bars, but detailed measurements are still needed.

During the field work, we observed only a very small proportion of bared bars and banks available for seedlings establishment. As a consequence and in coherence with our observation, the release of higher flows in specific periods was recommended to maintain the riparian morphology and improve its condition, as there is no periodical transport and sedimentation of seeds on the river banks.

Moreover, based on other studies of poplars, recruitment is naturally episodic, occurring only about 1 year of every 3 to 10, with medium or high spring flows (Scott et al., 1996; Cordes et al., 1997; Mahoney and Rood, 1998). In some Mediterranean rivers, the appropriate bankfull discharge was identified within a range of return intervals of 4 to 9 years. Therefore, such flood frequency could be considered as the minimum in the design of environmental flow regimes in Spain, in order to inundate part of the floodplain and make possible the seeds dispersal in the riparian area.

These recommendations do not necessarily mean compromising the water resources, as regeneration is associated with the management of high flows during wet periods, while in dry years other criteria can be applied to focus on the maintenance of minimum wet conditions for the plants and the habitats of other biological communities.

At the moment we are getting more data to improve some aspects of this study, regarding the spatial distribution of the target species, their growth curves and also the simulation of the regulated flow regime (integrating springs and temporary streams).

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