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PRIMARY RESEARCH PAPER

Distribution of benthic macroinvertebrates in a tropical reservoir cascade

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Abstract The functioning of systems arranged in cascades of reservoirs can be explained by the Cascading Reservoir Continuum Concept, providing a theoretical framework for addressing ecological processes. In this context, this study tested the following hypotheses: (i) the benthic macroinvertebrate assemblage shows a nested distribution along a reservoir cascade; and (ii) local factors explain the structure of the benthic assemblage in every reservoir along the cascade. Macroinvertebrates play essential role in aquatic systems, especially due to recycling and, in reservoirs, as important links in every food chain. Sampling was conducted quarterly between October 2006 and September 2010 in six reservoirs located in the São Francisco River, Brazil. The benthic macroinvertebrate assemblage showed nested distribution in the reservoirs, indicating that a loss of species occurs along the cascade. Each reservoir presented a different set of variables that explained the distribution of macroinvertebrates, showing the importance of local factors determining the composition and distribution of benthic assemblages in the reservoirs. Therefore, there is a clear interaction between the position of a reservoir along a cascade and the macroinvertebrate assemblages, which indicate the importance of considering this pattern during the decision-making process of constructing new dams on rivers already regulated.

Keywords Redundancy analysis · Tropical reservoirs · Nesting · Loss of diversity

Introduction

In their natural state, fluvial environments are among the most dynamic, diverse, and complex ecosystems (Humphries et al., 2014). Fluvial environments are and will likely continue to be the most degraded of all ecosystems (Dudgeon, 2010). As any other aquatic systems, fluvial ones have faced major changes to their watercourses, primarily due to anthropogenic

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processes (Tundisi & Matsumura-Tundisi, 2003). Changes in natural flow of rivers result in loss of biological diversity because water flow is one of the main forces structuring freshwater ecosystems (see Junk et al., 1989). The type and extent of the impacts of anthropogenic changes on biotic communities depend mainly on the intended water use (navigation, hydroelectricity generation, irrigation supply, and domestic water supply) (Lucadamo et al., 2012; Humphries et al., 2014). Consequently, freshwater ecosystems are among the most threatened ecosystems and exhibit a high rate of species extinction (Myers et al., 2000). In the Americas, particularly Brazil, one of the main sources of changes in aquatic environments is the construction of dams (and associated reservoirs) purposing the generation of electricity (Agostinho et al., 2007).

Dams disrupt continuity along rivers, as described by the serial discontinuity concept (SDC), which states that these interferences cause discontinuity in the physical, biological, and chemical characteristics of river courses depending on dam location, the number of serial dams, and the type of dam operation (Ward & Stanford, 1983). In large rivers, the proliferation of dams has changed the landscape and created series of reservoirs, demanding new paradigms and models to understand their effects on the structure and function of river ecosystems. Working from existing concepts, Barbosa et al. (1999) outlined the “Cascading Reservoir Continuum Concept” (CRCC), which proposed a theoretical framework for addressing ecological processes in systems with dams in series. This approach highlights the changes that occur in water quality, the trapping of sediments and nutrients, the ratio of coarse/fine particulate organic matter, thermal dynamics, and environmental connectivity. This concept forecasts that the prevalence of deposition processes over transport processes in semi-lentic environments causes the retention of sediment, particulate organic matter, and nutrients throughout the reservoir chain. This retention alters the trophic status and other limnological characteristics, resulting in oligotrophication throughout a system. These impacts act persistently and cumulatively to generate continuous changes in biotic and abiotic factors. In turn, these environmental changes will modify the structure of aquatic communities along a reservoir cascade and potentially affect the species diversity of the system. Theoretical arguments support this reasoning. However, few studies have addressed how these processes alter species diversity of a system.

The impact of river regulation on macroinvertebrates has been the focus of many studies worldwide (Behrend et al., 2012; Gillespie et al., 2014). Macroinvertebrates play essential role in aquatic systems, especially due to recycling and, in reservoirs, as important link in every food chain. Further research is required to understand the mechanisms influencing the new ecosystems created by the cascade of reservoirs. This understanding is crucial for the effective management of these systems because the construction of dams in series along rivers is a growing practice elsewhere. Thus, considering the importance of environmental filters on species distributions, the present study tested the following hypotheses: (i) the benthic macroinvertebrate assemblage exhibits a nested distribution along a reservoir cascade; and (ii) local abiotic factors explain the structuring of benthic assemblages in every reservoir. Based on these hypotheses, we predicted the following: (i) a cascade of reservoirs will promote upstream-to-downstream species loss, i.e., species richness will be greater upstream, and the reservoirs at the bottom of the cascade will contain a subset of the species from the first reservoir, resulting in a nested, gradient distribution of species. Thus, the richness and species composition of a reservoir will be correlated with the reservoir’s position within the cascade; and (ii) there will be no regional pattern in the distribution of the benthic assemblages across the entire reservoir cascade because most of these species have limited dispersal and are highly sensitive to local variations. Therefore, assemblages will be controlled by the characteristics presented by each reservoir.

Materials and methods

Study area

The hydropower potential of the São Francisco River basin (10°29′S, 36°24′W) is heavily exploited, with a total flooded area of 5856.2 km^2. The basin’s installed power-generation capacity is the second highest in Brazil. The basin is located in northeastern Brazil within the region known as the Drought Polygon, which is subject to long periods of extreme drought. With the exception of Três Marias

Reservoir, which is located in the upper region of the basin, the reservoirs (Sobradinho, Itaparica, Moxotó, Paulo Afonso, and Xingó) are located in the lower third of the basin (Fig. 1). Sobradinho, the largest artificial lake in South America (Table 1), is a prominent feature of the basin. The complex cascaded reservoirs in the São Francisco River basin are the only reservoir system located in a semiarid region of South America and are subject to marked seasonal variation in water flow.

The dams are subject to operational differences; Itaparica and Sobradinho are classified as accumulation reservoirs, whereas Moxotó, Paulo Afonso, and Xingó are classified as run-of-the-river reservoirs (Table 1). Therefore, due to differences in their position in the cascade and type of operation, they experience different ranges of variations in water level and mean hydraulic retention time. In addition to these operational differences, the reservoirs also differ greatly in their total area. The largest reservoir is Sobradinho (4,214 km^2), followed by Itaparica (828 km^2), Moxotó (98 km^2), Xingó (60 km^2), and Paulo Afonso (12.9 km^2).

Sampling and laboratory procedures

Sampling was conducted quarterly between October 2006 and July 2009 in Sobradinho and between December 2007 and September 2010 in the other reservoirs, using a modified Peterson grab sampler (0.0345 m^2). Sampling stations were selected to explore the area and represent the environmental variability within each reservoir; in other words, the samples were not taken randomly so that all the gradients of the reservoirs were sampled (lotic, transition, and lentic) and, within each gradient, samples were randomized. Therefore, in our sampling design, the number of sampling stations varied among reservoirs. We took into account the size of the reservoir and the seasonal variations of its volume during a year (more samples were taken in big reservoirs). At each sampling location, two sites were sampled: one in the main body of the reservoir (limnetic zone) and another near the shore (littoral zone). In the Sobradinho reservoir, twelve sampling sites were sampled (six in each of the limnetic and littoral zones). Eight sites were sampled in Itaparica (four in each of the limnetic and littoral zones), six in Moxotó (three in each zone), two in Paulo Afonso I, II, and III (PA I–II–III) (one in each zone), four in Paulo Afonso IV (PAIV) (two in each zone), and eight in Xingó (four in each zone).

At each site, three replicates were collected for analysis of biological material, stored in plastic bags, and fixed in 4% formalin; an additional sample was collected to analyze particle size and the content of

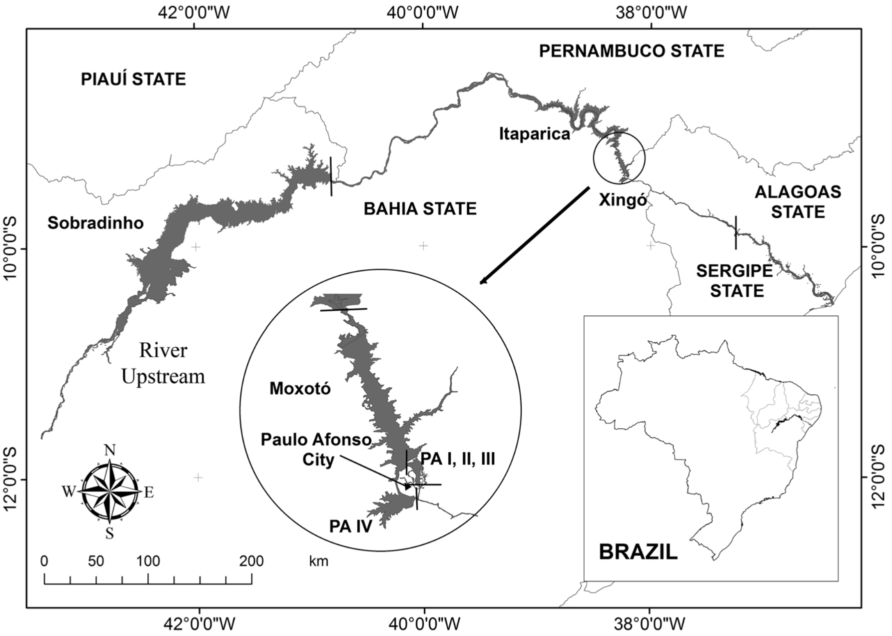

Fig. 1 Map presenting the location of the reservoir cascade along the São Francisco River basin and the position of the reservoirs in the cascade. *PA* Paulo Afonso

Table 1 Operational characteristics of the dams located in a cascade in the São Francisco River basin

Reservoir	Seq.	Type of operation	Area (km^2)	Length (km)	Volume (m^3)	W. res. (days)
Sobradinho	1	Accumulation	4,214	200	34.116×10^6	104.4
Itaparica	2	Accumulation	828	180	10.782×10^6	72
Moxotó	3	Run of the river	93	25	1.150×10^6	5
PA I, II, III	4	Run of the river	5.2	5	26×10^6	31
PA IV	5	Run of the river	12.9	7.38	127.5×10^6	31
Xingó	6	Run of the river	60	50	3.300×10^6	16

Seq sequence, *W. Res.* mean hydraulic retention time

organic matter in the sediment. The particle size composition of sediments (gravel in the sediment, clay, silt, and sediment texture) was performed according to the method of Reichardt (1990). The phosphorus concentrations and organic matter content were determined by the methods of EMBRAPA (1999) and nitrogen analysis followed Mendonça & Matos (2005). The environmental variables—water temperature (°C), pH, electrical conductivity (μS cm^{-1}), and dissolved oxygen concentration (mg l^{-1} O$_2$)—were determined in a vertical profile at each site with a multiparameter water quality meter. The depth was measured with the aid of an echo sounder.

In the laboratory, all biological material collected for analysis was washed with water in a series of sieves of the following mesh sizes: 2.0, 1.0, and 0.2 mm. The animals retained by the first two sieves were immediately removed and preserved in 70% ethanol, and all sediment retained by the 0.2-mm sieve was preserved in pure alcohol. The latter sediment was subjected to flotation in a saturated NaCl solution to separate the organic content from the inorganic content and facilitate the quantification and identification of macroinvertebrates.

The macroinvertebrates were identified and quantified under stereomicroscope and optical microscopes at the lowest possible taxonomic level (following Perez, 1988; Trivinho-Strixino & Strixino, 1995; Merritt & Cummins, 1996; Dominguez & Fernandez, 2001; Thorp & Covich, 2001) and preserved in 70% ethanol.

Data analysis

To test the hypothesis of species loss down the reservoir cascade, the NODF metric (Nestedness Metric Based on Overlap and Decreased Fill) was used as proposed by Almeida-Neto et al. (2008) and Ulrich et al. (2009). To perform this analysis, we constructed a presence–absence matrix of species, with the species in columns and reservoir samples in rows. In this matrix, columns represent the measure of regional richness (gamma diversity), the number of rows equals the number of locations or samples, and the fill is the percentage of cells that have presence values in the matrix. According to Almeida-Neto et al. (2008), perfect nesting occurs when approximately 50% of the matrix is filled and there is complete overlap from right to left and from top to bottom in the matrix. However, even patterns with a high fill value may be random patterns and do not indicate a pattern of nesting. The NODF value is the sum of all values of nested pairs, divided by the total number of pairs in the matrix. This calculation is performed using each pair combination of column and row. For more details on NODF, see Almeida-Neto et al. (2008). A total of 999 permutations were performed to estimate statistical significance. The nestedness metric was calculated using the "oecosimu" function implemented in the Vegan package (Oksanen et al., 2013) in R Core Team (2014). The implemented model was r00, which maintains the number of presences but fills them at random such that neither the species nor site totals are preserved.

The second hypothesis regarding the importance of local variables in each reservoir was tested by Redundancy Analysis (RDA, Legendre & Legendre, 1998). RDA is a direct gradient analysis that evaluates the effect of the predictor matrix (abiotic factors) on the response matrix (density of variables selected by the selection model). Model selection was based on the Akaike Information Criterion (AIC). We used the "vif.cca" function (vegan package) to evaluate the collinearity among variables. The significance of each axis of the RDA was tested by permutations. The RDA was performed using the "rda" function in the Vegan package (Oksanen et al., 2013) in R Core Team (2014). The permutation test was conducted using the "anova.cca" function. This function performs an ANOVA-like permutation test to assess the significance of the constraints. For more details, see the help functions in R.

Results

A total of 77 sampled taxa belonging to the following 13 groups were identified: Acarina, Bivalvia, Conchostraca, Decapoda, Gastropoda, Hydrozoa, Insecta, Nematoda, Nemertea, Oligochaeta, Ostracoda, Platyhelminthes, and Polychaeta. Among the six reservoirs sampled, Sobradinho had the highest taxonomic richness with 59 taxa, followed by Moxotó with 50, Itaparica with 44, Xingó with 38, Paulo Afonso (PA) IV with 26, and Paulo Afonso I–II–III with 19.

The benthic macroinvertebrate assemblage exhibited a nested distribution (NODF = 69.626; Matrix Fill % = 51.08; $P = 0.001$) among the six reservoirs analyzed (Sobradinho, Moxotó, Itaparica, Xingó, PA I–II–III, and PA IV). This result indicates that a loss of taxa occurs along the cascade (Fig. 2).

The presence–absence matrix was used to verify the occurrence of each taxon in each reservoir (Table 2). In addition, 15 taxa displayed a generalist distribution and were registered in all reservoirs: the mollusks *Asolene* sp., *Aylacostoma* sp., *Biomphalaria* sp., *Corbicula* sp., and *Melanoides* sp.; the chironomids *Ablabesmyia* sp., *Coelotanypus* sp., *Dicrotendipes* sp., and *Tanytarsus* sp.; the subclasses Acari, Hirudinea, and Oligochaeta; organisms from the classes Ostracoda and Turbellaria; and the phylum Nematoda. Sobradinho harbored the greatest number of unique taxa (14), followed by Moxotó (5), Xingó (3), and Itaparica (1). However, the PA IV reservoir did not contain any unique taxa.

In Sobradinho, the distribution of the benthic macroinvertebrates was influenced mainly by sampling station, conductivity, and depth (Fig. 3A). Together, these variables explained 26.2% of the total variation of the data. The model for Itaparica explained 44.4% of the total variation (Fig. 3B), with the main explanatory variables being sampling station, clay, sediment texture, depth, and pH. Less variation (20.0%) was explained by the model for Moxotó, with only sampling station and zones as important variables in the model (Fig. 3C). The model for Paulo Afonso explained 44.0% of the total variation, and only the variables sampling station and sediment texture were selected (Fig. 3D). In the model for Xingó, sampling station, gravel, and water temperature were selected; this model explained 36.8% of the total variation (Fig. 3E). Table 3 shows a summary of the RDA results for each reservoir. Importantly, a different set of variables explained the distribution of macroinvertebrates in each reservoir, indicating that local (abiotic) factors were responsible for determining the composition and distribution of the benthic communities.

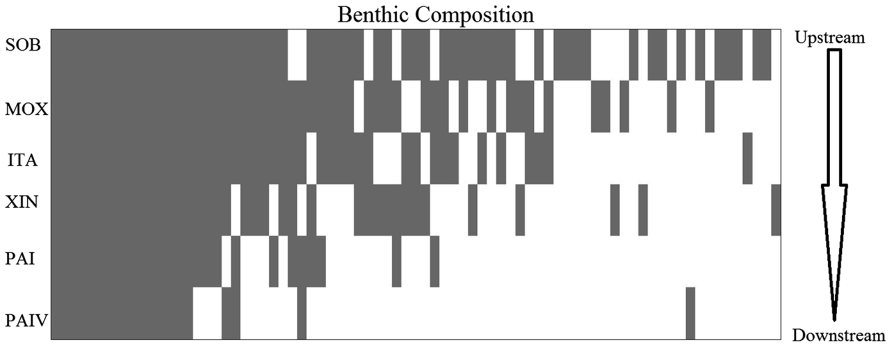

Fig. 2 Variations in macroinvertebrate assemblages' composition in the São Francisco reservoir cascade. *Dark cells* indicate presence and *white cells* indicate absence of a given taxa. *SOB* Sobradinho, *MOX* Moxotó, *ITA* Itaparica, *XIN* Xingó, *PAI* Paulo Afonso Complex I, II, III, *PAIV* Paulo Afonso IV

Table 2 Presence–absence matrix of the benthic macroinvertebrates collected in the six reservoirs: Sobradinho, Moxotó, Itaparica, Xingó, Paulo Afonso I–II–III (PAI), and Paulo Afonso IV (PAIV)

	Sobradinho	Moxotó	Itaparica	Xingó	PAIV	PAI
Ablabesmyia sp.	+	+	+	+	+	+
Acari	+	+	+	+	+	+
Aedokritus sp.	+	+	+	+		
Anadontites	+					
Asolene sp.	+	+	+	+	+	+
Axarus sp.	+		+			
Aylacostoma sp.	+	+	+	+	+	+
Biomphalaria sp.	+	+	+	+	+	+
Caenidae	+	+	+	+	+	
Caladomyia sp.	+	+	+	+		
Polymitarcyidae	+	+	+			
Carabidae	+					
Ceratopogonidae	+	+	+			
Chaoboridae	+					
Chironomus sp.	+					
Clinotanypus sp.	+	+				
Coelotanypus sp.	+	+	+	+	+	+
Collembola	+	+	+	+		
Complexo_*Harnischia*	+			+		
Conchostraca	+	+	+	+	+	
Corbicula sp.	+	+	+	+	+	+
Corixidae	+		+			
Cricotopus sp.	+	+	+			
Cryptochironomus sp.	+		+	+		
Coenagrionidae		+				
Curculionidae		+				
Decapoda				+		
Demycryptochironomus sp.		+				
Dicrotendipes sp.	+	+	+	+	+	+
Diplodon sp.	+	+	+	+	+	
Djalmabatista sp.	+	+	+	+		+
Dytiscidae	+					
Elmidae	+	+	+		+	
Ephydridae				+		
Eupera sp.		+	+	+		
Fissimentum sp.	+	+		+		
Goeldichironomus sp.	+	+		+		
Gomphidae	+	+	+	+		
Hebetancylus sp.		+		+	+	
Hirudinea	+	+	+	+	+	+
Hidrydae	+					
Hydrophilidae	+	+				
Hydroptilidae	+					
Idiopyrgus sp.	+		+	+		
Isoptera		+				
Labrundinea sp.	+		+			

Table 2 continued

	Sobradinho	Moxotó	Itaparica	Xingó	PAIV	PAI
Lepidoptera	+	+				
Leptohyphidae		+	+	+	+	
Leptoceridae	+					
Libellulidae		+		+		
Littoridina sp.		+	+		+	+
Lopescladius sp.	+		+	+		
Marisa sp.						+
Melanoides sp.	+	+	+	+	+	+
Microchironomus sp.	+					
Naucoridae		+				
Nematoda	+	+	+	+	+	+
Nemertea		+	+			
Nilothauma sp.	+					
Oligochaeta	+	+	+	+	+	+
Onconeura sp.	+		+			
Ostracoda	+	+	+	+	+	+
Parachironomus sp.	+	+		+	+	
Physa sp.	+					
Pisidium sp.	+	+	+		+	
Plathyhelminthes		+	+			
Polycentropodidae	+	+		+		
Polychaeta		+	+		+	
Polypedilum sp.	+	+	+			
Pomacea sp.	+					
Psychodidae			+			
Rheotanytarsus sp.	+					
Robackia sp.	+					
Staphylinidae				+		
Tanytarsus sp.	+	+	+	+	+	+
Thienemanniela sp.	+	+	+		+	+
Turbellaria	+	+	+	+	+	+

Crosses indicate taxon presence

Discussion

The effects of reservoir construction on biodiversity are diverse, and series of reservoirs are known to initiate or increase various processes (Barbosa et al., 1999; Agostinho et al., 2008; Drastík et al., 2008). Pronounced longitudinal changes in abiotic gradients are expected, with direct influence on the processes of colonization and organization of local assemblages. Modification in abiotic gradients is directly related to the position, along the river canal, in which the dam is constructed (Ward & Stanford, 1983). Thus, the synergism of these changes along the gradient directly or indirectly affects ecological aspects of assemblages at some level of resolution. It is expected a decrease in biodiversity and functional changes in the composition of the assemblages (Ward and Stanford, 1983, 1995), especially the sharp decrease of detrital material and habitat heterogeneity. A cascade of reservoirs can cause irreparable damage to the biota, as illustrated by the nested pattern of taxa observed in the São Francisco basin, with an upstream–downstream decrease in taxonomic richness.

In the present study, the tested hypotheses were corroborated, and the predictions regarding the distribution patterns of the benthic macroinvertebrate

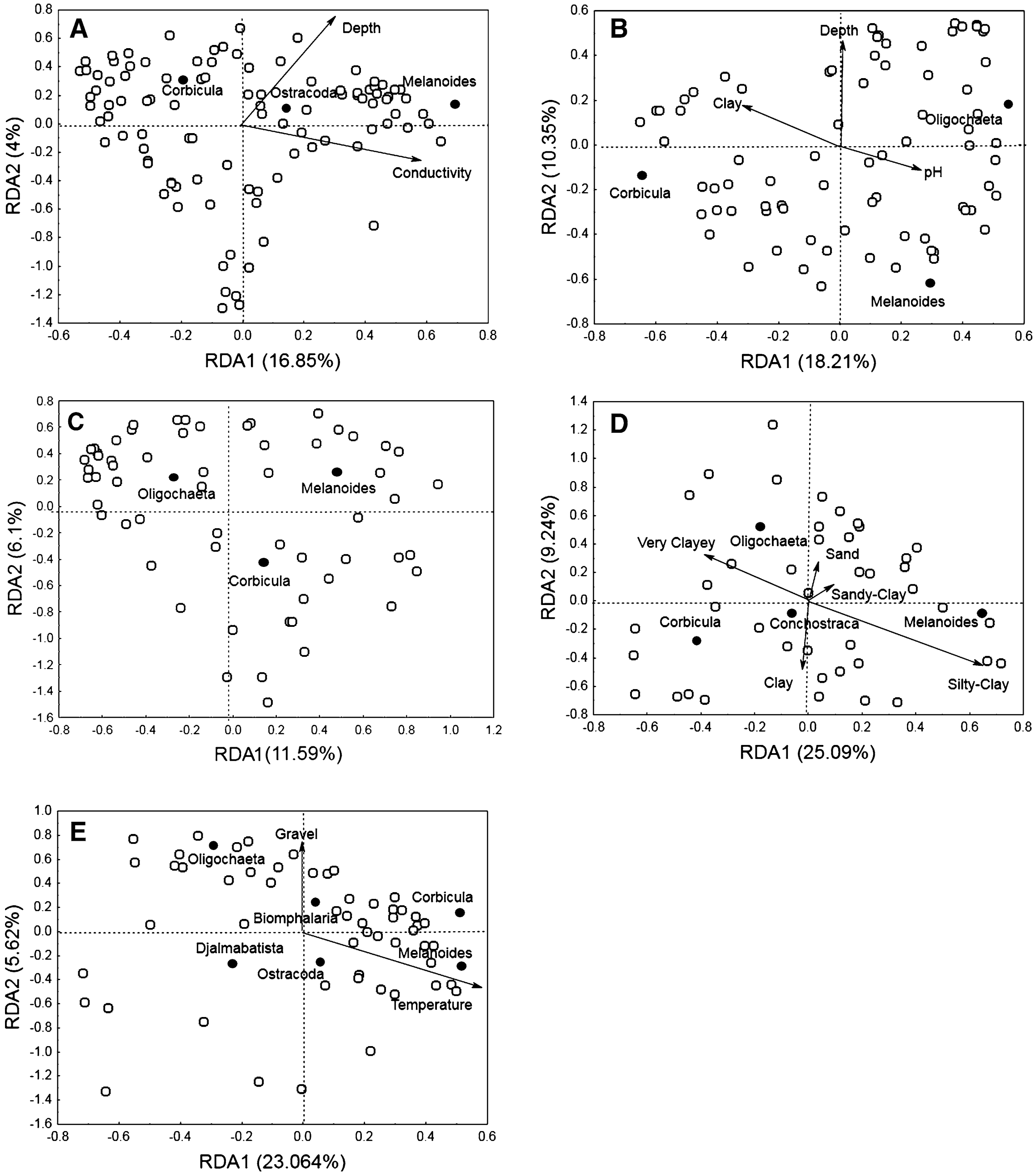

Fig. 3 Graphic representations of the Redundancy Analysis (RDA) for each reservoir: Sobradinho (**A**), Itaparica (**B**), Moxotó (**C**), Paulo Afonso IV (**D**), and Xingó (**E**). *Arrows* represent the influence of abiotic factors, *open circles* are samples, and *dark circles* represent taxa. Due to the high number of taxa, only the most important for the axis were plotted

assemblage were confirmed. The scope of these hypotheses is based on the premise that prior to the construction of dams, there was a full and continuous community in the São Francisco basin, i.e., the populations were structured according to the natural dynamics of the river. However, the series of dams in the São Francisco River has segmented the biological populations by creating new conditions and hindering their stabilization such that a different species composition exists in each segment.

Table 3 Results of the Redundancy Analysis (RDA) for each sampled reservoir: Sobradinho, Itaparica, Moxotó, Paulo Afonso IV (PAIV), and Xingó

	Sobradinho	Itaparica	Moxotó	PAIV	Xingó
Total explanation (%)	26.24	44.39	20	44.13	36.82
RDA1 (eigen values)	0.096402	0.1055	0.06094	0.09761	0.09985
RDA2 (eigen values)	0.022887	0.060	0.03206	0.0359	0.02434
RDA1 significance	0.005	0.005	0.005	0.005	0.005
RDA2 significance	0.005	0.005	0.005	0.005	0.005
R^2 (adjusted)	0.2148	0.2673	0.1352	0.266	0.2606

All results are significant ($P < 0.05$)

The benthic assemblage exhibited a nested distribution pattern in which the taxonomic richness decreased from upstream to downstream. The importance of local (pH, temperature, sediment texture, depth, and quantity of gravel) and spatial (the limnetic and littoral zones within a reservoir, sample station) factors to the *assemblage* composition was evident in all reservoirs. The nested pattern was attributed to the particular features of each reservoir and to water-level fluctuations that occur due to the operational procedures of each dam.

A nested pattern of benthic macroinvertebrates has also been reported for specific taxa, such as aquatic insects (Heino et al., 2009), and in a study of approximately 900 lakes and 85 fish metacommunities in Canada (Henrique-Silva et al., 2013). Several factors may explain this nesting (Almeida-Neto et al., 2008), including spatial variation in substrate composition and physicochemical properties (Heino et al., 2003). However, interactions among these factors, as well as habitat fragmentation caused by reservoir formation, can intensify the loss of species.

Assemblages of benthic macroinvertebrates clearly reflect the ecological conditions of the aquatic ecosystems they inhabit. Because dispersal is limited in these species, they are directly dependent on the characteristics of the local environment (Callisto et al., 2005; Costa & Callisto, 2006; Behrend et al., 2012). As a result, neighboring locations may exhibit substantial differences in species richness and diversity (Poff, 1997). Furthermore, the various conditions of each system (pH, temperature, sediment texture, depth, and quantity of gravel) are important influences of the community structure of these organisms (Townsend et al., 2003; Peeters et al., 2004; Behrend et al., 2012; Tagliaferro et al., 2013).

Reservoir size also influences the richness of the biota. As in natural systems, we expect a positive relationship between richness and the area of the ecosystem (MacArthur & Wilson, 1967). In this study, there was a positive relationship between area and species richness, with Sobradinho being the richest reservoir. However, we hypothesize that reservoir area alone is insufficient to explain this pattern because species richness was also correlated with reservoir position along the cascade. Geographical distance and environmental dissimilarity clearly affect global patterns of diversity (Qian & Ricklefs, 2012). The greatest variation in diversity in the reservoir cascade appears to be explained by the environmental heterogeneity of these systems. Thus, environmental heterogeneity promotes greater variation in species composition, which may be crucial to the coexistence and distribution of species (Shmida & Wilson, 1985).

Systems arranged in cascades have interconnected ecological processes, resulting in complex interaction dynamics. The relative increase in deposition processes over transport processes along the cascade promotes the retention of sediment, particulate organic matter, and nutrients along the cascade reservoirs, changing the trophic state and other limnological characteristics of the system (Straskraba, 1990; Barbosa et al., 1999). This results in an oligotrophication process from upstream to downstream. Along with the changes in both physical and biological parameters resulting from impoundments, this oligotrophication is directly associated with dam position in the system (Ward & Stanford, 1995), such that the construction of dams in series produces cumulative and synergistic effects. Knowledge of the particular characteristics of each reservoir cascade, such as morphology, presence of streams, human activities, and type of dam operation, is essential to understanding the processes in different reservoirs as well as over the entire cascade.

Reservoirs are never stable (steady state) (Costa & Callisto, 2006). Each reservoir is unique, and all vary from year to year (e.g., water level, biochemical properties) as a result of their dynamics and transport patterns (Kimmel et al., 1990; Ford, 1990). The water-level fluctuations in reservoirs are controlled by energy demands and produce daily fluctuations that potentially influence community structure (Benson & Hudson, 1975; Agostinho et al., 2008). Moreover, water-level fluctuations can directly affect benthic macroinvertebrates because a single rapid decrease in the water level can displace individuals from their aquatic habitat (Hunt & Jones, 1972; McEwen & Butler, 2010).

The results of the present study are an important step toward the improved management of aquatic systems that are directly influenced by the construction of reservoirs, which fragment and artificially control a system that was formerly subject to continuous and natural dynamics. Thus, each reservoir must be analyzed separately, and its operating regime must take into account local species and biological communities because, in the absence of natural dynamics, efforts are needed to stabilize the remaining biotic community.

This management could be accomplished by controlling the daily flow of water from the reservoir because the macroinvertebrates of the littoral zone are highly dependent on water levels, by monitoring the limnological characteristics of each reservoir to avoid rapid changes in physical and chemical parameters and prevent the release of low-oxygen water, and finally by monitoring land use around the reservoirs because the reduction of riparian vegetation and incoming pollutants can cause many changes in the established communities and eliminate sensitive taxa. The contribution of our research was to illustrate a longitudinal pattern in the macroinvertebrate assemblage along a reservoir cascade and the effects of changing habitat attributes and water quality. Unfortunately, we could not evaluate temporal variations associated to the construction of the impoundment, due to lack of previous data. Having baseline data of ecosystems before anthropogenic modifications is crucial; thus, we encourage research that takes into account this aspect, which certainly will contribute to improve our knowledge about the organization patterns of aquatic communities in regulated rivers.

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