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The Effects of Urbanization on Biodiversity and Water Quality in the Rio das Velhas Basin, Brazil

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Abstract.—In Brazil, most urban sewage is discharged without treatment into rivers. This is the situation for the Rio das Velhas, which receives in its upper course the sewage of the state capital of Minas Gerais, Belo Horizonte, with more than 2.4 million inhabitants. Our study focuses on the effects of basin urbanization on aquatic biodiversity and water quality in the Rio das Velhas. We use the assemblage structure and taxonomic composition of fishes and benthic macroinvertebrates as biological indicators of water quality. Effects of Belo Horizonte's discharge included changes in water quality and declines in fish and benthos richness and diversity. However, the absence of dams in the Rio das Velhas main course, associated with connectivity with the Rio São Francisco system and tributaries in excellent condition, increase its rehabilitation potential.

Introduction

Rivers have an important role in the biosphere as conduits for water, nutrients, sediments, woody debris, and biota from the continents to the sea. They are used by humans for transportation, fisheries, hydropower, and domestic, industrial, and agricultural water supplies (Petts 1989). Rivers also support unique and complex ecological communities and often influence the structure and functioning of the surrounding terrestrial ecosystem. Because of this, and the critical role of freshwater as a human resource, ecologists are increasingly asked to assess or monitor river "health," "status," or "condition" (Bailey et al. 2004).

Changes in environmental factors often initiate qualitative modifications in species composition and biodiversity. For example, eutrophication may cause a shift in primary producers, which in turn may change faunal species composition. Through time, a sequence of modifications may give rise to a fundamentally altered trophic network structure and function (Marques et al. 2002). Many rivers, streams, lakes, and reservoirs have been damaged as a consequence of the increasing impact of human activities (McAllister et al. 1997). This situation is particularly noticeable in areas of dense human population, especially in the urban environment, where watercourses show highly degraded water quality, receiving not only a great amount of domestic and industrial wastewater, but also sediments and trash. Thus, urban rivers have been transformed, losing their natural characteristics, many of them preserving little of their original biological diversity (Shepp and Cummins 1997).

In Brazil, most urban sewage is discharged without treatment into rivers. In addition, in large cities, rivers and streams are canalized or placed below streets in culverts. Intensive urbanization along Brazilian rivers has contaminated water bodies, thereby increasing water-born diseases and altered catchment hydrography and hydrology, which in turn has increased flooding, land sliding, and siltation of navigation channels. These same physical and chemical changes in Brazil's urban rivers have also markedly altered their aquatic biota (Tundisi 2003).

For more than a century, Brazilian water resource management has been dominated by outdated legal doctrines, weak implementation of good laws, and a focus on water chemistry. Yet the most direct and ef-

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fective measure of water body condition is the status of its living systems. These systems are the product of millennia of adaptation to climatic, geological, chemical, and biological factors. Biota integrate everything that has happened where they live, as well as what has happened upstream and upland. When something alters the landscape around rivers′ headwaters, life in lowland reaches is affected (Karr and Chu 1999). Although the neotropical biogeographic area is the world's richest region for freshwater fish species (around 8,000 species, Schaefer 1998), there are few published studies regarding the effects of urbanization on neotropical aquatic fauna. Our study focuses on the effects of basin urbanization on aquatic biodiversity and water quality in the Rio das Velhas. We use the assemblage structure and taxonomic composition of fishes and benthic macroinvertebrates as biological indicators of river quality.

Methods

Study Area

The Rio São Francisco basin, with an area of 631,133 km^2, covers 7.4% of Brazil. It is situated between 21° and 7°S latitudes and receives precipitation ranging from 350 to 1,900 mm in average years. The Rio São Francisco has an average annual discharge of 100 × 10^9 m^3 with an average flow of 3.150 m^3/s at its mouth (PLANVASF 1986). The 2,900-km river crosses five Brazilian states and is the 31st longest river in the world (Welcomme 1985). Its water is used for electricity generation, irrigation, urban and industrial supplies, navigation, and fisheries (Diegues 1994).

The Rio das Velhas is the longest tributary in the São Francisco basin. It is oriented in a southwest to northeast direction and extends 761 km from its headwaters, at an altitude of 1,520 m, to its confluence with the São Francisco River, at an altitude of 478 m. The estimated average annual flow is 300 m^3/s (Q95% = 103.69 m^3/s) with a drainage area of 29,173 km^2 and a mean width of 38.3 m (CETEC 1983).

The headwaters of the Rio das Velhas are located in a transition zone between the Atlantic rainforest and cerrado, which is a common savanna-like vegetation of central Brazil. Both biomes are identified as world biodiversity hotspots because they have exceptional concentrations of endemic species undergoing rapid habitat loss (Myers et al. 2000). Below its headwaters to its mouth, it flows only through cerrado. Another vegetation formation occurs near high elevation headwaters: the "campos rupestres," or rocky shrublands, such as seen in the Rio Cipó, one of its most important tributaries. This formation is very rich in floral and faunal species, with high diversity and endemism (Costa et al. 1998).

The Rio das Velhas has significant social and economical importance. Belo Horizonte, the state capital of Minas Gerais, with more than 2.4 million inhabitants (IBGE 2000), is located about 100 km from the Rio das Velhas headwaters. The river provides most of the city's water supply. The metropolitan region of Belo Horizonte (MRBH) consists of 34 counties situated around the capital. The total human population of MRBH is approximately 4.5 million people. The sewage from 3.2 million people is collected, but only 27.5% of it receives secondary treatment. In addition, MRBH is the most industrialized region of the state. The combination of sewage and industrial waste has made the Rio das Velhas the most polluted large river of Minas Gerias State.

The effect of native Americans on the region is unknown. But the settlement of Minas Gerais (translates to General Mines) by Europeans initiated extensive mining and contributed to degradation that continues to this day. Also, gold and gem explorations in the early 16th century produced the towns of Sabará and Ouro Preto. The changes caused by mining were greatest in the gravel plains and on the riverbeds (Dean 1996). Situated on the banks of the Rio Arrudas, Belo Horizonte is located about 100 km from the Rio das Velhas headwaters, Belo Horizonte was built in 1897 to be the capital of the state of Minas Gerais. Since 1898, an industrial and urban center emerged and started a new cycle of mining activities, mainly characterized by iron mines and iron industries next to the Rio das Velhas (FUNDO-FUNDEP 2000). Presently, the Rio das Velhas is severely damaged by urbanization and mining activities in its watershed. However, well-preserved tributaries with low human density persist in the basin. The most important source of pollution is located on the river's upper course, where mining debris and most of the domestic and industrial wastewater from the MRBH are discharged.

The capital's urban concept was oriented to the rationalist philosophy of humans dominating nature (SUDECAP 2001). Therefore, the city was designed with no concern for regional hydrography (Figure 1). Small and large streams were canalized to accommodate roads, waste, and sewage. Until 2000, the flood control policy of the MRBH was rapid water evacuation through canals and revetted streambeds. About 200 km of watercourses have been canalized in the city of Belo Horizonte, representing one-third of the

FIGURE 1. Plan of Belo Horizonte downtown, indicating the original (top) and current (bottom) stream courses.

drainages in the MRBH (SUDECAP 2001). Only recently, some streams have been chosen for environmental rehabilitation and sanitation in their natural courses.

Sampling Design

Water quality and benthos.—Water quality and benthos sampling sites included six stations along the Rio das Velhas main stem (Figure 2). In relation to the MRBH discharges, one site is located upstream (São Bartolomeu – RV-01), two in the MRBH (Sabará – RV-02 and Lagoa Santa – RV-03), and three downstream (Curvelo – RV-04, Corinto – RV-05 and Lassance – RV-06). Mean distance between sites was 59 km. For the analysis, these sites were grouped into upper (RV-01 and RV-02), middle (RV-03 and RV-04), and lower (RV-05 and RV-06) courses.

We also sampled another 13 tributary sites in the MRBH, including one located upstream and another downstream of each sewage treatment plant that is being built in Onça and Arrudas tributaries. The sites were chosen for geographic location above and below disturbances, common physical characteristics, and ease of access. Substrate types at most sites included sand, cobble, and vegetation in canalized third- to fifth-order reaches. But there was no substantial difference in site substrate (>90% sandy bottom), and common habitat types (riffles in streams and mid-channel in rivers) were sampled at all sites. Site length was 5–10 times the average bank-full width of the stream (as suggested by Newbury 1984). Sites were located away from the influ-

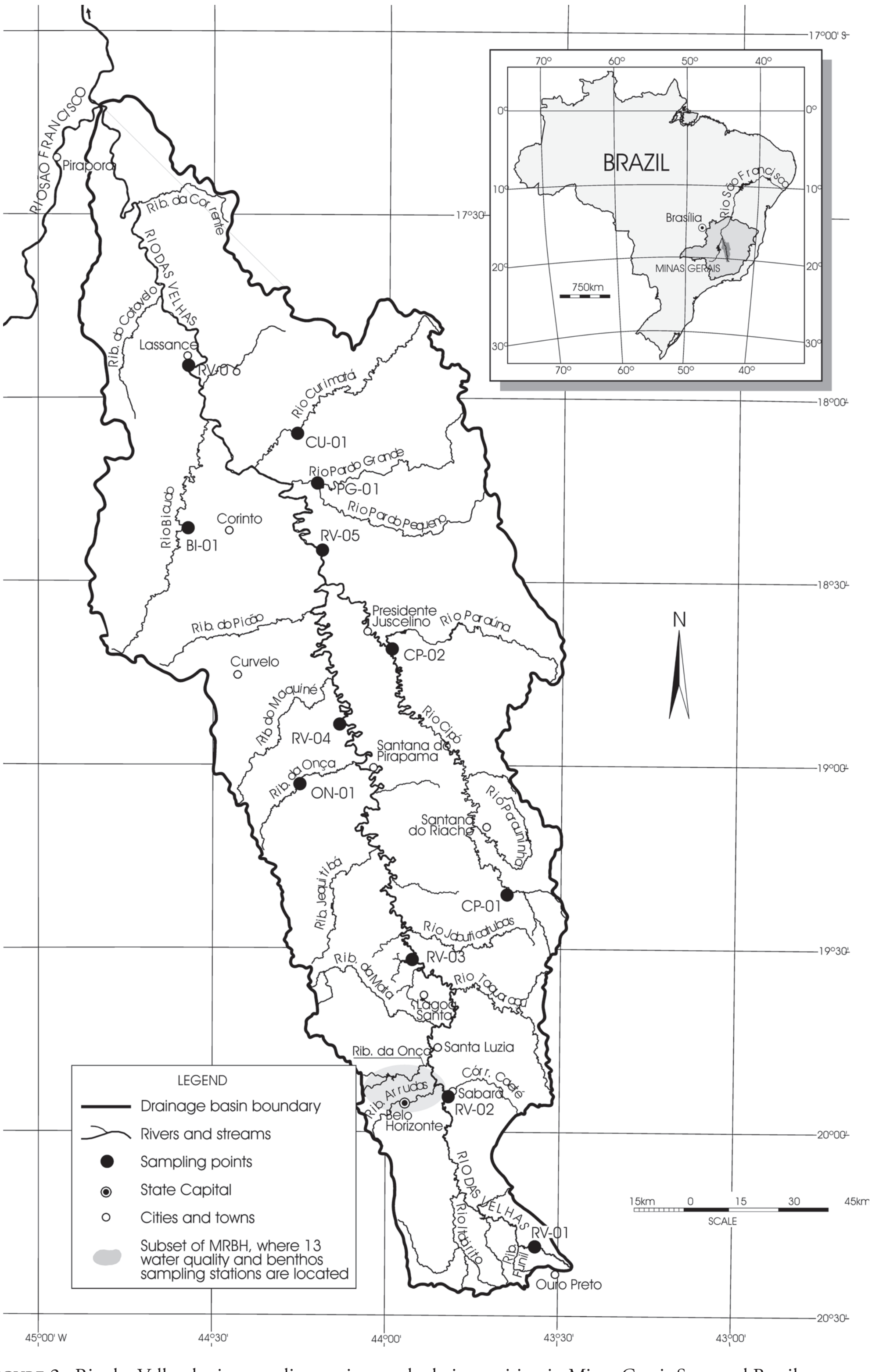

FIGURE 2. Rio das Velhas basin, sampling stations and relative position in Minas Gerais State and Brazil.

ence of tributaries or other water bodies. When a stream was sampled at more than one site, the sites were separated by a minimum of 120–150 stream widths or 10–15 pool-riffle sequences. Thus, in streams with an average width of 10 m, sites were 50–100 m long and had a minimum of 1.2 km between adjacent sites on the same stream (as suggested by Bailey et al. 2004). We sampled in the rainy and dry seasons.

Temperature, dissolved oxygen, conductivity, turbidity, and pH were measured in situ using a Horiba U-10 multi-probe and portable YSI samplers. Depth and velocity were measured with a Global Water flowmeter. We collected one water sample from each site with a Van Dorn sampler in the morning (0900–1100 hours), stored the bottles in an ice box for less than 4 h, and took samples to the metropolitan laboratory of COPASA (Companhia de Sanea-mento de Minas Gerais) for determination of total and dissolved nutrients (total-P, total-N, nitrite, nitrate, organic-N, and NH_4^+) and total dissolved solids, according to Lenore et al. (2002). For the microbiologic analyses (thermotolerant coliforms, total coliforms, *Escherichia coli* and fecal streptococcus), two subsurface water samples were taken directly into sterile glass bottles and returned to the COPASA laboratory, where they were kept on ice and processed within 8 h. Total and fecal coliforms were determined using the most probable number method (MPN; Lenore et al. 2002).

Five random sediment samples were collected at each site with a Van Veen dredge (area of 0.045 m^2), without focusing on a specific habitat. In the laboratory, samples were washed through 1.00-, 0.50-, and 0.25-mm sieves, sorted under a stereomicroscope, and identified organisms were deposited in the Reference Collection of Benthic Macroinvertebrates of the Institute of Biological Sciences, Federal University of Minas Gerais, Brazil. Insects were identified to genus and others to family, according to Cranston (2000), Domínguez et al. (2001), Epler (2001), Pérez (1988), and Trivinho-Strixino and Strixino (1995). We determined granulometric composition of the sediments as proposed by Suguio (1973), and modified by Callisto and Esteves (1996). Organic matter content of sediment was determined by ashing previously dried samples in an oven at 550°C for 4 h.

Fish.—Fish sampling stations include the same six benthos and water quality sites along the Rio das Velhas mainstem and five well-preserved tributaries: Cipó (CP-01 and CP-O2), Bicudo, (BI-01), Curimataí (CU-01), Pardo Grande (PG-01), and da Onça (ON-01) rivers (Figure 2). These tributaries were included to compare main-stem sites, affected by a huge urbanized area, with water courses located in areas with low human density. Except for Rio Cipó, which was sampled five times, every sampling station was visited two or three times from 1999 to 2002, including at least one dry and one wet season.

Fish were caught with gill nets (20 m long, with 3- to 16-cm stretch mesh), seines (5 m long and 1-mm mesh), cast nets (3-cm stretch mesh), and kick nets (1-mm mesh). Gillnets were fished in the water column for 14 h overnight. Seines were used in shallow areas or littoral zones, kick nets were employed in nearshore aquatic macrophytes and in riffles, and cast nets were used in habitats too deep to wade. The three latter methods were employed for 1–3 h and used only qualitatively to maximize the number of species collected. Reaches 50–100 m were surveyed, depending on depth and water flow. All sampled fishes were identified to species and specimens were placed in the University of São Paulo Zoology Museum (MZUSP).

Results

Water Quality

The Rio das Velhas upper course waters were slightly alkaline to slightly acidic, intermediate in conductivity and total suspended solids, well oxygenated, and relatively clear (Table 1). The sediment organic matter was low. Total phosphorus and total nitrogen were also low.

The MRBH tributaries were slightly acidic to alkaline, with very low dissolved oxygen (Table 1). Comparing the sampling stations upstream and downstream of the two Belo Horizonte sewage treatment plants (STPs), substantial differences were found in pH (8.6 upstream and 7.43 downstream for Onça and 7.13 upstream and 5.8 downstream for Arrudas), with very low oxygen levels in both streams (<0.5 mg/L). In both tributaries, conductivities were relatively high (>350 μS/cm), and the waters were very turbid (>100 NTU), with high TDS (244–428 mg/L). Sediments were sandy with 0.66–48.01% dry weight of organic matter. Nutrient concentrations were high (total N = 16.66 ± 4.83 mg/L, total P = 2.16 ± 1.28 mg/L).

Baleares, Onça, and Cardoso are the most important tributaries in MRBH and showed the highest concentrations of microorganisms (>2.3 × 10^7 coliforms/mL, >2.4 × 10^5 *E. coliform*/mL), low oxygen levels (<2.0 mg/L), high conductivity (219 ± 187 μS/cm) and nutrient concentrations (total N = 14.3 + 6.9 mg/L, total P = 0.97 ± 1.12 mg/L), moderate turbidity (30–143 NTU), slightly acidic to slightly alkaline pH (6.8–7.7), and sandy sediments.

TABLE 1. Water quality in upper, middle, Belo Horizonte metropolitan region (MRBH) and lower das Velhas River (*, not measured).

Sampling subbasins	Depth (m)	Width (m)	Velocity (m/s)	Flow (m^3/s)	pH	Conductivity (μS/cm)	Dissolved oxygen (mg/L)	TDS (mg/L)	Turbidity (NTU)	Temp (°C)	Total-N (mg/L)	Total-P (mg/L)	*E. coli* (*N*/mL)	Fecal *Streptococcus* (*N*/mL)	Sediment organic matter (% dry weight)
Upper part															
Minimum	0.5	4.5	0.58	3.11	5.9	26.5	6	44	2	18.2	0.019	0.019	2,400	1,500	0.99
Maximum	2.0	25.0	2.5	29.00	7.78	83	8.4	112	11	25.6	1.3	0.74	24,000	20,000	7.19
Mean	1.3	17.5	1.92	18.50	7.05	40.22	6.95	71.00	5.50	22.60	0.250	0.20	9,700	12,000	3.06
Standard deviation	0.8	8.5	0.70	13.5	0.65	25.68	1.19	29.10	3.94	3.18	0.75	0.36	12,000	9,500	2.20
MRBH															
Minimum	0.3	4.5	0.58	3.11	5.77	275.00	0.50	244.00	18.00	22.70	12.00	0.60	24,000	6,000	48.01
Maximum	2.5	25	2.00	29.00	8.61	603.00	4.48	428.00	120.00	27.90	24.00	5.40	98,000	200,000	0.66
Mean	2.0	12	1.57	15.50	7.46	459.50	1.73	308.60	44.30	24.49	16.66	2.16	45,000	20,000	5.74
Standard deviation	1.5	3.5	0.35	3.79	0.66	96.02	1.45	59.60	29.8	1.36	4.83	1.28	22,500	15,500	10.33
Middle part															
Minimum	0.6	25	0.44	15.00	7.33	13.5	3.2	10	3.4	23	0.019	0.019	160	56,000	0.5
Maximum	1.7	50	1.28	22.44	7.4	260	7.5	172	127	27.2	7.12	1.5	8200	6	7.81
Mean	0.71	25	0.50	20.20	7.25	146.06	5.65	116.25	49.90	25.16	2.55	0.39	2,400	11.435	4.01
Standard deviation	0.3	15	0.65	2.30	0.35	71.85	1.40	52.22	55.65	1.22	4.60	0.74	6,500	24.914	2.57
Lower part															
Minimum	1.0	30	0.16	4.75	6.7	13.00	6.2	24.00	3.4	22.00	*	0.019	0	0	0.17
Maximum	3.18	100	1.18	212.50	7.93	275.00	8.00	84.00	143.00	29.3	*	0.21	13,000	1,020	15.47
Mean	2.2	75	0.43	136.03	7.25	73.25	6.80	57.00	48.29	25.80	*	0.05	5,200	790	3.78
Standard deviation	2.5	60	0.67	67.85	0.33	81.16	0.56	23.58	52.79	2.04	*	0.07	2,420	320	4.40

The middle stretch of Rio das Velhas had slightly alkaline to slightly acidic waters, intermediate conductivity, and was well oxygenated (Table 1). A considerable number of coliform and fecal streptococus were seen, indicating contamination by directly discharged, domestic untreated sewage from the MRBH tributaries.

In the lower course of the Rio das Velhas, oxygen was 6.2 ± 0.5 mg/L at Barra do Guaicuí and 8.0 ± 0.3 mg/L, between Corinto and Augusto de Lima counties (Table 1). The sediments had low organic matter (1.15% at Corinto and Augusto de Lima, and 15.47% at Lassance), but waters showed high conductivity (275 µS/cm at Lassance) and high turbidity (143 NTU at Barra do Guaicuí).

Benthic Macroinvertebrates

Benthic macroinvertebrates were dominated by oligochaetes (87.9%), chironomids (mainly *Chironomus* and *Polypedilum* – 8.25%), and other dipterans, such as Psychodidae (3.78%). In the upper reach (RV-01, RV-02), tolerant taxa were found in high densities, mainly dominated by chironomids (*Ablabesmyia, Chironomus, Cryptochironomus*, *Fissimentum, Polypedilum),* psychodids, empidids, elmids, odonates, *Biomphalaria straminea,* and oligochaetes. A total of 13 taxa were found. Numerically dominant taxa included chironomids (up to 1,000 ± 250/m^2), *Physa* (120,000 ± 45,000/m^2), *Biomphalaria straminea* (250 ± 65/m^2), and oligochaetes (4,300 ± 1,500/m^2).

In the MRBH tributaries, we found 12 taxa, with numerical dominance by oligochaetes (74,000 ± 25,000/m^2), chironomids (up to 13,000 ± 5,600/m^2, mainly *Chironomus* and *Polypedilum*), and psychodids (up to 4,000 ± 2,500/m^2).

In the middle Rio das Velhas (RV-03, RV-04), we collected 21 taxa, with Sphaeriidae (1,926 ± 1,461/m^2), chironomids (1,600 ± 1,300/m^2), hirudineans (1,400 ± 1,800/m^2), and oligochaetes (93,000 ± 60,700/m^2) most abundant.

In the lower reach (RV-05, RV-06), 23 taxa were found and the introduced Asian snail *Melanoides tuberculatus* (607 ± 405/m^2) was abundant, as well as Sphaeriidae (415 ± 551/m^2), *Physa* (919 ± 821/m^2), and Elmidae (452 ± 538/m^2).

Fish

Fish and macroinvertebrates had similar distribution patterns along the Rio das Velhas main channel. Fish richness and Shannon Diversity Index of benthic macroinvertebrates decreased downstream of the MRBH streams, between sampling sites RV02 and RV03 (Figure 3). This effect was greatest during the dry season, but was moderated by water dilution in the rainy season. The effects of urbanization on the fish fauna of the main stem were also marked in comparison with tributaries. The 81 species recorded in the tributaries represent almost 83% of the total fish species of the whole basin, including native and alien records. We found 37 species (34% of local fauna) exclusively in these tributaries. The sampling stations located in the main stem also had the larger number of alien species, especially those sites located immediately downstream of Belo Horizonte (Table 2).

Discussion

According to Brazilian law, (regulation number 1469, 29 December 2000), all of the studied reaches of Rio das Velhas are inappropriate for human consumption without prior treatment and inappropriate for primary contact, aquatic sports, and bathing. The Rio das Velhas has very low potential for recreational use without further treatment by the sanitary company (COPASA-MG). Most Brazilian cities have experienced uncontrolled development and increased occupation of river margins and their floodplains. Many cities are trying to solve problems of sanitation and flooding with river canalization. Canalization increases water velocities, reducing residence time and accelerating domestic effluent and pollutant transport. Such changes also lower richness and diversity in the Rio das Velhas downstream of MRBH, highlighting the effects of sewage discharge on the main channel. However, urbanization costs are even higher in the small water courses draining the metropolitan area. Besides the poor benthos assemblage and water quality, pollution and canalization of MRBH streams have eliminated most native fish species. Only a few well-preserved headwater reaches, protected as natural reserves or water supply sources, support typical headwater fishes, such as *Trichomycterus* and *Astyanax.*

Urbanization has also changed fish assemblages in the natural lakes of the MRBH. Lagoa Santa is a shallow permanent lake located north of Belo Horizonte, inside the metropolitan region. Between 1850 and 1856, Reinhardt collected fish in Lagoa Santa (Lütken 2001). Comparisons between the historical and recent data showed that at least 70% of the original fish fauna is now extinct (Pompeu and Alves 2003). The reasons were directly related to urbanization: the obstruction and canalization of the natural connection between Lagoa Santa and the Rio das Velhas, the elimination of

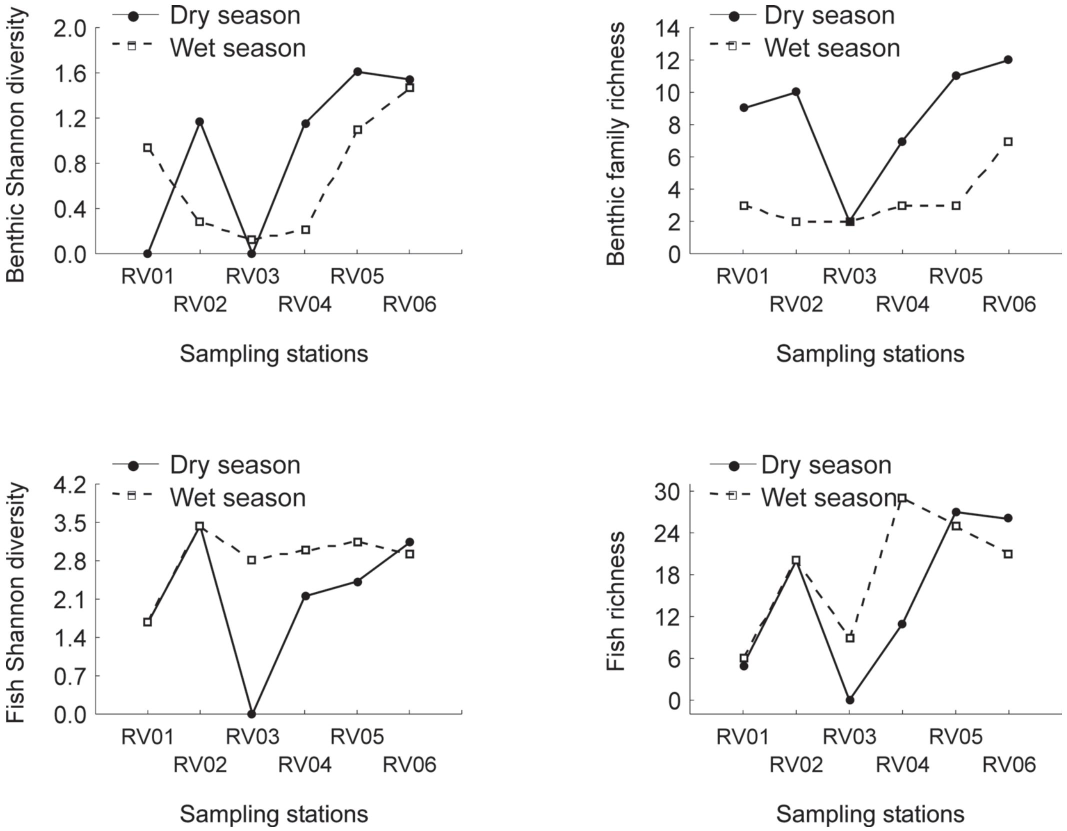

FIGURE 3. Richness and Shannon Diversity Index for fish and benthos along the Rio das Velhas main course, in the dry and wet seasons.

littoral (Cyperaceae) and submerged (Characeae) vegetation, and the introduction of alien fish species.

Another important effect of urbanization on the basin is regular fish kills, mainly in the beginning of the rainy season (Alves et al. 2000). Heavy organic discharges from the MRBH accumulate in the river bottom during the dry season. At the beginning of the summer/wet season, this material is suspended and water temperatures increase. Rapid decomposition of the organic matter depletes dissolved oxygen, causing frequent fish kills. Recent radiotelemetry studies have shown that Rio das Velhas is an important route for large migratory species from São Francisco River (A. Godinho, Universidade Federal de Minas Gerais, personal communication). Annual kills of adults and burying of the eggs and larvae lead to annual decreases of resident fish populations and those that migrate from the Rio São Francisco to spawn. However, our data indicate that the most severe effects of the MRBH urbanization on fish and benthos in the Rio das Velhas occur during the winter/dry season. Some researchers (Bozzetti and Schulz 2004; B. C. T. Pinto and F. G. Araujo, Universidade Federal Rural do Rio de Janeiro, and R. M. Hughes, Oregon State University, unpublished data) concluded the same for other rivers in southeastern Brazil, linking the effect to pollutant concentration and more efficient sampling during the dry season.

In aquatic environments, processes that determine structural diversity are closely related to the fluvial regime, which determines depth, velocity, substrate types, and channel shape (Angermeier 1997). The fluvial regime also is linked to the seasonal flood cycle, which affects sediment, organic matter fluxes, and biomass production (Junk et al. 1989). In the tropics, many fish species use river floodplains for feeding, reproduction, and refuge (Agostinho and Zalewski 1996). Fragmentation and habitat simplification are broadly described as the main threats to biodiversity conservation because they directly interfere with the rates of colonization and extinction (Kareiva et al. 1995) and are the main causes of fish species extinction in North America (Miller et al. 1989). There are no dams in the Rio das Velhas main

TABLE 2. Number of native and alien fish species per family collected at each site. See Figure 2 for locations of sample sites.

Family	Total species	Tributaries						Rio das Velhas					
		BI-01	CP-01	CP-02	CU-01	ON-01	PG-01	RV-01	RV-02	RV-03	RV-04	RV-05	RV-06
Native families	102												
Acestrorhynchyidae	1	1	–	1	1	–	1	–	–	–	–	1	–
Anostomidae	8	4	1	6	4	1	1	–	2	–	1	4	3
Apteronotidae	1	–	–	1	–	–	–	–	–	–	–	–	–
Aspredinidae	2	–	–	1	1	–	–	–	–	–	–	–	–
Auchenipteridae	1	1	–	–	–	–	1	–	–	–	–	–	–
Callichthyidae	1	–	–	–	–	–	–	–	–	1	–	–	–
Characidae	30	12	11	9	10	6	16	2	4	2	9	11	9
Cichlidae	4	–	–	–	1	–	–	–	–	1	–	3	1
Crenuchidae	3	2	3	2	3	2	2	2	1	–	–	–	2
Curimatidae	4	2	2	3	2	1	2	–	–	2	3	–	1
Engraulidae	1	–	–	–	–	–	1	–	–	–	–	–	–
Erythrinidae	2	2	1	2	1	1	1	1	1	–	1	1	1
Gymnotidae	1	1	–	1	1	1	–	–	1	1	1	1	–
Loricariidae	18	7	4	10	7	7	6	2	2	–	5	3	9
Parodontidae	4	1	1	4	2	2	2	–	1	–	1	1	3
Pimelodidae	14	7	3	10	4	6	4	1	5	–	–	5	8
Poeciliidae	1	–	1	–	–	–	–	–	–	–	–	–	–
Prochilodontidae	2	1	1	1	1	1	1	–	–	–	2	2	1
Scianidae	1	–	–	–	–	–	–	–	–	–	–	–	1
Sternopygidae	2	1	–	2	1	1	1	–	1	–	1	1	1
Trichomycteridae	1	–	1	–	–	–	–	–	–	–	–	–	–
Alien families	5												
Callichthyidae	1	1	–	–	–	–	–	–	–	1	1	–	–
Cichlidae	2	–	–	1	–	–	1	–	1	1	2	2	1
Cyprinidae	1	–	–	–	–	–	–	1	1	–	–	–	–
Poeciliidae	1	–	–	–	–	1	–	–	–	–	–	1	–
Total	107	43	29	54	39	30	40	9	20	9	27	36	41

stem and no observed changes in its flow regime. This connectivity with the Rio São Francisco system and tributaries in excellent condition, increase the rehabilitation potential of the Rio das Velhas (Pompeu et al. 2004).

In addition, there are 12 sewage treatment plants already installed within the MRBH and others are being designed and built. The DRENURBS Project (Environmental Rehabilitation and Sanitation of Valleys and Natural Riverbeds of Belo Horizonte) is also being implemented. Its main goals are water course cleaning, sediment control, institutional reinforcement by Belo Horizonte City Hall, and integration of water resources with urban scenery.

An environmental monitoring program has begun for the Rio das Velhas as part of the Manuelzão Project. Physical, chemical, and biological indicators are being used to: (1) determine the contribution of the Rio das Velhas to the condition of the Rio São Francisco; (2) identify point and diffuse pollution sources throughout the basin; (3) assess aquatic ecosystem health and environmental quality; and (4) monitor changes in water quality due to sanitation interventions and sewage treatment. The assessment and monitoring will employ modified monitoring designs and indices of biotic integrity used by the USEPA's Environmental Monitoring and Assessment Program.

The objective of the Manuelzão Project is to return the fishes to the Rio das Velhas. The project adopts the basin as a research, planning, and social mobilization unit. The basin perspective helps to integrate nature, history, environment and social relationships, and human health. Our data, collected as part of this project, contribute to the knowledge of freshwater biodiversity in the Rio das Velhas, which can be useful for Brazilian decision makers. We are using the Reference Condition Approach (RCA, least disturbed sites) of Hughes (1995) and Bailey et al. (2004) for biological assessment in the Rio das Velhas basin. The RCA has a number of key features that make it useful for our purposes: (1) It defines and quantifies ecosystem health; (2) it incorporates variation among healthy ecosystems; and (3) it uses the deviation of a test site from Reference Condition to measure the effect of stressors on the ecosystem. We measure variability in benthos and fishes among sites in "Reference Condition" in four subbasins (Taquaraçú, Paraúna, Curimataí, and Itabirito). These reference subbasins are minimally exposed to human stressors such as effluent discharges or land uses that often disturb ecosystems. We plan to elaborate, test, and validate an empirical model to explain as much of the variability in the reference site biota as possible, based on the environmental characteristics of the sites.

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