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The use of Risk Incidence and Diversity Indices to evaluate water quality of semi-arid reservoirs

Evaldo de Lira Azevêdo[a,*], Carlinda Raílly Medeiros[b], Wilma Izabelly Ananias Gomes[c], Daniele Jovem da Silva Azevêdo[d], Rômulo Romeu Nóbrega Alves[a,e], Thelma Lúcia Pereira Dias[a,e], Joseline Molozzi[c,e]

[a] Universidade Federal Rural de Pernambuco – UFRPE, Programa de Pós-Graduação em Etnobiologia e Conservação da Natureza, Rua Dom Manoel de Medeiros, s/n, Dois Irmãos, Recife, PE CEP: 52171-900, Brazil
[b] Universidade Federal do Pará – UFPA, Programa de Pós-Graduação em Ecologia, ICB, Rua Augusto Corrêa, 01, Bairro Guamá, Belém, PA CEP: 66075-110, Brazil
[c] Universidade Estadual da Paraíba – UEPB, Programa de Pós-Graduação em Ciência e Tecnologia Ambiental, Rua Juvêncio Arruda, s/n, Bairro Universitário, Bodocongó, Campina Grande, PB CEP: 58429-600, Brazil
[d] Universidade Federal de Minas Gerais – UFMG, Programa de Pós-graduação em Ecologia Conservação e Manejo da Vida Silvestre, ICB, Av. Pres. Antônio Carlos, 6627, Pampulha, Belo Horizonte, MG CEP: 31270-901, Brazil
[e] Universidade Estadual da Paraíba – UEPB, Programa de Pós-graduação em Ecologia e Conservação, CCBS, Rua das Baraúnas, 351, Bairro Universitário, Bodocongó, Campina Grande, PB CEP: 58429-500, Brazil

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ABSTRACT

Local ecological knowledge of water quality indicators can be an important element in the management and conservation of aquatic ecosystems from a biocultural conservation perspective. We investigated the ecological indicators of water quality used by local communities that live around reservoirs in the semi-arid region of Brazil to compare their Risk Incidence Indices with their Diversity Indices. This research was undertaken at four reservoirs, and interviewed 126 members of human communities, using a semi-structured format. The macrobenthic fauna was sampled at 332 sites within the reservoirs for the bio-indicator analyses. Among the ecological indicators of water quality cited by the interviewees, the most notable were water color and odor. When the Risk Incidence Index was high, the Biodiversity Index was found to be low. Larger proportions of Oligochaete occurred in reservoirs with low biological diversity, indicating that local ecological knowledge reflected reservoir water quality. Our studies showed that local ecological knowledge of water quality indicators, in conjunction with traditional indicators such as the macrobenthic fauna, can be used for biocultural conservation purposes.

1. Introduction

Water supplies in the semi-arid region of Brazil largely depend on surface water accumulated in reservoirs (Araújo, 2003). These artificial ecosystems are essential for the social and economic development of the region and are integral to local historical and cultural contexts (Robock, 2011; Lima et al., 2012). Rural communities living around reservoirs generally use that water directly, without any purification process before consumption (World Health Organization and UNICEF, 2015), but invariably develop some form of local ecological knowledge (LEK) to judge water quality.

Local ecological knowledge corresponds to the accumulated knowledge of a specific group of people about a local ecosystem, and represents a fundamental link between social and ecological systems (Olsson and Folke, 2001; Eufracio-Torres et al., 2016; Silva-Junior and Santos, 2017). Understanding this local knowledge is viewed as increasingly important in a new field of conservation – biocultural conservation. Biocultural conservation advocates biological conservation, but emphasizes the insertion of local knowledge, innovations, and practices into bottom-up management systems (Gavin et al., 2015). LEK can help our understanding of the positions taken by local communities in relation to their water resources – a perspective foreseen in the Convention on Biological Diversity (CBD, 1992).

Understanding local ecological knowledge of water quality indicators in hydrographic basins can aid in the management and conservation of those that resource, optimize the work of scientists and managers by furnishing new and valuable information from local communities (Cvitanovic et al., 2016), and encourage the implementation of biocultural conservation approaches (Gavin et al., 2015).

* Corresponding author.
E-mail addresses: evaldoazevedo@yahoo.com.br, evaldo.azevedo@ifce.edu.br (E.d.L. Azevêdo).

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Studies have shown that the main indicators used by human communities to assess water quality are color (David, 1971; Moser, 1984; House and Sangster, 1991; Smith et al., 1995; Cottet et al., 2013; West et al., 2015) and odor (Nare et al., 2006; West et al., 2015). These studies have demonstrated that the organoleptic properties of water are fundamental to the evaluation of their quality by resource users (Espinosa-García et al., 2015). Studies have shown that human communities use biological indicators such as changes in assemblages of aquatic organisms (including the death of fish) to assess water quality (Nicolson and Mace, 1975; Hallwass et al., 2013).

Perception is a phenomenon that involves exposure to stimuli as well as environment familiarity that can be interpreted cognitively (Ingold 2000; Spinosa-Gacía et al., 2014, Albuquerque et al., 2014; West et al., 2015). An individual's exposure to risk situations develop what is called risk perception (Jakus et al., 2009; Albuquerque et al., 2014; Rambonilaza et al., 2016). Perceptions of that sort about water resources can directly affect water use, and can also be associated with socioeconomic factors (Artell et al., 2013). Afroz et al. (2015), for example, evaluated water pollution risk perceptions among Malaysian families, and observed that factors such as gender, age, and educational level influenced each individual's perception of water quality. Although requiring qualitative assessments, risk perceptions can be quantified by calculating the Risk Incidence Index (*Ij*) (Albuquerque et al., 2014). Although simple, the Risk Incidence Index (*Ij*) calculation (Albuquerque et al., 2014) may be important for an exploratory analysis and identification of local risks. However, there are other approaches that can be employed, as development of models for assist of decision makers (Li et al., 2016; Li et al., 2017; Chen et al., 2017). In addition to understanding local ecological knowledge in terms of indicators of water quality and applying Risk Incidence Indices, it is also important to investigate how these elements actually reflect water quality in local ecosystems. To that end, a combination of water quality assessment methodologies should be employed. Traditionally water quality assessment is performed through chemical and physical analyzes (e.g. transparency, temperature, oxygen concentration, and nutrient concentrations) (Goulart and Callisto, 2003) or through the analysis of bioindicators such as aquatic macrophytes (Faria et al., 2013; Farnese et al., 2014; Gonçalves et al., 2015), phytoplankton (Vilhena et al., 2014; Schuster et al., 2015), zooplankton (Sousa et al., 2008; Perbiche-Neves et al., 2013; Azevêdo et al., 2015a,b), fish (Sarpedonti et al., 2013; Osório et al., 2014; Steffens et al., 2015), and the macrobenthic fauna (Pereira et al., 2012; Molozzi et al., 2013; Uherek and Gouveia 2014; Azevêdo et al., 2015a,b; Melo et al., 2015).

The macrobenthic fauna has been widely used in bio-monitoring. Those organisms comprise several taxonomic groups, with Oligochaeta, Mollusca, and Diptera predominating in Brazilian reservoirs (Pamplin et al., 2006; Molozzi et al., 2013; Azevêdo et al., 2017). Changes in structural aspects and the distributions of their biological communities reflect long-term environmental changes (Morgan et al., 2006; Macedo et al., 2014; Martins et al., 2015) and differ from physical and chemical water assessments (which have greater potential for diagnosing short-term changes) (Goulart and Callisto, 2003).

Within that context, we investigated the indicators of water quality degradation used by local communities living in around reservoirs in the semi-arid region of Brazil, and investigated whether their perceptions of those indicators are related to socioeconomic characteristics. Evaluated whether there are differences in local knowledge between different communities. Moreover, we also applied the Risk Incidence Index and the Biological Diversity Index to relate risk perceptions to macrobenthic fauna. Our work was guided by the hypotheses: 1 – The main local ecological indicators of reservoir water quality are the colors and the odors of the water and the macrobenthic fauna composition; 2 – Local ecological knowledge is correlated with socioeconomic variables (gender, age, activity, income, educational level, and time of residence around the reservoir); 3 – There are differences in local ecological knowledge about water quality indicators among human communities; and, 4 – The highest Risk Incidence Index values occur in communities where local reservoirs have the lowest Biodiversity Index.

2. Materials and methods

2.1. Study area

The study sites were located in the semi-arid region of northeastern Brazil (Pereira-Junior, 2007), which has a marked overall annual water deficit and has recently been experiencing since 2012 one of the most severe droughts in the last 50 years (World Meteorological Organization (WMO): WMO statement on the status of the global climate in, 2013). The region has mean annual temperatures above 20 °C, with annual precipitation varying between 280 and 800 mm. Evapotranspiration is greater than precipitation, with rainfall being extremely variable, but usually concentrated in three or four months of the year (Araújo, 2011; Alvares et al., 2013). These conditions make reservoirs essential for the establishment and persistence of human life in the region.

The present study was developed in two Brazilian states (Rio Grande do Norte and Paraíba), evaluating local communities and reservoirs in two municipalities in each state: the Sumé (7°40′14.86″S, 36°54′25.57″W, municipality of Sumé) and Poções (7°53′33.20″S; 37°00′31.54″W, municipality of Monteiro) reservoirs were studied in Paraíba State, focusing on the local communities living around them, both situated in the Paraíba river watershed; the Traíras (6°30′52.99″S, 36°55′58.50″W, municipality of São José do Seridó) and Sabugí (6°39′10.79″S; 37°12′20.55″W, municipality of São João do Sabugí) reservoirs, in Rio Grande do Norte state, as well as the local communities around them, are both located in the Piranhas-Assú river watershed (Fig. 1).

2.2. Design and ethnobiological data collection

Ethnobiology approach seeks to know and understand the perceptions, knowledge and concept that a given human group shows on the nature (Posey, 1987; Albuquerque et al., 2014). In our study, we evaluated the water quality indicators that are used by local communities living in around reservoirs. Therefore, we selected four reservoirs, being two with better environmental quality (Sabugí and Sumé) than the others (Traíras and Poções) (Fig. 2).

The residences about 200 m from the margin of the reservoirs (considering the highest volume of the reservoirs, although during the study period the reservoirs has showed low volume) were previously selected using satellite images. The choice of those interviewees was based on the greater probability of their maintaining contact with the reservoir because they lived quite around it. All the residences that had residents were visited. The interviews always were performed with a householder (female or male). The ethnobiological data was collected in September and October/2015. A semi-structured form was developed for the interviews to collect socio-economic data (e.g. gender, age, educational attainment, occupation, income, and residence time in local) and information about the perceptions of the local community of water quality indicators. A total of 126 people were interviewed: 22 in the community around the Sumé reservoir, 38 in Poções, 31 in Traíras, and 35 in Sabugí.

The objectives of the study were explained to the participants before each interview, and their permission was obtained for recording their information by signing a Free and Informed Consent Term, according to Resolution 466/2012 of the Brazilian National Health Council. Ethical approval for the study was obtained from the Ethics Committee of the State University of Paraíba – UEPB (Approval NO 1.030.872).

Of the individuals interviewed, 64.3% ($n = 81$) were males and 35.7% ($n = 45$) females, ranging in age from 18 to 82 years (51.1 ± 14.14); 24.6% ($n = 31$) of the interviewees were illiterate, 3.2% ($n = 4$) had completed their elementary education, 60.3% ($n = 76$) had not completed their elementary education, 3.2% ($n = 4$)