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Landscape runoff, precipitation variation and reservoir limnology

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Abstract

Landscape runoff potential impact on reservoir limnology was indirectly evaluated by assessing the effect of precipitation variation on several water quality parameters, on *Anabaena* (Cyanophyta) and crustacean zooplankton abundances. The obtained results showed that total phosphorus increased with strong precipitation events whereas water transparency presented an opposite trend. Wet periods followed by long dry periods favored *Anabaena* dominance, which induced an accentuated decreasing on all crustacean zooplankton species abundance. Therefore, in a climate changing scenario these data are crucial to monitor and predict the effect of landscape changes on aquatic ecosystem integrity and ultimately in water quality.

Keywords:Landscape runoff impact,Precipitation,Reservoir limnology ,Water quality

1. Introduction

In Mediterranean region, both intensity and quantity of precipitation can vary markedly from one year to another. Such variability can generate different kinds of seasonal patterns, modifying water turnover time and changing the intensity of environmental and biological processes occurring in the water column of aquatic systems. Furthermore, the external loading of nutrients, organic matter and pollutants often increases with intensive precipitation events. The intensity and the magnitude of these loadings depend on land use, vegetation cover and landscape patchiness. Azibo Reservoir is located in the Iberian Peninsula on the Portuguese part of international River Douro catchment. In this region, most precipitation occurs between October and March in a very irregular pattern from one year to another (Fig. 1). Total annual precipitation varies between is around 760 mm, and in a "normal" autumn/winter season total precipitation is around 500 mm (Instituto de Meteorologia, 2009). In contrast to what happens in other reservoirs in the region, water level fluctuations caused by human activity are not very accentuated in Azibo. Thus, this reservoir provides a good environment to study the potential effects of quantity and intensity of precipitation without the interference of internal disturbances generated by extreme anthropogenic water level fluctuations. The objective of the present research is to evaluate the potential impact of landscape runoff on reservoir limnology. This was achieved indirectly through the assessment of the effects of precipitation variation on (1) environmental variables such as total phosphorous (TP), dissolved oxygen (DO), conductivity, pH, water transparency and chlorophyll *a* (Chl *a*); (2) *Anabaena* and crustacean zooplankton species abundance.

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2. Methodology

Water, *Anabaena* and crustacean zooplankton samples were collected in the deepest point of the reservoir in four distinct hydrological years: (1) 2000/2001; (2) 2001/2002; (3) 2007/2008 and (4) 2008/2009. Details on sampling methodology and laboratorial procedure are described in Geraldes and Boavida (2004; 2007). As most precipitation occurs between October and March samples collected during this period were classified as "winter season" the others were considered as "summer station". A Kruskal-Wallis test was performed for each environmental variable and *Anabaena* abundance to determine whether mean values obtained for each year were significantly different. Non-metric Multidimentional Scaling (N-MSD) was used for expressing similarity between zooplankton samples. In this method samples are arranged in a continuum in such a way that those close together are similar and those which are far apart are dissimilar The statistical analysis were performed using SPSS 16 and CAP 3, respectively.

3. Results

The total precipitation recorded during the period of study is presented in Table 1. Significant inter-annual differences were found for TP (χ= 10.01; p= 0.001), for conductivity (χ= 34.71; p= 0.000), for water transparency (χ= 19.74; p= 0.000) and for *Anabaena* densities (χ= 13.97; p= 0.003). The maxima of TP and the minima of water transparency was recorded in the winter 2000/2001. The low value of water transparency observed in winter 2001/2002 was a consequence of the increasing of *Anabaena* abundances (Table 1). The lowest densities for all crustacean zooplankton species was coincident with this period and with winter 2001/2002 (Table 2). N-MSD for zooplankton samples also indicate the existence of seasonal and annual differences in crustacean zooplankton abundances (Figure 2).

4. Discussion

The observed variations in TP, water transparency and in *Anabaena* and crustacean zooplankton abundances were related to changes in rainfall/ landscape runoff intensity. Similar results were obtained by authors studying reservoirs located in other regions influenced by Mediterranean climate (e.g. Armengol *et al.* 1999; Soria *et al.* 2000). The variation of landscape runoff concomitantly with precipitation intensity was evidenced by the notice that TP concentrations in water samples obtained downstream of one of Azibo Reservoir tributary were 103μg l^{-1} at the beginning of the rainfall period decreasing subsequently to 76 μg l^{-1} and to 16 μg l^{-1} by the end of rainfall period (Geraldes, unpubl. data). Besides, the lowest mean values of TP and the highest values of water transparency noticed in the reservoir during the years with low precipitation reinforce the above evidence. The dominance of *Anabeaena* from October 2001 to December 2001 (dry winter) occurred subsequently to a wet winter. The nutrient increasing scenario created during the wet period (Winter 2000/01) followed by the environmental conditions (e.g. absence of water turbulence, larger water residence time and higher irradiance) created by the subsequent dry periods (summer 2001 and winter 2001/2002), had lead to *Anabaena* dominance over the other groups of phytoplankton assemblage. As this alga is not edible by the most of the species of crustacean zooplankton their densities decreased accentually. Changes in limnological parameters are related to variations in precipitation intensity, which ultimately influence landscape runoff. Therefore, long term data series on reservoir abiotic and biotic components will allow to understand how changes in surrounding landscape will influence reservoir ecological processes and consequently water quality.

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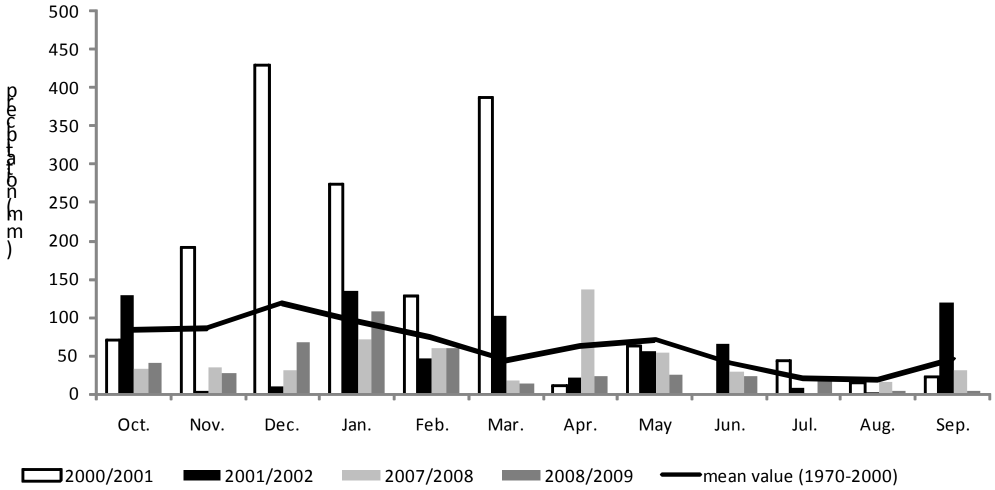

Figure1: Precipitation noticed for hydrological years of 2000/2001, 2001/2002, 2007/2008 and 2008/2009 in the Bragança city (Agroclima Lab-ESAB unpubl. data) the other data (Instituto de Meteorologia, 2009)

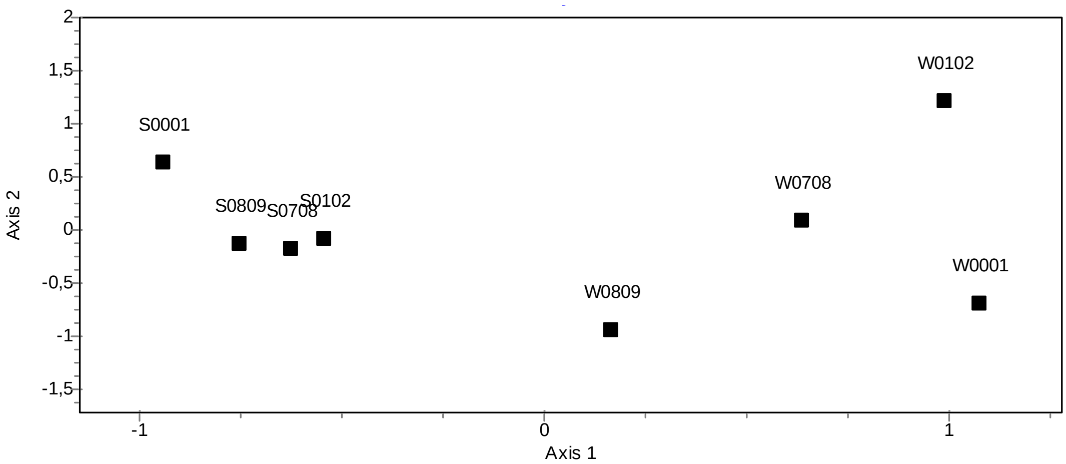

Figure 2: N-MDS analysis for crustacean zooplankton data.

Table 1: Total precipitation, mean and standard deviation (in brackets) of environmental variables

Variables	2000/2001		2001/2002		2007/2008		2008/2009	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
Total precipitation (mm)	1482	156.9	423.5	217.7	245.5	263.9	315.9	97.7
TP (µg/l)	66.96 (21.70)	64.30(18.15)	60.29(9.85)	61.45(7.15)	47.53(10.06)	31.56(7.16)	46.67(18.62)	31.67(24.01)
Water temperature (ºC)	10.68 (2.66)	20.33(3.19)	10.09 (3.77)	18.87(4.72)	10.54(3.27)	18.38(3.55)	10.58(3.65)	20.00(4.04)
Conductivity (µS cm^{-1})	54.67(10.67)	58.92(6.65)	48.42(4.92)	64.33(9.17)	91.60 (2.78)	90.35(3.19)	89.92(4.56)	98.78(1.16)
DO (mg/l)	9.06 (1.39)	9.70(1.42)	8.71(0.46)	8.48(0.76)	8.58(1.16)	8.58(1.29)	9.67(0.67)	9.44(1.07)
pH	6.6-7.0	7.0-8.4	6.9-8.3	7.5-7.9	6.0-6.4	6.3-7.2	6.0-6.8	6.5-8.2
Water transparency (m)	2.83(1.51)	4.33(0.44)	3.00(0.71)	4.21(1.74)	4.30(0.67)	5.75(0.42)	5.42(1.07)	6.42(1.5)
Chl a (µg/l)	2.05(0.95)	1.16(0.77)	3.31 (1.68)	1.10(0.48)	2.54(1.46)	1.58(1.33)	1.31(3.45)	2.67(1.50)
Anabaena (ind l^{-1}x 10^3)	0.23(0.26)	14.97(33.76)	90.07(97.91)	0.29(0.43)	0.0	0.0	0.0	4.78(7.84)

Table 2: Mean densities and standard deviation (in brackets) of the crustacean zooplankton species.

Species (ind m^3x 10^3)	2000/2001		2001/2002		2007/2008		2008/2009	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
Cladocera								
Daphnia longispina/pulex	0.90 (0.98)	1.89(3.72)	0.30(0.19)	0.54(0.69)	0.62(0.71)	2.16(2.07)	3.41(2.51)	1.30(1.69)
Ceriodaphnia pulchella	2.98 (5.79)	3.19(3.70)	0.14 (0.24)	3.93(4.33)	1.19(1.35)	3.52(6.47)	2.32(4.30)	3.60(7.87)
Diaphanosoma. brachyurum	0.0	0.31(0.54)	0.0	0.71(1.13)	0.21(0.31)	1.24(2.11)	0.40(0.83)	1.21(1.16)
Bosmina longirostris	0.07 (0.09)	0.22(0.18)	0.06(0.02)	0.17(0.16)	0.06(0.08)	0.06(0.05)	0.07(0.04)	0.19(0.32)
Copepoda								
Acanthocyclops robustus	0.04(0.04)	0.21(0.16)	0.10 (0.12)	0.09(0.66)	0.11(0.06)	0.07(0.04)	0.05(0.07)	0.13(0.14)
Copidodiaptomus numidicus	2.65(2.20)	3.47(2.84)	0.86(0.86)	5.67(0.92)	3.07(2.02)	4.39(1.36)	3.66(3.20)	4.52(1.50)
Nauplii	0.22(0.28)	1.97(1.53)	0.88(0.67)	2.56(1.50)	1.65(1.63)	1.63(0.82)	2.18(2.34)	3.18(3.37)