AUTHOR(S): ABREU DA COSTA, T.R.A., WEBER, O.B., PESTANA, C.J. and CAPELO-NETO, J.

TITLE: Bioindicators assessing water quality and environmental impacts of water treatment plant sludge.

YEAR: 2017

Publisher citation: ABREU DA COSTA, T.R.A., WEBER, O.B., PESTANA, C.J. and CAPELO-NETO, J. 2017. Bioindicators assessing water quality and environmental impacts of water treatment plant sludge. International journal of environment and sustainable development [online], 16(1), pages 25-42. Available from: https://doi.org/10.1504/IJESD.2017.10001350

OpenAIR citation: ABREU DA COSTA, T.R.A., WEBER, O.B., PESTANA, C.J. and CAPELO-NETO, J. 2017. Bioindicators assessing water quality and environmental impacts of water treatment plant sludge. International journal of environment and sustainable development, 16(1), pages 25-42. Held on OpenAIR [online]. Available from: https://openair.rgu.ac.uk

BIOINDICATORS ASSESSING WATER QUALITY AND ENVIRONMENTAL IMPACTS OF WATER TREATMENT PLANT SLUDGE

Talitha R. Alves Abreu da Costa[1], Olmar Baller Weber[2], Carlos J. Pestana[3], José Capelo-Neto*[4]

[1] Master in Civil Engineering, Department of Hydraulic and Environmental Engineering, Federal University of Ceará, 713. Fortaleza, Ceará, Brazil – 60451-970. E-mail: litha_nne@yahoo.com.br.

[2] Researcher, Embrapa - Brazilian Agricultural Research Corporation, Dr[a]. Sara Mesquita St., 2270, Fortaleza, Ceará, Brazil –60511-110. E-mail: olmar.weber@embrapa.br;

[3] Research Fellow at the School of Pharmacy and Life Science, Robert Gordon University, Garthdee House, Garthdee Road, Aberdeen AB10 7QB, UK. E-mail: c.j.pestana@rgu.ac.uk.

[*4] Lecturer and Researcher, Department of Hydraulic and Environmental Engineering, Federal University of Ceará, 713. Fortaleza, Ceará, Brazil – 60451-970. E-mail: capelo@ufc.br

ABSTRACT

This study had as objectives to assess water quality using macro-invertebrate communities in Gaviao artificial reservoir (Brazil), used to supply potable water to 2.5 million people, and to evaluate how these organisms responded to the discharge of water treatment sludge into a natural wetland. A total of 1,621 specimens across 23 taxa were identified. Mollusca were the dominant and most frequent group while Insecta presented the most richness. Based on feeding mode, there were more predator organisms than scrapers. The Biological Monitoring Working Party (BMWP') method showed to be more sensible to water quality variations than ASPT index, going from polluted to questionable water quality more frequently. The chemical parameters analyzed showed no significant variations and were not a sensitive

method for assessing water quality. No organisms could be found downstream of the sludge discharge point, indicating a high impact of sludge disposal on local biota.

Keywords: macro-invertebrates; bioindicators; artificial reservoir; water quality; water treatment sludge.

1. INTRODUCTION

Concerns with the deterioration of water resources' quality and the safety of aquatic ecosystems are increasing because of the large amount and diversity of pollutants discharged every day. The problem of deterioration of water quality is magnified in arid and semiarid regions due to irregular rainfall and high evaporation rates (Gheyi et al., 2012; Levy, 2011; Santos et al., 2014). These diverse and complex factors that have an impact on water resources have generated an additional burden to the regional and national economies, since it increases the costs of aquatic ecosystems recovery and water treatment for human consumption. Poor water quality impoverishes local populations and inhibits sustainable development (Alvarez et al., 2013; Tundisi, 2008). In Brazil, most of the sludge generated at water treatment plants (WTPs) is still disposed irregularly into the environment, despite the existing environmental laws governing the matter (Oliveira et al., 2004; Tartari et al., 2011). This inadequate disposal can have negative impacts, both by increasing the amount of solids and turbidity and introducing toxic agents into the water, as well as compromising the stability of aquatic life (Filho et al., 2013; Hoppen et al., 2006). Traditionally, the assessment of these environmental impacts is accomplished by measuring chemical and physical variables (CONAMA, 2005; Fonseca et al., 2014; Who, 1996). However, many authors (Beneberu et al., 2014; Bere and Tundisi, 2012; Calderon et al., 2014; Rinaldi, 2007) state that the use of biological responses as environmental degradation indicators are more advantageous compared to chemical and physical parameters since these non-biological measurements only represent a snapshot of the moment they were collected. This means a large number of samples to evaluate temporal variation are required. Thus, the study of human interventions through sensitive biological communities or biomarkers represent an advantage over chemical and physical indicators (Demars and Edwards, 2009; Gomes et al., 2014; Roa et al., 2012).

Macro-invertebrate communities have been widely used as biomarkers for a number of reasons: they are ubiquitous, respond to perturbations in all aquatic environments at any given time, and there is a large number of species that offers a broad spectrum of responses. Furthermore, it utilizes simple and cost effective collecting methodologies and allows for relatively uncomplicated organism identification (Findik, 2013; Gullan and Cranston, 2008; Vidal-Abarca et al., 2013).

A number of studies have been conducted considering the sensitivity of the macro-fauna in Brazil (Couceiro et al., 2007; Cummins et al., 2005; Magris and Destro, 2010; Ottoni, 2009; Rodrigues and Ferreira-Keppler, 2013). Freire (2007) identified that Gaviao Reservoir's aquatic fauna is composed mainly of fish and amphibians. Leitao (2006) studied the zooplankton community composition and abundance in this same reservoir. However, despite its regional importance, no studies have been published focusing on bio-monitoring and invertebrate fauna surveys such as mollusks, annelids, insects and other invertebrates. The present study aims to gain an insight regarding the aquatic macroinvertebrate community of Gaviao reservoir, to elucidate how those organisms respond to the WTP sludge disposal and to categorize Gaviao reservoir water quality using the Biological Monitoring Working Party (BMWP) index.

2. MATERIALS AND METHODS

2.1 Geographic location

This research was conducted in Gaviao Reservoir witch has a total capacity of 33.30 x 10^6 m^3, a hydraulic detention time of approximately 40 d, and it is located 30 km south of Fortaleza, Ceara, Brazil. Gaviao Reservoir is included in the Fortaleza Metropolitan Region (FMR) watershed and receives contribution from the Gaviao river during the rainy season (February to May) and from the Pacajus-Pacoti-Riachao Reservoir system, all year long, through two channels that transport water from the Jaguaribe river and Castanhao reservoir. It is responsible for supplying water to approximately 2.5 million people and to the industrial complexes located in the FMR (Freire, 2007).

The FMR WTP is located downstream of Gaviao dam. It utilizes descendent direct filtration, using poly aluminum chloride (PAC) and a cationic organic polymer as coagulation agents, chlorine dioxide and chlorine as pre oxidant and disinfectant agents, respectively, and fluorosilicic acid as recommended by the Brazilian Ministry of Health. The filters backwash process utilizes treated chlorinated water. The backwash water, as well as the water treatment sludge is discharged without any treatment to a natural wetland located downstream and besides the reservoir dam, before it reaches the Gaviao river.

2.2 Sampling locations

Six sampling locations were selected, four located upstream from and two further downstream of the dam, where the waste from the WTP is disposed (Figure 1). Criteria when considering sampling site locations were: accessibility, different substrates such as macrophytes or rocks and a depth between 1 and 2 m. Because for most lakes and reservoirs the amount of benthic taxa is higher in the coastal zone (Smiljkov et al., 2008; Trichkova et al., 2013), the four points upstream were selected alongside the dam, spaced at regular intervals.

The rainy season contributes over 75 % of the mean annual precipitation, which is 1066 mm a^{-1} on average. Evaporation can reach up to 1700 mm a^{-1} and the average annual temperature is 26 °C (Datsenko, 2000).

The metropolitan watershed has a crystalline foundation, represented by a Gneiss-Migmatite Complex and granitic rocks, predominantly Acrisol and Arenosol (COGERH, 2010). The reservoir's permanent protection area is composed almost entirely of arboreal vegetation and anthropized areas are limited.

2.3 Macro-invertebrate sampling

The reservoir's epifauna was collected from between 1 to 2 m depth from October 2012 to May 2013. Except for the months of March and April, samples were collected monthly at the four selected locations across the dam (P1, P2, P3, and P4), in addition to two other locations downstream of the dam (J1 and J2). At each location, three samples were collected with a trawl net (0.5 mm mesh) supported by a 25cm wide square frame, as suggested by ISO standards (AQEM, 2002). To facilitate the capture of organisms, the net was passed on the bottom and sides, near the vegetation and sediment of the reservoir and the wetland (Sterz, 2011). The invertebrates removed from the sampled material were placed in a micro tubes fixed with aqueous ethanol (90%) and then sealed within 48 h (INADG, 2008).

2.4 Sample triage and data analysis

The invertebrate screening process consisted of separating large groups and discarding exuvia, empty shells and fragments such as legs, antennas or wings. All collected organisms were stored in aqueous ethanol (70 %) for identification into their taxonomic families. A stereomicroscope (Nikon SMZ745T) was used (10 to 50 X magnification), according to a method adopted from several researchers (Agudo-Padron, 2008; Bennetti et al., 2006; Froehlich, 2007; Garcia-Davila and Magalhaes, 2003; Leite and Sa, 2010; Pes et al., 2005), and by pictorial keys (Almeida et al. 2008; Bis and Kosmala, 2005; Kannowski, 1992; Moretti, 2004; Pinho, 2008; Segura et al., 2011).

Five categories were used to classify the macro-invertebrates' feeding mode: (1) gathering collectors; (2) filtering collectors; (3) shredders; (4) predators and; (5) scrapers (Cummins and Merritt, 1996).

The BMWP score system (National Water Council, 1981) is a water quality assessment method that consists of attributing a score ranging from 1 to 10 to each taxonomic family according to their tolerance to water pollution. Taxonomic families that are intolerant to pollution are ranked highest while families that are capable of tolerating pollution have lower scores (Armitage et al., 1983). When summing all scores obtained for each family present in each sample, it was possible to frame the values obtained into seven biological quality classes (Table 1).

In this work the BMWP adaptations by Alba-Tercedor and Sanchez-Ortega (1988) , Alba-Tercedor (1996, 2000), Baldan (2006), Cota et al. (2002), Junqueira (2009), Loyola (1998), Monteiro et al. (2008) and Toniolo et al. (2001) were used, referred to as BMWP'.

In order to establish a correlation between the BMWP' biotic index and the water quality in the reservoir, the scores attributed to families detected at sampling locations P1, P2, P3, and P4 were summed, and compared to the global water contamination index (GWCI).

The Average Score Per Taxon index (ASPT), which represents the ratio between the BMWP' value and the total families found in sampling locations (P1, P2, P3, and P4) was also used. The use of the ASPT index is important to confirm the results obtained by BMWP' (Cota et al., 2002; Junqueira, 2009). By using the ASPT index, the following water classification can be obtained: clear (> 6); questionable quality (5 to 6); moderately polluted (4 to 5); and severely polluted (< 4), according to Mandaville (2002).

Rainfall data were obtained in a rain gauge station located at Itaitinga (FUNCEME, 2013) from October 2012 to May 2013. Raw water from Gaviao reservoir and the WTP sludge were analyzed for pH, total hardness, conductivity, total aluminum and total dissolved solids based on APHA (2005). Those parameters were used since they are utilized by the State Water and Wastewate Company to assess water quality and the environmental impact of the sludge.

3. RESULTS AND DISCUSSION

3.1 Chemical variables

The Gaviao Reservoir inflow and outflow were approximately 8200 L s^{-1} with a total volume ranging from 90 to 95 % of its maximum capacity. From October to December 2012 no rainfall was observed in the reservoir or in the Pacajus-Pacoti-Riachao Reservoir system watersheds. Rainfall was detected in Gaviao reservoir watershed during January (61 mm), February (228 mm) and May 2013 (124 mm), as well as in its tributary reservoirs' watersheds: Pacajus (53; 43; and 150 mm) and Pacoti-Riachao (14; 93; and 120mm) (FUNCEME, 2013).

The water pH in Gaviao reservoir varied from 7.6 in November to 8.4 in January, a typical pH value for Brazilian semiarid region superficial water storage (COGERH, 2010). According to Sprague's (1985) classification, total hardness varied from moderately hard in October (130 $mg_{CaCO3}.L^{-1}$) to hard in December (174.7 $mg_{CaCO3}.L^{-1}$). The concentration of aluminum varied between 0.04 $mg_{Al}.L^{-1}$ in November and 0.02 $mg_{Al}.L^{-1}$ in January and February (Table 2), below the threshold of 0.1 $mg_{Al}.L^{-1}$ established for freshwater by CONAMA (2005). The raw water conductivity ranged from 832.5 $\mu S.cm^{-1}$ in December to 728.9 $\mu S.cm^{-1}$ in May. In the case of the state of Ceara, due to high evaporation rates, conductivity should not be used as an indicator of pollution or anthropogenic impact. The WTP sludge displayed pH between 6.9 and 7.3 and aluminum concentration varied from 0.08 $mg_{Al}.L^{-1}$ in December to 1.08 $mg_{Al}.L^{-1}$ in January (Table 2). Although neither federal nor state legislation stablishes a maximum amount of aluminium allowed in the wastewater, Schmidt (2002) showed that dissolved aluminium concentrations as low as 0.18 $mg_{Al}.L^{-1}$ can strongly impair benthic macroinvertebrate communities.

3.2 Macroinvertebrate characterization

A total of 1,621 invertebrate specimens were collected from October 2012 to May 2013. Those organisms were distributed across 4 phyla (Annelida, Mollusca, Platyhelminthes, Arthropoda), 6 classes (Clitellata, Gastropoda, Turbellaria, Arachnida, Malacostraca, Insecta) and 23 families. Only two specimens could be classified up to their order. Based on this identification, a table with the scores for each taxon was drawn for the Gaviao Reservoir (Table 3).

A total of 338 specimens were collected in October, November and December 2012 (dry season), and 1,283 specimens occurred in January, February and May 2013 (rainy season). Taxonomic richness was scarce in the dry season, especially in November 2012 and abundant in wet period especially in February 2013. This correlates with Abilio (2007), who noted greater taxonomic richness during the wet season in Taperoa II and Namorado reservoirs, located in the state of Pernambuco, on the South-central border of Ceara state.

The communities present during the rainy season may be different from that of the dry season (Bispo and Oliveira, 2007), due to differing reproductive cycles. However, according to Sonoda (2010), this seasonal variation should not affect the method's water classification capability.

Most species were obtained at location P1 (1,030), followed by P2 (369), P3 (209), and P4 (13). This difference between locations may be related to the presence of macrophytes, which were abundant at locations P1, P2 and P3 but were sparse at sampling point P4. According to Shimabukuro and Henry (2011), the littoral community is more diverse where higher macrophyte densities are present. According to Taniwaki and Smith (2011) macrophytes also maintain substrate stability, allowing for greater organism density.

Groups identified in the Gaviao reservoir were also found in other reservoirs in Brazil. Eight reservoirs along Paranapanema River, in the state of Sao Paulo, presented a total of 96 taxa. The benthic macroinvertebrates were represented by 7 major zoological groups, presenting the greatest richness with the class Insecta, with 60 taxa (Jorcin and Nogueira, 2008). Eight of these families were also found in Gaviao reservoir (Polycentropodidae, Chironomidae, Stratiomyidae, Ceratopogonidae, Glossiponiidae, Thiaridae, Ancylidae, Physidae, Planorbidae and Hydrobiidae).

In Americana reservoir, also in the state of Sao Paulo, Pamplin (2006) collected 19 taxa of macro-invertebrates, among which the following families also were present in Gaviao Reservoir: Chaoboridae, Chironomidae, Ceratopogonidae, Glossiphoniidae, Thiaridae, Polycentropodidae and Stratiomyidae). The Bodocongo reservoir, located in the same semi-arid region, presented 11 families (Viana et al, 2013), among which 8 families (Chironomidae, Thiaridae, Ampullaridae, Ancylidae, Planorbidae, Libellulidae, Physidae e Baetidae) were also found in Gaviao Reservoir.

Predation (13) was the most abundant feeding mode, followed by scrapers (8). It should be observed that no shredders we detected in this study. These results can be explained by the fact that predators and scrapers are less restrictive and can be found in several types of environments (Vannote et al., 1980).

The presence of scrapers may also have been influenced by the presence of periphyton, which thrive in lentic water bodies (Callisto and Esteves, 1998) and are the main food source for scraper organisms. The absence of shredders may have been caused by the fact that they are more common in areas with a dense dossal, such as lakes or rivers with riparian forest, which is not the case for the sampling locations in this investigation (Taniwaki and Smith, 2011).

Most frequently encountered were the taxonomic families of the Thiaridae, Ancylidae, Planorbidae, Hydrobiidae, Lestidae and Chironomidae, found throughout the entire period of study. The Glossiphoniidae, Pionidae, Noteridae, Caenidae, and Physidae families were less frequent and were only encountered during one month. The most abundant family was Planorbidae, with 559 collected specimens (34 %), followed by Hydrobiidae and Thiaridae with 318 (20 %) and 234 (14 %) specimens, respectively. Phyasidae, Caenidae, Notoeridae and Glossiphonidae were represented by only one specimen each (<1 %) (Table 4). No eudominant families were encountered, that is, none with over 60% relative abundance throughout the period of study.

Mollusks were the most frequent, dominant and abundant taxon. From the six sampled families, Planorbidae, Hydrobiidae, Thiaridae represented 68 % of total collected specimens. This abundance of mollusks can be related to the water pH levels (average pH 8.0) found in the Gaviao Reservoir (Table 2). Abilio (2002) studied water resources in the semi-arid region of Paraiba state, Brazil, and also noted greater abundance of mollusks in high pH environments. According to Leite (2001), electric conductivity and water pH can influence mollusk population composition and abundance.

According to Rosenberg and Resh (1993), aquatic environments' macro-invertebrate family abundance is reduced with decreasing environmental quality. Usually, when there is a predominance of one specie or when the community is dominated by few species, there are strong indications of negative environmental impacts.

Two mollusk families collected are related to water-borne diseases: Planorbidae, intermediate host of *Schistosoma mansoni* (schistosomiasis) and *Fasciola hepatica* (fasciolosis), and Thiaridae , intermediate host of *Paragonimus westermani* (paragonimiasis) and *Clonorchis sinensis* (oriental liver fluke) (Pointer, 1993). Furthermore, the family Thiaridae to which the invasive species *Melanoides tuberculata* belongs may be harmful to endemic fauna, since it is highly adaptable and competes for food and habitat.

By applying the BMWP' method to organisms collected a score of 91 was obtained, which indicates that the water in Gaviao Reservoir is of questionable quality. More families occurred in February (19), October (16), and November (10). As shown in Table 7, after correlating the BMWP' biotic index with the IAP (2003) index, water quality ranged from questionable (October 2012, January and February 2013) to polluted (November and December 2012 and May 2013).

Results obtained with the ASPT index responded differently from those of BMWP' during the sampling period. In October 2012 the ASPT method showed severe pollution, while the BMWP' method showed questionable water quality. As for the other months, the ASPT remained at moderate pollution levels (Table 8) while BMWP' varied to polluted, moderate pollution and back to polluted water.

The differences in ASPT and BMWP' in October 2012, January, and February 2013 may be related to the fact that some of the families collected in those months may score lower in the BMWP'. On the other hand, the presence of organisms that are sensitive to organic pollution, such as Trichoptera and Ephemeroptera, in January and February 2013 may reinforce the hypotheses that water quality actually improved in those months. Since chemical parameters analyzed during the sampling period had no significant variations, other factors such as rainfall or chemicals that were not monitored, may have contributed to the emergence of these families.

The biological data obtained supports the results of a study conducted by Vidal and Capelo-Neto (2014), who conducted chemical and physical analyses and compared their findings to the time series data (2005 to 2009) provided by COGERH (2010). The authors observed a gradual increase in total concentrations of nitrate, ammonia and phosphorus since 2005. The concentrations found recently were clearly higher than average historical data showing that in general, Gaviao Reservoir water quality is progressively worsening, despite seasonal improvements due to rainfall.

Although the sampling frequency undertaken was the same as those upstream of the dam, no macro-invertebrates were observed downstream. Therefore, it was not possible to apply either the BMWP' score or the ASPT index to assess water quality. According Sanches and Junk (2003), the effect of improper disposal into the environment of waste generated by WTPs has proven extremely damaging. The discharge of WTPs wastewater into waterways can introduce sediments in these environments and promote toxicity in aquatic organisms, mainly due to metals such as aluminum, high concentrations of solids, turbidity and increasing the biological oxygen demand (BOD). Untreated sludge released into an aquatic environment with low speed may cause sedimentation and thereby isolation of the benthic layer (Kress et al., 2004), color changes, and disturbances in the chemical and biological composition on the receiving body (Barbosa et al., 2001; Schmidt et al., 2002).

Another parameter that may have caused this absence of macro-invertebrate is the residual chlorine present in the sludge with possible damage to the food chain. Palmer et al. (2003) mentioned the toxic effects of residual chlorine on aquatic life especially fish and macro-invertebrates. Pasternak et al. (2003) proved the toxicity of residual chlorine and chloramines and concluded that the non-disinfected sewage is less harmful to aquatic biota than chlorinated ones.

4. CONCLUSIONS

The macro-invertebrate communities detected in Gaviao Reservoir were divided into 4 phyla (Annelida, Mollusca, Platyhelminthes, Arthropoda), 6 classes (Clitellata, Gastropoda, Turbellaria, Arachnida, Malacostraca, Insecta), 23 families and 1,621 specimens. No eudominant families were found. Most of these species were collected during the rainy season. Regarding the feeding mode, it was identified that more predators than scrapers were present, no shredders were found.

Invertebrate families Planorbidae, Hydrobiidae, Thiaridae represented 68% of specimens found in the Gaviao Reservoir. Mollusk need to be monitored more closely since two families that act as intermediate host of a potentially harmful parasite to humans were found.

ASPT method indicated that Gaviao's water was severely polluted in October 2012 and moderately polluted from November 2012 to May 2013, while the BMWP' method showed apparently to be more sensible to water quality variations, going from polluted to questionable water more frequently. The chemical parameters analyzed showed no significant variations and were not a sensitive method for assessing water quality.

No macro-invertebrates were collected or observed downstream from the WTP sludge discharge point, and therefore nether the BMWP' nor the ASPT index could not be applied to assess water quality, despite a monthly sampling effort. It is important to conduct more detailed studies on the impact of untreated WTP sludge and waste water disposal on aquatic biota, analyzing in more details the biochemical interactions involved.

5. ACKNOWLEDGEMENTS

The authors would like to acknowledge and thank the Brazilian Agricultural Research Corporation (Embrapa), the Water and Wastewater Company of Ceara (CAGECE) and the Federal University of Ceara- UFC for their support of this investigation.

6. REFERENCES

Abilio, F.J.P., Ruffo, T.L.M., Souza, A.H.F.S., Florentino, H.S., Junior, E.T.O., Meireles, B.N. and Santana, A.C.D. (2007) 'Benthic macroinvertebrates as indicators of environmental quality of water bodies of the caatinga', *Oecol. Bras.* **11** (3), 397-409.

Agudo-Padron, A.I. (2008) 'Systematic Listing Continental Mollusca occurring in the State of Santa Catarina, Brazil', *Comunicaciones de la Sociedad Malacologica del Uruguay*, **9** (91), 147 – 179.

Almeida, A.O., Coelho, P.A., Luz, J.R., Santos, J.T.A. and Ferraz, N.R. (2008) 'Decapod crustaceans in fresh waters of southeastern Bahia, Brazil', *Rev. Biol. Trop.,* **56** (3), 1225-1254.

Alba-Tercedor, J. and Sanchez-Ortega, A. (1988) 'Un método rapido y simples para evaluar la calidad biologica de las aguas corrientes basado en el de Hellawell (1978)', *Limnetica* **4**, 51-56.

Alba-Tercedor, J. (1996) 'Macroinvertebrados acuaticos y calidad de las aguas de los rios. IV Simposio del aguas en Andalucia (SIAGA).' *Almeria,* 2 [online] http://www.ephemeroptera-galactica.com/pubs/pub_a/pubalbaj1996p203.pdf. (Accessed 05 March 2013).

Alba-Tercedor, J. (2000) 'BMWP', un adattamento spagnolo del British Biological Monitoring Working Party (BMWP) Score System', *Biol. Amb.*, **14** (2), 65-67.

Alvarez, B.L., Leal, J.A.R., Cruz, G. S, Ramirez, J. M., Lozada, S.E.C; Medrano, M.C.N. and Martinez, L.F.P. (2013) 'Water poverty index assessment in semi-arid regions: the case of San Luis Potosi Valley (Mexico)', *Rev. Internat. Contam. Ambient*. **29** (4), 249-260.

Assessment System for Ecological Quality of Streams and Rivers Throughout Europe using Benthic Macroinvertebrates - AQEM, (2002) 'Manual for the application of the AQEM system: A comprehensive method to assess European streams using benthic macroinvertebrates, developed for the purpose of the water framework directive, version 1.' [online] www.fliessgewaesserbewertung.de (Accessed 10 January 2013)

Armitage, P. D., Moss, D., Wright, J.F. and Furse, M.T. (1983) 'The performance of a new biological water quality score system based on macroinvertebrates over a wide range of unpolluted running-water sites', *Water Res.* **17** (3), 333-347.

APHA, AWWA, WEF (2005) *Standard methods for the examination of water and wastewater, 21th ed.* Washington, DC, American Public Health Association, American Water Works Association and Water Environment Federation.

Baldan, L.T. (2006) *Composition and diversity of benthic macroinvertebrate assemblage and its use in evaluation of water quality in the river Pinto Morretes, Paraná, Brasil.* Master Dissertation, Federal University of Parana, Paraná, Brazil.

Barbosa, F.A.R., Callisto, M. and Galdean, N. (2001) 'The diversity of benthic macroinvertebrates as an indicator of water quality and ecosystem health: a case study for Brazil', *Aquat. Ecosyst. Health* **4**, 51-59.

Bere, T. and Tundisi, J.G. (2012) 'Applicability of the Pampean Diatom Index (PDI) to streams around Sao Carlos-SP, Brazil', *Ecol. Indic*. **13** (1), 342-346.

Beneberu, G., Mengistou, S., Eggermont, H. and Verschuren, D. (2014) 'Chironomid distribution along a pollution gradient in Ethiopian rivers, and their potential for biological water quality monitoring', *Afr. J. of Aquat. Sci.* **39** (1), 45-56.

Bennetti, J.C. Fiotentin, G.L., Cueto, J.A.R. and Neiss, U.G. (2006) 'Identification keys for families of water beetles occurring in Rio Grande do Sul, Brazil', *Neotrop. Biol. Cons*. **1** (1), 24-28.

Bis, B. and Kosmala, G. (2005) 'Identification Cards for Freshwater Macroinvertebrates.' *Produced by the EC funded project CONFRESH226682-CP-1-2005-1-GR-COMENIUS-C21.* [online] http://www.nhmc.uoc.gr/confresh (Accessed 01 October 2013).

Bispo, P.C. and Oliveira, L.G. (2007) 'Diversity and structure of Ephemeroptera, Plecoptera and Trichoptera (Insecta) assemblages from riffles in mountain streams of Central Brazil', *Rev. Bras. Zool.* **24**, 283–293.

Calderon, M.R., Gonzalez, P., Moglia, M., Gonzales, S.O. and Jofre, M. (2014) ‘Use of multiple indicators to assess the environmental quality of urbanized aquatic surroundings in San Luis, Argentina’, *Environ. Monit. Assess,* **186** (7), 4411- 4422.

Company of Water Resources Management – COGERH. (2010) Revision of the metropolitan water catchment management plan. Phase 1: Basic studies and diagnostic. (Internal Report).

National Council for the Environment – CONAMA (2005). Resolution No 357, published in DOU No 053 of 18/03/2005, pp.58-63. [online] http://www.mma.gov.br/port/conama/res/res05/res35705.pdf. (Accessed 11 January 2013).

Cota, L., Goulart, M., Moreno, P. and Callisto, M. (2002) ‘Rapid assessment of river water quality using an adapted BMWP index: a practical tool to evaluate ecosystem health’, *Verh. Internat. Verein. Limnol.* **28**, 1-4.

Couceiro, S.R.M., Hamada, N., Ferreira, R.L.M., Forsberg, B.R. and da Silva, J.O. (2007) ‘Domestic sewage and oil spills in streams: Effects on edaphic invertebrates in flooded forest, Manaus, Amazonas, Brazil’. *Water air soil poll.* **180**, 249-259.

Cummins, K.W., Merritt, R.W. and Andrade, P.C.N. (2005) ‘The use of invertebrate functional groups to characterize ecosystem attributes in selected streams and rivers in south Brazil’. *Stud. Neotrop. Fauna Environ.* **40** (1), 69-89.

Cummins, K.W. and Merritt, R.W. (1996) ‘Ecology and distribution of aquatic insects’, in Merritt, R.W., Cummins, K.W. (Eds.), An introduction to the aquatic insects of North America. Dubuque: Kendall/Hunt. Chapter 6, pp. 74-86.

Datsenko, Y.S. (2000) ‘Study of the water quality in artificial reservoirs in Ceara – Brazil’. Fortaleza: Federal University of Ceará. (Internal Report).

Demars, B.O.L and Edwards, A.C. (2009) ‘Distribution of aquatic macrophytes in contrasting river systems: A critique of compositional-based assessment of water quality’ *Sci. Total Environ.* **407** (2), 975 - 990.

Filho, S.S.F., Piveli, R.P., Cutolo, S.A.C. and Oliveira, A.A. (2013) ‘Water treatment plant sludge disposal into stabilization ponds’, *Water Sci. Technol.* **67** (5), 1017–1025.

Findik, O. (2013) ‘Spatial and seasonal distribution of macroinvertebrates in high altitude reservoir (Beyler Reservoir, Turkey)’, *Chinese J. Oceanol. Limn.*, **31** (5), 994-1001.

Fonseca, B.M., de Mendonca-Galvao, L., Padovesi-Fonseca, C., Abreu, L.M. and Fernandes, A.C.M. (2014) 'Nutrient baselines of Cerrado low-order streams: comparing natural and impacted sites in central Brazil', *Environ. Monit. and Assess.* **186** (1), 19-33.

Fundação Cearense de Meteorologia e Recursos Hídricos – FUNCEME (2013). Portal Hidrológico do Ceara. [online] http://www.hidro.ce.gov.br. (Accessed 02 October 2013).

Freire, R.H.F. (2007) Contribution to the limnological understanding of two Brazilian semi-arid region water reservoirs that supply water to the metropolitan area of Fortaleza: Pacajus and Gaviao (Ceara, Brazil)**.** Unpublished PhD thesis, University of Sao Paulo, Sao Carlos, Brazil.

Froehlich, C.G. (2007) 'Online Guide: Identification of larvae of aquatic insects of the State of Sao Paulo – Brazil' [online] http://sites.ffclrp.usp.br/aguadoce/guiaonline (Accessed 20 August 2013).

Gheyi, H.R., Paz, V.P.S., Medeiros, S.S. and Galvao, C.O. (eds) (2012) 'Water resources in semi-arid regions of Brazil - Campina Grande, PB: National Institute for Semi-Arid, Cruz das Almas, BA: Federal University of Recôncavo da Bahia' [online] http://www.insa.gov.br/wp-content/themes/insa_theme/acervo/recursos-hidricos-II.pdf. (Accessed 15 June 2013).

Gomes, A.I., Pires, J.C.M., Figueiredo, S.A. and Boaventura, R.A.R. (2014) 'Multiple linear and principal component regressions for modelling ecotoxicity bioassay response', *Environ. Technol.* **35** (8), 945-955.

Gullan, P. J. and Cranston, P. S. (2008). *The Insects: a summary of entomology,* 3rd ed., Roca Press, Sao Paulo, Brazil.

Garcia-Davila, C.R. and Magalhaes, C. (2003) 'Taxonomic of the fresh water shrimp (Crustacea: Decapoda: Palaemonidae, Sergestidae) from the Peruvian Amazon', *Acta Amaz.* **34** (4), 663 - 686.

Hoppen, C., Portella, K.F., Joukoski, A., Trindade, E.M. and Andreoli, C.V. (2006) 'The use of centrifuged sludge from a water treatment plant (WTP) in Portland cement concrete matrices for reducing the environmental impact', *Quimica Nova* **29** (1), 79-84.

Instituto da Agua I. P. - INAG, (2008) Manual for biological assessment of water quality in river systems according to the Water Framework Directive - Protocol for sampling and analysis for the fish fauna. Ministry of Environment, Spatial Planning and Regional Development [online] http://www.apambiente.pt/dqa/assets/protocolo-de-amostragem-e-an%C3%A1lise-para-a-fauna-pisc%C3%ADcola.pdf. (Accessed 26 November 2012).

Instituto Ambiental do Paraná - IAP, 2003. Quality Assessment of Water Through Benthic macroinvertebrates - BMWP Index. Department of the Environment and Water Resources. [online] http://www.meioambiente.pr.gov.br/modules/conteudo/conteudo.php?conteudo=91. (Accessed 10 January 2013).

Jorcin, A. and Nogueira, M.G. (2008) 'Benthic macroinvertebrates in the Paranapanema reservoir cascade (southeast Brazil)', *Braz. J. Biol.* **68** (4), 1013-1024.

Junqueira, V. M. (2009) 'Preparation of the Rio Verde Grande watershed Water Resources Plan - Brazil / Water Quality Report - Contract N° 031/ANA/2008'. [online] http://www.verdegrande.cbh.gov.br/planobacia/20090519_Relatorio_Preliminar_Qualidade_Aguas_Sedimentos.pdf. (Accessed 26 November 2013).

Kannowski, P. B. (1992) Review of Aquatic Invertebrates of Alberta by Hugh F. Clifford. Great Plains Research: A Journal of Natural and Social Sciences. Paper 114. [online] http://digitalcommons.unl.edu/greatplainsresearch/114. (Accessed 10 January 2013)

Kress, N., Herut, B. and Galil, B.S. (2004) 'Sewage sludge impact on sediment quality and benthic assemblages off the Mediterranean coast of Israel - a long-term study', *Mar. Environ. Res*. **57** (3), 213–233.

Leitao, A.C., Freire, R.H.F., Rocha, O. and Santaella, S. T. (2006) 'Zooplankton community composition and abundance of two Brazilian semiarid reservoirs', *Acta Limnol. Bras.,* **18** (4), pp.451-468.

Leite, R. L. (2001) Influence of aquatic macrophytes on the water quality of reservoirs in the semiarid region of Paraiba. Unpublished Master dissertation, Federal University of Paraiba / PRODEMA. Joao Pessoa – PB, Brazil.

Leite, G.L.D. and Sa, V.G.M. (2010) Handout: Taxonomy, Nomenclature and Species Identification. Montes Claros, MG – Brazil.

Levy, G.J. (2011) 'Impact of long-term irrigation with treated wastewater on soil-structure stability-The Israeli experience', *Israel J. Plant Sci.* **59**, 95-104.

Loyola, R.G.N. (1998) Contribution to the study of benthic macroinvertebrates in tributaries of the left bank of the Itaipu Reservoir, Parana, Brazil, through combined physical-chemical, bacteriological and benthic macroinvertebrates as bioindicators. IAP. November of 1998. Curitiba. Technical Report, p.39.

National Water Council (1981) River Quality: the 1980 survey and further outlook. NWC, London, UK.

Magris, R.A. and Destro, G.F.G. (2010) 'Predictive modelling of suitable habitats for threatened marine invertebrates and implications for conservation assessment in Brazil', *Braz. J. Oceanog.* **58** (4), 57-68.

Mandaville, S. M. (2002) Benthic macroinvertebrates in freshwaters – taxa tolerance values, metrics and protocols. (Project H-1) Soil& water conservation society of Metro Halifax. p.128. [online] http://lakes.chebucto.org/H-1/tolerance.pdf. (Accessed 2 May 2014).

Monteiro, T. R.; Oliveira, L. G. and Godoy, B. S. (2008) 'Biomonitoring of water quality using benthic adaptation of the biotic index BMWP to the Meia Ponte River basin-GO', *Oecolog. Bras.* **12** (3), 553-563.

Moretti, M.S. (2004) Atlas of rapid identification of main groups of benthic macroinvertebrates. Belo Horizonte, MG. Adapted in part from: Pérez, G.R. 1988. Guide to the study of aquatic macroinvertebrates of the Department of Antioquia. University of Antioquia. Editorial Presencia Ltda. Bogota, Colombia.

Oliveira, E.M.S., Machado, S.Q. and Holanda, J.N.F. (2004) 'Characterization of waterworks waste (sludge) aiming its use in red ceramic', *Ceramica* **50**, 324-330.

Ottoni, B.M.P. (2009) *Evaluation of water quality of the Piranhas-Acu/RN river using the macroinvertebrate community.* Unpublished Master dissertation, Federal University of Rio Grande do Norte, Natal.

Palmer, C.G., Williams, M.L. and Gordon, A.K. (2003) 'Riverine macroinvertebrate responses to chlorine and chlorinated sewage effluents - Community structure in the Umsunduze and Umbilo Rivers, KwaZulu-Natal, South Africa', *Water SA,* **29** (4), 473-481.

Pamplin, P.A.Z., Almeida, T.C.M. and Rocha, O. (2006) 'Composition and distribution of benthic microinvertebrate in Americana Reservoir (SP, Brazil)', *Acta Limnol. Bras.* **18** (2), 121-132.

Pasternak, J.P., Moore, D.R.J. and Teed, R.S. (2003) 'An ecological risk assessment of inorganic chloramines in surface water', *Hum. Ecol. Risk Assess*, **9** (2), 453- 482.

Pes, A.M. O., Hamada, N. and Nessimian, J. L. (2005) ‘Identification keys to families and genera of Trichoptera (Insecta) in Central Amazonia, Brazil’, *Rev. Brasil. Entomol.*, **49** (2), 181-204.

Pinho, L.C. (2008) Diptera. In: Guide on-line: Identification of larvae of aquatic insects of the State of Sao Paulo. Froehlich, C.G. (org.). [online] http://sites.ffclrp.usp.br/aguadoce/guiaonline. (Accessed 15 Febuary 2013).

Rinaldi, S.A. (2007) *Use of benthic macroinvertebrates in the assessment of anthropogenic impact on the banks of the Jaragua State Park, Sao Paulo-Brazil***.** Unpublished Master dissertation, University of Sao Paulo, Brazil.

Roa, O., Yeber, M.C. and Venegas, W. (2012) ‘Genotoxicity and toxicity evaluations of ECF cellulose bleaching effluents using the *Allium* cepa L. Test’, *Braz. J. Biol.* **72** (3), 471-477.

Rodrigues, H.D.D. and Ferreira-Keppler, R.L. (2013) ‘Catalogue of type specimens of invertebrates in the collection of the National Research Institute of Amazonia, Manaus, Brazil’. *Zootaxa*, **3716** (2), 192-206.

Santos, J.C.N., Andrade, E.M., Neto, J.R.A., Meireles. A.C.M. and Palacio, H.A.Q. (2014) ‘Land use and trophic state dynamics in a tropical semi-arid reservoir’. *Rev. Cienc. Agron*. **45** (1), 35-44.

Segura, M.O., Valente-Neto, F. and Fonseca-Gessner, A.A. (2011) ‘Family level key to aquatic Coleoptera (Insecta) of Sao Paulo State, Brazil’, *Biota Neotrop*. **11** (1), 393-412.

Shimabukuro, E.M. and Henry, R. (2011) ‘Controlling factors and benthic macroinvertebrate distribution in a small tropical pond, lateral to the Paranapanema River (Sao Paulo, Brazil)’ *Acta Limn. Bras.* **23**, 154-163.

Smiljkov, S., Slavevska-Stamenkovic, V., Prelic, D. and Paunovic, M. (2008) ‘Distribution of benthic macroinvertebrates in Mantovo Reservoir (South-East part of the FYR Macedonia), (BALWOIS)’ [online] http://balwois.com/balwois/administration/full_paper-1181.pdf. (Accessed 25 February 2013).

Schmidt, T.S., Soucek, D.J. and Cherry, D.S. (2002) ‘Integrative assessment of benthic macroinvertebrate community impairment from metal-contaminated waters in tributaries of the upper Powell River, Virginia, USA’. *Environ. Toxicol. Chem.* **21** (10), 2233–2241.

Sonoda, K.C. (2010) Guidelines for evaluation of aquatic macroinvertebrates in river basins. Planaltina, DF: Embrapa - Brazilian Agricultural Research Corporation, branch Cerrados.

Sprague, J.B. (1985) 'Factors that modify toxicity', in Rand, G.M. & Petrocelli, S.R. (Eds.) Fundamentals of aquatic toxicology: methods and applications, Hemisphere Publishing Corporation, Washington, USA. pp.124-163.

Sterz, C., Roza-Gomes, M. F. and Rossi, E. M. (2011) 'Análise microbiológica e avaliação de macroinvertebrados bentônicos como bioindicadores da qualidade da água do Riacho Capivara, município de Mondaí, SC', *Unoesc & Ciência – ACBS*, **2** (1) 7-16.

Taniwaki, R.H. and Smith, W.S. (2011) 'Using benthic macroinvertebrates for biomonitoring the anthropic activity in the drainage basin of Itupararanga reservoir, Votorantim – SP, Brazil', *J. Health Sci. Inst.*, **29** (1), 7 – 10.

Tartari, R., Diaz-Mora, N., Modenes, A.N. and Pianaro, S.A. (2011) 'Generated sludge at water treatment station Tamandua, Foz do Iguacu, PR, as additive in red clay for ceramics. Part I: Characterization of sludge and clay Parana third plateau)', *Ceramica* **57**, 288-293.

Toniolo, V., Mattiello, I., Caetano, J.A. and Wosiack, A.C. (2001), 'Benthic macroinvertebrates as indicators of water quality impact on the Sagrado River (Coastal Basin, PR), caused by disruption of Olapa oil pipeline'. In Brazilian Congress of Limnology, Proceedings VIII. Joao Pessoa, Brazil, p. 248.

Trichkova, T., Tyufekchieva, V., Kenderov, L., Vidinoval, Y., Botev, I, Kozuharov, D., Hubenov, Z., Uzunov, Y., Stoichev, S. and Cheshmedjiev, S. (2013) 'Benthic Macroinvertebrate Diversity in Relation to Environmental Parameters, and Ecological Potential of Reservoirs, Danube River Basin, North-West Bulgaria', *Acta Zool. Bulg.*, **65** (3), 337-348.

Tundisi, J.G. (2008) 'Water Resources in the Future: Problems and Solutions', *Estudos Avancados*, **22** (63), 7-16.

Vannote, R.L., Minshall, G.W., Cummins, K.W., Sedell, J.R. and Cushing, C.E. (1980) 'The river continuum concept', *Can. J. Fish. Aquat. Sci.,* **37** 130 – 137.

Viana, L.G, Batista, D.J.M, Moura, G.C., Vasconcelos, J.F. and Silva, S.M. **(**2013), 'Use of benthic macroinvertebrates as indicators of water quality of a reservoir in the Brazilian semiarid northeast' in I International Workshop About Water in the Brazilian semiarid. Campina Grande, Brazil.

Vidal-Abarca, M.R, Sanchez-Montoya, M.M., Guerrero, C., Gomez, R., Arce, M.I., Garcia-Garcia, V. and Suarez, M.L. (2013) ‘Effects of intermittent stream flow on macroinvertebrate community composition and biological traits in a naturally saline Mediterranean stream’ *J. Arid Environ*. **99**, 28-40.

Vidal, T.F. and Capelo-Neto, J. (2014) ‘Dynamics of nitrogen and phosphorus in reservoir in the semi-arid region using mass balance’, *Rev. Bras. Eng. Agric. Ambient.* **18** (4), 402–407.

WHO (1996). Water Quality Assessments - A Guide to Use of Biota, Sediments and Water in Environmental Monitoring. Second Edition. World Health Organization, London, UK. p. 651.

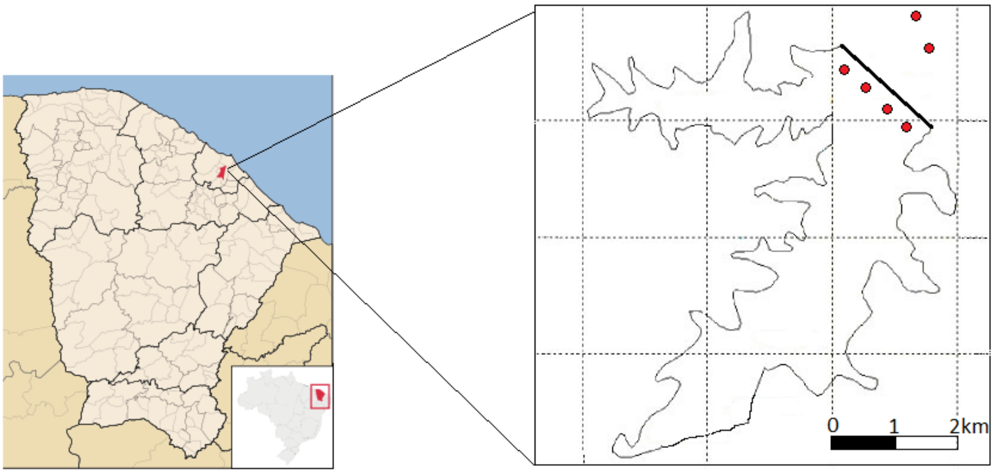

Figure 1: Geographical location of Gaviao Reservoir and sampling locations (Adapted from Abreu, 2006).

Table 1: Relationship between BMWP and water quality.

Class	Quality	Range	Significance	Color
I	Excellent	> 150	Very clear water (pristine water)	Lilac
II	Good	121 - 150	Clear water, unpolluted or system is not perceptibly altered	Dark blue
III	Acceptable	101 - 120	Very little pollution, or system is slightly altered	Light blue
IV	Questionable	61 - 100	Moderate effects of pollution are clear	Green
V	Polluted	36 - 60	Contaminated or polluted water (altered system)	Yellow
VI	Very polluted	16 - 35	Very polluted water (system is significantly altered)	Orange
VII	Extremely polluted	< 16	Extremely polluted water (system is strongly altered)	Red

Modified from IAP (2003)

Table 2: Chemical characteristics of Gaviao Reservoir raw water (RW) and sludge (SL) from the WTP from October 2012 to May 2013.

	2012						**2013**					
Parameters	October		November		December		January		February		May	
	RW	SL	RW	SL	RW	SL	RW	SL	RW	SL	RW	SL
pH	8.0	7.1	7.6	6.9	8.0	7.1	8.4	7.3	8.3	7.1	-	-
Total Hardness ($mg_{CaCO3}.L^{-1}$)	130.0	Na	155.3	Na	174.7	Na	172.8	N/a	172.8	Na	166.9	Na
Conductivity ($\mu S.cm^{-1}$)	788.8	Na	802.7	Na	832.5	Na	828.0	Na	811.9	Na	728.9	Na
Total Aluminum ($mg_{Al}.L^{-1}$)	0.03	0.22	0.04	0.42	0.04	0.08	0.02	1.08	0.02	0.71	-	-
Total Dissolved Solids ($mg.L^{-1}$)	433.8	Na	441.4	Na	457.8	Na	517.2	Na	446.5	Na	400.9	Na

Na - Not Analyzed; Ab - Absent; Ps - Present;

Table 3: Scores used for Gaviao Reservoir

Taxon	**Score**	**Pollution tolerance**
Lestidae, Libellulidae	8	Smaller tolerance
Polycentropodidae	7	
Thiaridae, Palaemonidae, Ancylidae,	6	
Noteridae*	5	
Caenidae, Baetidae, Stratiomyidae, Hydracarina (Pionidae, Mideopsidae, Arrenuridae)	4	
Gerridae, Mesoveliidae, Notonectidae, Corixidae, Glossiphonidae, Physidae, Planorbidae, Hydrobiidae, Ampullariidae**	3	
Chironomidae	2	Higher tolerance

Adapted from Alba-Tercedor and Sanchez-Ortega (1988) and Alba-Tercedor (1996, 2000). *Junqueira (2009) ** Miller (2008).

Table 4: Analysis of macroinvertebrates of Gaviao Reservoir from October 2012 to May 2013.

Taxa (feeding groups)	**Frequency**	**Oct/12**	**Nov/12**	**Dec/12**	**Jan/13**	**Feb/13**	**May/13**
TURBELLARIA							
Specimen 1 **(1)**	f	+	--	--	--	--	+
ANNELIDA							
Glossiphoniidae **(4)**	ff	--	--	--	--	--	+
GASTROPODA							
Ampullaridae **(5)**	F	+	--	+	+	--	++
Thiaridae **(5)**	FF	+++	++++	+++	+++	++	+++
Ancylidae **(5)**	FF	+	+	+	+	+	+
Physidae **(5)**	ff	--	--	--	--	+	--
Planorbidae **(5)**	FF	++++	++++	++++	++++	+++	++++
Hydrobiidae (5)	FF	+	+	+	+++	++++	++
HYDRACARINA							
Mideopsidae **(4)**	f	--	+	--	--	+	--
Arrenuridae **(4)**	f	+	--	--	+	+	--
Pionidae **(4)**	ff	--	--	--	--	+	--
DECAPODA							
Palaemonidae **(4)**	F	--	+++	++	+	+	--
ISOPODA							
Specimen 1 **(1,2)**	f	--	--	--	+	+	+
ODONATA							
Lestidae **(4)**	FF	+	+++	++	+	+	+
Libellulidae **(4)**	F	--	+	++	+	--	+
HEMIPTERA							
Corixidae **(4)**	F	+	+	++	+	+	--
Notonectidae **(4)**	F	+	--	+	+	+	--
Mesoveliidae **(4)**	f	+	--	++	--	+	--
Gerridae **(4)**	f	--	--	+	--	+	+
COLEOPTERA							
Noteridae **(4)**	ff	+	--	--	--	--	--
TRICHOPTERA							
Polycentropodidae **(1,2,4)**	f	--	--	--	+	+	++
DIPTERA							

Chironomidae **(1,2,4,5)**	FF	+	+	+	+++	++	+++
Stratiomyidae **(1)**	f	+	--	--	--	+	--
EPHEMEROPTERA							
Baetidae **(1,5)**	f	--	--	--	+	+	--
Caenidae **(1)**	ff	+	--	--	--	--	--

According to feeding mode: (1) gathering collectors; (2) filtering collectors; (3) shredders; (4) predators; (5) scrapers. According to dominance [+++++ (Eudominant - over 60% relative abundance); ++++ (Dominant - from 25 to 59% relative abundance); +++ (Almost Dominant - from 10 to 24% relative abundance); ++ (Not very dominant - from 5 to 9% relative abundance); + (Not dominant - less than 5% relative abundance]; and according to frequency [FF (when the taxon was recorded throughout the entire period of study); F (when the taxon was recorded in at least 4 months during the study); f (when the taxon was recorded for a period of less than four months); ff (when the taxon was recorded in only one month throughout the study)].

Table 7: BMWP' scores for the Gaviao Reservoir, from October 2012 to May 2013.

Month	Taxa number	BMWP'	Class	Quality	Significance	Color
Oct/12	16	63	IV	Questionable	Moderate effects of pollution are clear	green
Nov/12	10	49	V	Polluted	Contaminated or polluted water	yellow
Dec/12	13	57	V	Polluted	Contaminated or polluted water	yellow
Jan/13	15	66	IV	Questionable	Moderate effects of pollution are clear	green
Feb/13	19	76	IV	Questionable	Moderate effects of pollution are clear	green
May/13	13	52	V	Polluted	Contaminated or polluted water	yellow

Table 8: ASPT scores for the Gaviao Reservoir, from October 2012 to May 2013.

Month	ASPT	Quality
Oct/12	3.9	Severe pollution
Nov/12	4.9	Moderate pollution
Dec/12	4.3	Moderate pollution
Jan/13	4.4	Moderate pollution
Feb/13	4	Moderate pollution
May/13	4	Moderate pollution