Original research

ETHNOBIOLOGY AND CONSERVATION

Local ecological knowledge as a complementary basis for the management of water resources

Jessé Renan Scapini Sobczak[1], Alice Teresa Valduga[2], Rozane Maria Restello[2], Rafael Imlau Cardoso[2], Luiz Ubiratan Hepp[2] and André Boccasius Siqueira[1]

[1]Department of Biological Sciences and Zootechny, Federal University of Santa Maria, Palmeira das Missões Campus, Independência Avenue, 3751, Vista Alegre, Palmeira das Missões, RS, 98300-000, Brazil.
[2]Department of Biological Sciences, Regional University Integrated of Alto Uruguai e das Missões, 99700-000, Erechim Campus, Brazil.
E-mail addresses: JRSS (jesserenan@yahoo.com.br), ATV (valice@uri.com.br), RMR (rrozane@uri.com.br), RIC (rafael.i.cardoso@hotmail.com), LUH (lhepp@uricer.edu.br), ABS (aboccasius@ufsm.br).

Ethnobiology and Conservation 2013, 2:10 (03 November 2013)
ISSN 2238-4782

ethnobioconservation.com

Abstract

Public participation in the management of water resources is gradually being incorporated into environmental monitoring programs. However, effective performance depends on the applicability of the methods and on the scope of public enrollment because of the complexity of the local ecological knowledge (LEK) acquired to support the process. This study aimed to evaluate the relationship between LEK and scientific knowledge (SK), with an emphasis on water quality. Social and natural science methods were used. The study involved a conservation unit (CU) located in the Alto Uruguai region of southern Brazil and consisted of two stages: (i) interviews using a socio-environmental diagnosis of the community surrounding the CU and (ii) the collection of benthic macroinvertebrates at sampling sites located within and outside the CU. The study hypothesis that LEK could predict water quality was not confirmed ($r = 0.19$; $p = 0.07$). However, the data suggested that LEK might tend to act as an indicator of environmental quality. Although, the relationship between LEK and SK was not completely specified, the study identified several features associated with water quality. This result provided a preliminary approach to the understanding of water quality. We suggest that future studies include additional variables potentially related to water quality and that such studies also incorporate temporal perspectives. The addition of LEK to SK can, indeed, furnish a more complete understanding of the management and conservation of a natural system.

Keywords: *Biological variables - Ethnolimnology - Environmental conservation - Participatory monitoring.*

Introduction

In the past decade, there has been an increasing and explicit academic interest in the role of local ecological knowledge (LEK) in the science and governance of environmental systems, particularly in ecology (Alves 2008; Johannes et al. 2000; Laborde et al. 2012a). The formal inclusion of LEK may improve environmental scientific research in at least two dimensions (Calheiros et al. 2000): first, the policy recommendations resulting from such research are more likely to be accurate, recognized and implemented by local people who have 'bought in' to the research process; secondly, local people may derive a sense of personal and community pride from helping interested and educated outsiders with their research. *Perception indicators may therefore, according to Webb (2004), represent a crucial tool for evaluation, given the widespread lack of quantitative data in many biologically important regions.* This could contribute through the formation of groups of voluntary environmental agents in the communities and may be incorporated into official programs (Firehock and West 1995; Fore et al. 2001; Buss 2008).

Meanings related to particular locations emerge from this process, particularly in relation to aquatic systems (Strang 2004; Toussaint 2008). The engagement of local communities has also been identified as a key component of 'adaptive management' for water resources and beyond (Pahl-Wostl et al. 2007; Huitema et al. 2009), a complementary approach to integrated management that emphasizes continuous learning and experimentation between and among scientists, managers, and communities to better address the complexity and uncertainty inherent in social–ecological systems (Tompkins and Adger 2004). The field of human ecology studies the relationships between people and their environment and normally involves conservation units (CUs) in which the people reside or that affect the people in various ways. The majority of CUs were created without considering aquatic environments; however, they are capable of protecting a considerable number of water bodies and are therefore of great importance for aquatic species (Agostinho et al. 2005; Abell et al. 2007).

According to Bensusan (2006), if improper use of land and natural resources continues outside protected areas, the future of the CUs will be threatened. Among the aquatic organisms that have suffered as a result of intense habitat degradation, benthic macroinvertebrate assemblages have been frequently studied due to their importance in the flow of energy and nutrient cycling in freshwater ecosystems. These assemblages are highly useful indicators of environmental quality (Rosenberg and Resh 1993; Moretti et al. 2007; Trevisan and Hepp 2007; Melo 2009). Assessing and considering the perspectives of all groups affected by a management decision, including citizens who perceive meanings for a particular place (thereby 'stakeholders' in any decision affecting that place), have been encouraged by water management frameworks in the past two to three decades through the implementation of participatory processes under the general framework of 'integrated management' (United Nations 1992; European Union 2000; Creighton 2005).

Davis and Wagner (2003) argue that LEK can be translated, practically and fundamentally, into alternative approaches to the relationships with and management of naturally occurring resources. It can be argued that these approaches would necessarily be much more sensitive to and inclusive of LEK, thereby embodying local practices, concerns, priorities and sensibilities. These approaches would also serve to provide peoples and communities with a much greater capacity to self-direct and self-manage, thereby empowering them through the provision of control over core factors in their lives and livelihoods. These practices are related to the ways in which people manage the environment itself and the engagement of the people influences these practices. *The users of these resources view the environment in different ways, and their actions are based on their perceptions, experiences and knowledge* (Blakie 1995).

According to Laborde et al. (2012b), studies that attempt to apply LEK to resource management remain scarce because LEK is (i) generally qualitative, requiring social science methods to be accessed and interpreted and, (ii) because there is no way to quantify the uncertainty of information obtained through LEK, making it difficult to integrate this information with a natural science framework. To address the issue of the quantification of the uncertainty of LEK information, the present study is part of an effort to meet the demands of environmental and governmental agencies for monitoring approaches and for the development of evaluation methods for the management of water resources. The researchers must abandon their preconceptions, must hear and understand what the interlocutor is saying, must not make translation errors and must not treat preliminary analyses as if they were conclusive (Siqueira 2012a).

In addition, Albuquerque (2013) comments that *we must advance not only the incorporation of theory into our work, but must also evaluate the quality and appropriateness of the methods we use*. In limnological research, changes are necessary to allow the discipline to become a science that is also focused on the application of results to the recovery, sustainable use and preservation of continental aquatic ecosystems (Esteves 2005). For this purpose, we hypothesized that LEK can predict and complement SK, i.e., LEK can guide the process of scientific inquiry. To this end, the aim of this study was to evaluate the relationship between LEK and SK, with an emphasis on water quality, using a socio-environmental diagnosis of a community in the area surrounding a CU.

Materials and methods

Study area

This study was conducted in the northern region of the state of Rio Grande do Sul (southern Brazil), in the Mata do Rio Uruguai Teixeira Soares Municipal Natural Park (PTS) (Figure 1). The area of the park is 429.65 ha. The annual average precipitation is 1,708 mm (Restello and Penteado-Dias 2006). The PTS is the first area established to protect biodiversity in the Alto Uruguai region and is one of the noteworthy fragments of the remaining araucaria rain Forest (Oliveira-Filho et al. 2006). Given this background, the location was selected for study because a human settlement in the area was available for research. The villages surrounding the PTS are Nossa Senhora da Saúde, São Caetano and Teixeira Soares or Esperança (Figure 1).

In the study region, agricultural areas are located west of the Teixeira Soares river in the vicinity of the villages of Nossa Senhora da Saúde and Teixeira Soares. However, note that a substantial number of pensioners reside in these areas. This characteristic is related to the population exodus that agricultural zones are experiencing to the detriment of local and regional urban centers (Socioambental 2001). The research was conducted in march and october 2009 and, involved two stages. The first stage was to analyze the LEK of the communities surrounding the PTS, whereas the second was to evaluate the water quality within and outside the PTS.

Figure 1. Localization and distribution of sampling sites and surrounding communities for the current study of the Mata do Rio Uruguai Teixeira Soares Municipal Natural Park (PTS).

Local ecological knowledge: data collection

The present research was designed to elicit information from the residents of the study area. The modeling framework used in the research involved a two-stage approach consisting of model formation and testing (Figure 2). The first stage involved an interactive process of definition and redefinition of variables based on the results of structured interviews, whereas the second stage involved adjustments to the model following the interviews and the insights that resulted from the interviews. The principle behind this approach is that people understand their own circumstances better than researchers from outside the area (Gladwin 1989).

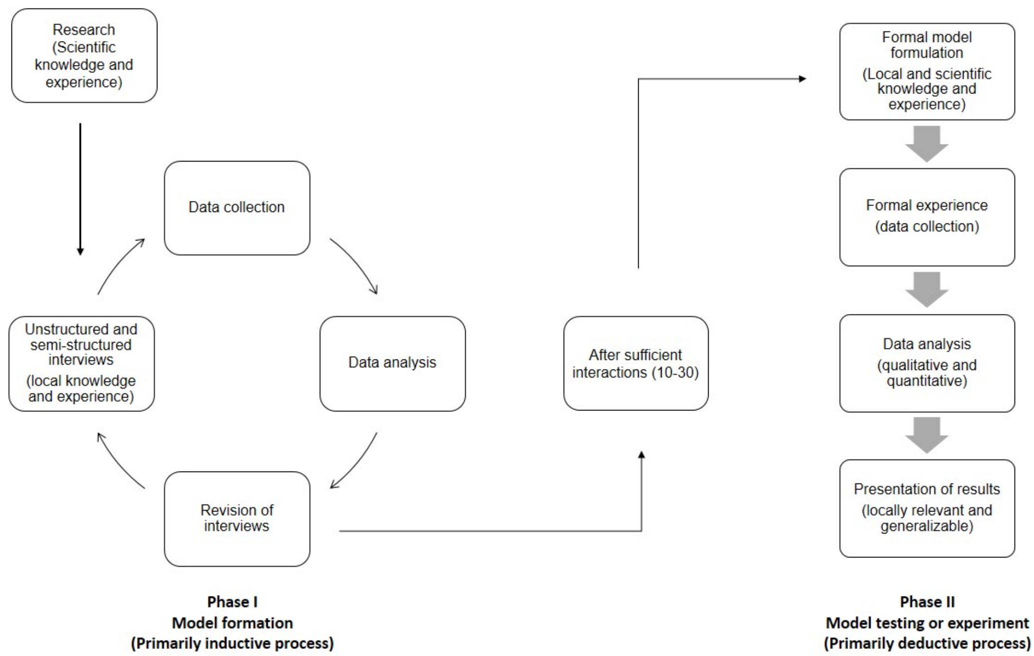

Figure 2. Research methodology combining local ecological and scientific knowledge, adopted from Calheiros et al. (2000).

Initial visits to the study area were made, and, a draft questionnaire was tested in a pilot study. Laborde et al. (2012b) consider such a prior approach a key element of studies that aim to integrate LEK and SK. Accordingly, following adjustments to the questionnaire, data were collected from residents belonging to the Neighbour's Association of the PTS (NAPTS). The ages of the residents ranged from 52 to 80 years. A member of each family was interviewed, resulting in a total of 12 questionnaires. Each questionnaire included ten questions (Table 2). Gladwin (1989) states that research of this type requires a minimum of ten interviews. In fact, the present study included 12 head-of-household oral interviews. These interviews represented 100% of the member families of the NAPTS.

At the time of the interview, the questionnaires were given to the family member(s), who had the option of choosing the respondent. Davis and Wager (2003) have discussed a highly problematic aspect of LEK documentation to date, namely, the lack of attention to methodology. The identification and selection of local knowledge "experts" is an issue of particular concern.

Water quality

Benthic macroinvertebrates were collected in the spring (October/2009) at six sites in the hydrographic basin from stone substrates in second- and third-order streams with a Surber sampler (0.1 m² area and 250 µm mesh net). At each sampling site, two pseudo-replicates were collected, totaling 0.2 m² in area for the site. The sites were located within the PTS and in the area surrounding it (Table 1). The collected biological material was fixed *in loco* with 80% alcohol, taken to the laboratory and washed in 2.0, 0.5 and 0.25 mm mesh sieves. Organisms were identified at the lowest possible taxonomic level using the identification guidelines of Merritt and Cummins (1996), Fernandez and Domingues (2001) and Costa et al. (2006). According to Melo (2005), Corbi and Trivinho-Strixino (2006) and Buss and Vitorino (2010), *family-level identifications of benthic macroinvertebrates for biomonitoring purposes do not compromise the results*. The identified material was deposited in the Collection of Benthic Invertebrates at the Museum of Alto Uruguai, Regional University Integrated of Alto Uruguai e das Missões (URI).

Table 1. Characterization of the sampling sites located inside and outside in the Mata do Rio Uruguai Teixeira Soares Municipal Natural Park.

Sampling sites	**Lat/long**		**Rivers**	**Altitude (m)**	**Width (m)**	**Depth (m)**
p1	-27°29’54.4’’	-51°57’00.9’’	Teixeira Soares	398	4	0.07
p2	-27°30’32.4’’	-51°57’17.4’’	Quinto	414	3.5	0.08
p3	-27°29’42.3’’	-51°56’22.8’’	São Caetano	392	1.5	0.05
p4	-27°30’36.7’’	-51°56’16.1’’	São Caetano	619	0.9	0.09
p5	-27°30’05.6’’	-51°55’34.6’’	Esperança	621	2	0.11
p6	-27°29’36.4’’	-51°55’21.9’’	Esperança	431	2.2	0.13

Data analysis

Several techniques can be used for gathering both qualitative and quantitative LEK data, such as conversations with informants (Silvano et al 2008), guided tours (Huntington 1998), semi-directive interviews (Marques 1991) and, standardized structured questionnaires containing previously defined questions (Johannes 1993; Silvano 2004). There is not an ideal one as the best approach depends ultimately on the goals of each study (Huntington, 2000). This way, the choice according to aim was to analyze the LEK of the community by standardized structured questionnaires (see Table 2). In the present study, the LEK of the community was analyzed by standardized structured questionnaires (Table 2). In addition, a biological index was used to evaluate the water quality (Biological Monitoring Working Party Index- BMWP) from the identified fauna. The BMWP index is based on 1-10 scores for each family based on their sensitivity/tolerance to anthropogenic impacts. The water quality is based on the sum of scores of all families at a site, and a table is used to determine the water quality of the site (Mandaville 2002). Note that this instrument was originally designed for use in Europe. The characteristics of the Alto Uruguai region (southern Brazil) differ from those of the European sites for which the instrument was originally designed. However, many studies have used this tool with satisfactory results (Junqueira et al. 2000; Konig et al. 2008; Monteiro et al. 2008; Roche et al. 2010).

The relationship between LEK and water quality (benthic macroinvertebrate composition) was assessed with a Mantel test (Legendre and Legendre 1998; Manly 2008). The data matrix representing the knowledge of the residents was constructed based on categories that were related relatively closely to the topic of water resources (Table 2). The test was based on 10,000 permutations (Jackson and Sonners 1989). The analysis was performed using the ‘vegan’ package of the R statistical system (Oksanen et al. 2009; R Development Core Team 2009). The Mantel test consists of calculating a correlation between two distance matrices. This calculation is followed by a randomization procedure or the use of a parametric approximation to evaluate whether the observed correlation differs from a random expectation (Jackson and Sonners 1989; Manly 2008; Bini 2004). This analysis is interesting and appropriate for this purpose because any type of data can be used to construct association matrices (e.g., continuous, ordinal or binary data) (Peres-Neto and Jackson 2001).

Results

Local ecological knowledge: arrangement of questionnaires

At the time of the survey, 12 residents were available and agreed to participate in the study. These individuals can be considered key players due to their influence on river health and the ecological integrity of the watershed. Our sample appears quantitatively sufficient because it includes the entire study population (deterministic approach). In general, the inhabitants felt committed to and responsible for environmental protection according to the answers shown by variables 1, 6 and 8 (Table 2). Three of the variables (3, 5 and 9) elicited responses that varied among the interviewees.

Table 2. Answers of the interviewed residents (%) to the questionnaire items related to water quality.

Variables	Yes	No
1. I see the importance in keeping the vegetation (riparian zone).	75	25
2. I perceive a change in the water quantity of the water bodies/rivers.	75	25
3. I perceive a change in the water quality of the water bodies/rivers.	50	50
4. The dry spell has been aggravated.	83	17
5. The dry spell is a natural phenomenon.	50	50
6. The septic tank is the final destination of the sewer.	83	17
7. I participate in Environmental Education events.	75	25
8. I would like to learn more about water and/or related subjects.	83	17
9. I use water bodies/rivers for animals drink.	58	42
10. I prefer the time before the Park.	67	33

Water quality

During the study, a total of 1,362 organisms were identified. Chironomidae was the most abundant family. According to the BMWP index, the water quality was good or very good at five sites (Figure 3).

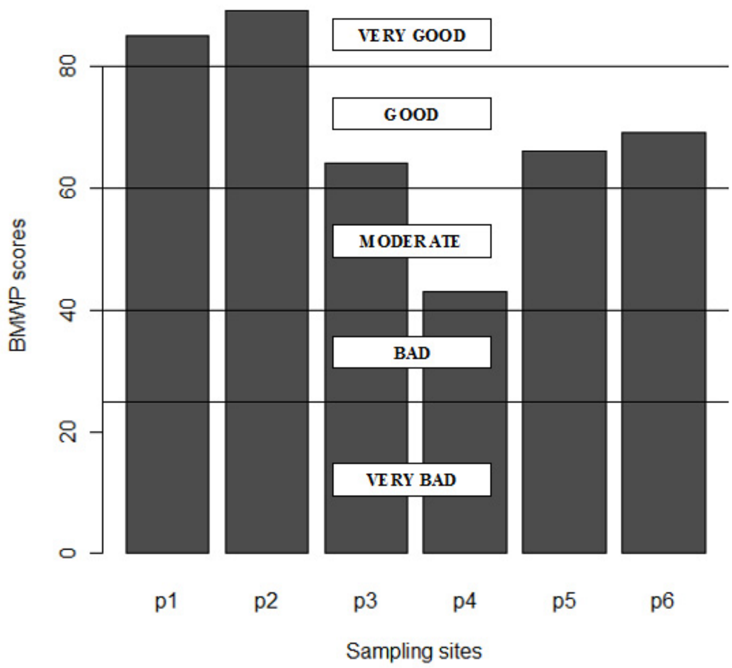

Figure 3. BMWP values for sampling sites located within and outside the Mata do Rio Uruguai Teixeira Soares Municipal Natural Park.

Local ecological knowledge and scientific knowledge: a possible approach?

The inhabitants' knowledge was integrated with the conditions during the period of the study and with the benthic macroinvertebrate composition to construct a biotic matrix to correlate the answers of the interviewees. The Mantel test revealed a positive correlation (r= 0.19; p= 0.07).

Discussion

The results of the Mantel test showed that the knowledge of those interviewed was not a statistically significant reflection of the water quality found at the sampling sites. Although the hypothesis was not confirmed, the positive correlation indicated a trend in the expected direction. *Water quality is a social construct* (World Resources Institute 2001) in which the LEK of the individuals is based on the relationship established with the environment over time. In ethnolimnology, knowledge is difficult to quantify because it may not be an accurate reflection of reality or, as science perceives the process, does not emphasize the interactions between humans and the environment; people living in communities that are highly concerned about water quality are less likely to agree strongly about this issue (Gartin et al. 2010).

The analysis of the separate variables showed that *Perceived change in the water quality of the rivers* and *the dry spell is a natural phenomenon* (Table 2) resulted in disparate answers. We may argue that the observations of the present study reflect the spatial and environmental heterogeneity of the inhabitants. These variables are closer than others in terms of water quality and quantity perception, respectively, and these characteristics contributed to the final result (Mantel test). Franca (2006) has commented that maintaining the qualitative and quantitative recovery of the water sources is strongly conditional on people's social conscience relative to the environmental benefits generated by protected ecosystems. The same author has noted that the residents who use water from the rivers are more strongly dependent on this resource, are more inclined to be in contact with the environment and are therefore capable of recognizing negative environmental effects.

According to previous studies, the improvement in the integrity of water bodies located inside of CUs relative to water bodies on the margins is evident and is effective for facilitating the preservation and biodiversity of lotic ecosystems (Agostinho et al. 2004; Takeda et al. 2004; Train and Rodrigues 2004; Paz et al. 2008). *The lack of participation of any social actor, especially the ones that are more affected by environmental problems, reduce and simplify the reality and the complexity of environmental problems, allowing only partial interventions* (Buss 2006). The authors of this previous study have suggested that involvement in specific regulatory practices, which are focused on the substantial participation of the interested parties, could increase concern (interest) for the environment because participation in environmental politics is a significant determining factor in the environmental perception of water pollution. Participation may represent and further enable interactions between forces that complement and antagonize a community.

Nevertheless, ethnographic studies rescue local knowledge from a portion of the population that has direct or indirect contact with the environment (Siqueira 2012b), as reported in the present study. The environmental and social profiles of the inhabitants suggest that they are highly capable of acting to favor the conservation of the environment on both a medium-term and a long-term basis. This scenario requires educational intervention so that inhabitants contribute to the maintenance of all aspects of biodiversity, e.g., the delicate relationship between the environment and the socioeconomic and cultural historical context of the region.

The primary function of the strategy of including public participation in the process of environmental management while contributing to the autonomy and citizenship of those who live next to these areas (environmental monitoring) has the advantage that the local inhabitants use scientific monitoring tools to track the changes in the environmental conditions and also become active citizens in the process. The perception of the inhabitants, in this case, does not have a specific mechanism by which it represents the environmental conditions of the site. In contrast, variables related to water quality are used to understand the environmental conditions. Moreover, previous studies have shown that the duration of engagement with the process and the public's pro-environment perceptions have the strongest relationship to the issue of water pollution (Gelcich et al. 2008) and that the addition of LEK to SK provides a more complete understanding of the management and conservation of a natural system (Calheiros et al. 2000).

This study demonstrates that the decentralization of power helps to support the management of water resources by minimizing time and costs and improving the quality of life. The increasing importance of ethnolimnology is confirmed by its use as a tool for environmental conservation by directly associating economic, cultural, biological and social issues (Souto and Alves 1999; Luna 2008). According to Silvano et al. (2005), LEK is a key element in determining strategies for conserving natural resources. Although the understanding of the connection between LEK and SK is incomplete, progress has been made in identifying the features of LEK associated with water quality. These results offer a preliminary approach to understanding the connection between LEK and SK. We suggest that future studies include additional variables potentially related to water quality and that such studies also incorporate temporal perspectives.The proposed methods can be incorporated in conservation efforts and/or used in ways that differ from alternative approaches to similar issues, contributing to better engagement of the complex collaboration between LEK and SK and to comprehensive quantitative data collection.

Acknowledgments

We thank all of the inhabitants for their contribution to this research, and we thank Daniel Buss (FIOCRUZ-RJ) for useful comments on an early version of this article. The first author also acknowledges to Cristiane Biasi (UFSM), Raquel Fetter (UnB) and Paula Miotto (IFRS) by providing support for field work. Luiz U. Hepp received financial support from Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) and Fundação de Amparo à Pesquisa do Estado do Rio Grande do Sul (FAPERGS). This manuscript was revised by American Journal Experts (Certificate Verification Key: EC28-7BC1-123F-B814-BA4).

References

Alves DS (2008) **Taking Things Public: A contribution to address human dimensions of environmental change**. *Philosophical Transactions of the Royal Society B* 363: 1903-1909.

Abell R, Allanb JD, Lehnera B (2007) **Unlocking the potential of protected areas for freshwaters**. *Biological Conservation* 134: 48-63.

Agostinho AA, Thomaz SM, Gomes LC (2004) **Threats for biodiversity in the floodplain of the Upper Paraná River: effects of hydrological regulation by dams**. *Ecohydrology and Hydrobiology* 4: 255-268.

Agostinho AA, Thomaz SM, Gomes LC (2005) **Conservation of the biodiversity of Brazil's inland waters**. *Conservation Biology* 19(3): 646-652.

Acselrad H (1992) **Meio ambiente e democracia**. 1 ed. IBASE, Rio de Janeiro, RJ, Brazil.

Albuquerque UP (2013) **How to improve the quality of scientific publications in ethnobiology.** *Ethnobiology and Conservation* 2:4.

Bensusan N (2006) **Conservação da Biodiversidade em áreas protegidas**. 1 ed. Rio de Janeiro, RJ, Brazil.

Blaikie P (1995) **Changing environments of changing views? A political ecology for developing countries**. *Geography* 80: 203–214.

Bini LM (2004) **Análises Multivariadas e Limnologia: Exploração, síntese e inferência de um mundo aquático complexo**. In: Carlos Eduardo de M. Bicudo; Denise de C. Bicudo. (eds.). Amostragem em Limnologia. 1ed. São Carlos: RIMA, p. 73-108.

Buss DF (2006) **Possibilidades da participação pública em programas de biomonitoramento de rios**. *Boletim da Sociedade Brasileira de Limnologia* 1: 42-47.

Buss DF (2008) **Desenvolvimento de um índice biológico para use de voluntários na avaliação da qualidade da água de rios**. *Oecologia Brasiliensis* 12: 516-526.

Buss DF, Vitorino AS (2010) **Rapid Bioassessment Protocols using benthic macroinvertebrates in Brazil: evaluation of taxonomic sufficient**. *Journal of The North American Benthological Society* 29: 562-571.

Calheiros DF, Seidl AF, Ferreira CJA (2000) **Participatory research methods in environmental science: local and scientific knowledge of a limnological phenomenon in the Pantanal wetland of Brazil**. *Journal of Applied Ecology* 37: 684-696.

Corbi JJ, Trivinho-Strixino S (2006) **Influence of taxonomic resolution of stream macroinvertebrate communities on the evaluation of different land uses**. *Acta Limnologica Brasiliensia* 18: 469-475.

Costa C, Ide S, Simonka CE (2006) **Insetos imaturos – metamorfose e identificação**. 1 ed. Holos, Ribeirão Preto, SP, Brazil.

Creighton JL (2005) **The public participation handbook: making better decisions through citizen involvement**. Jossey-Bass, Wiley, San Francisco, California, USA.

Davis A, Wagner JR (2003) **Who knows? On the importance of identifying "experts" when researching local ecological knowledge**. *Human Ecology* 31:463–489.

Esteves FA (2005) **A limnologia brasileira: aspectos históricos, estudo da arte e desafios futuros**. In: Roland F, César D, Marinho M (eds) Lições de limnologia. RiMa, São Carlos, SP, Brazil, pp. 29-52.

European Union (2000) **Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for the community action in the field of water policy**. Official Journal L 327. [http://ec.europa.eu/environment/water/water-framework/links/index_en.htm]. Acessed 15 May 2013.

Fernandez HR, Domingues E (2001) **Guía para la determinación de los artropodos bentónicos Sudamericanos**. Universidad Nacional de Tucumán, Tucumán, Argentina.

Firehock K, West J (1995) **A brief history of volunteer biological water monitoring using macroinvertebrate**. *Journal of the North American Benthological* Society 14:197-202.

Fore LS, Paulsen K, O'Laughlin K (2001) **Assessing the performance of volunteers in monitoring streams**. *Freshwater Biology* 46: 109-123.

Franca N (2006) **Educação Ambiental na Gestão Participativa: fortalecimento do conselho consultivo do Parque Nacional da Tijuca – Projeto Água em Unidade de Conservação**. 1 ed. IBASE, Rio de Janeiro, RJ, Brazil.

Gartin M, Crona B, Wutich A, Westerhoff P (2010) **Urban Ethnohydrology: Cultural Knowledge of Water Quality and Water Management in a Desert City**. *Ecology and Society* 15(4): 36.

Gelcich S, Kaiser MJ, Castilla JC, Edwards-Jones G (2008) **Engagement in co-management of marine benthic resources influences environmental perceptions of artisanal fishers**. *Environmental Conservation* 35(1): 36–45.

Gladwin C (1989) **Ethnographic decision tree modeling**. Qualitative research methods series, no 19. Sage publications, Newbury Park, CA, USA.

Huitema D, Mostert E, Egas W, Moellenkamp S, Pahl-Wostl C, Yalcin R (2009) **Adaptive water governance: assessing the institutional prescriptions of adaptive (co-) management from a governance perspective and defining a research agenda**. *Ecology and Society* 14(1): 26.

Huntington HP (1998) **Observations on the utility of the semi-directive interview for documenting traditional ecological knowledge**. *Artic* 51: 237–242.

Huntington HP (2000) **Using traditional ecological knowledge in science: methods and applications**. *Ecological Applications* 10: 1270–1274.

Jackson DA, Sonners KM (1989) **Are probability estimates from the permutation model of Mantel's test stable?.** *Canadian Journal of Zoology* 67: 766-769.

Johannes RE (1993) **Integrating traditional ecological knowledge and management with environmental impact assessment**. In: Inglis JT (ed) Traditional Ecological Knowledge: Concepts and Cases. Canadian Museum of Nature, IDRC: Ottawa, pp. 33–39.

Johannes RE, Freeman MMR, Hamilton RJ (2000) **Ignore fishers' knowledge and miss the boat**. *Fish and Fisheries* 1: 257–271.

Junqueira MV, Amarante MC, Dias CFS, França ES (2000) **Biomonitoramento da qualidade das águas da Bacia do Alto Rio das Velhas (MG/ Brasil) através de macroinvertebrados**. *Acta Limnológica Brasiliensia* 12: 73-87.

Konig R, Suzin CRH, Restello RM, Hepp LU (2008). **Qualidade das águas de riachos da região norte do Rio Grande do Sul (Brasil) pelo uso de variáveis físicas, químicas e biológicas**. *Pan-American Journal of Aquatic Sciences* 3 (1): 84-93.

Laborde S, Imberger J, Toussaint S (2012) **A Wall out of Place: a Hydrological and Sociocultural Analysis of Physical Changes to the Lakeshore of Como, Italy**. *Ecology and Society* 17(1): 33.

Laborde S, Imberger J, Toussaint S (2012b) **From the Cover: Contributions of local knowledge to the physical limnology of Lake Como, Italy**. *Proceedings of the National Academy of Sciences* 109:17, 6441-6445.

Legendre P, Legendre L (1998) **Numerical Ecology**. 2ed. Elsevier Science, Amsterdam, Germany.

Luna BC (2008) **Etnolimnologia do Açude Acauã: Um conhecimento para gestão ambiental integrada**. MSc. dissertation, Federal University of Paraíba, João Pessoa, PB, Brazil.

Mandaville SM (2002) **Benthic macroinvertebrates in freshwaters taxa tolerance values, metrics and protocols**. EPA, Washington, USA.

Manly BJF (2008) **Métodos Estatísticos Multivariados**. **Uma Introdução**. 3 ed. Artmed, Porto Alegre, RS, Brazil.

Marques JGW (1991) **Aspectos ecológicos na etnoictiologia dos pescadores do complexo estuarino-lagunar de Mundaú Manguaba, Alagoas**. PhD Thesis, State University of Campinas, Campinas, SP, Brazil. [http://en.scientificcommons.org/50628762] Acessed 5 Apr 2011.

Melo AS (2005) **Effects of taxonomic and numeric resolution on the ability to detect ecological patterns at local scale using stream macroinvertebrate**. *Archiv fur Hydrobiologie* 164: 309-323.

Melo AS (2009) **Explaining dissimilarities in macroinvertebrate assemblages among stream sites using environmental variables**. *Zoologia* (Curitiba. Impresso) 26: 79-84.

Merritt RW, Cummins KW (1996) **An introduction to the aquatic insects of North America**. Dubuque, Kendal/Hunt, USA.

Monteiro TR, Oliveira LG, Godoy BS (2008) **Biomonitoramento da qualidade de água utilizando macroinvertebrados bentônicos: adaptação do índice biótico BMWP à bacia do rio Meia Ponte-GO**. *Oecologia brasiliensis* 12 (3): 553-563.

Moretti MS, Gonçalves JF, Ligeiro R, Callisto M (2007) **Invertebrates colonization on native trees leaves in a Neotropical stream (Brazil)**. *International Review of Hydrobiology* 92(2):199-210.

Oksanen J, Kindt R, Legendre P, O'Hara B, Simpson LG, Solymos PM, Stevens H, Wagner H (2009) **Vegan: Community Ecology Package**. R package version 1.15-4. [http://CRAN.R-project.org/package=vegan]. Acessed 25 Feb 2010.

Oliveira-Filho AT, Jarenkow, JA, Rodal MJN (2006) **Floristic relationships of seasonally dry forests of eastern South America based on tree species distribution patterns.** In: Pennington RT, Lewis GP, Ratter JA, (eds) Neotropical Savannas and Dry forests Plant Diversity, Biogeography and Conservation. CRC,Boca Raton, pp. 159–192.

Paz A, Moreno P, Rocha L, Callisto M (2008) **Efetividade de áreas protegidas (APs) na conservação da qualidade das águas e biodiversidade aquática em sub-**

bacias de referência no rio das Velhas (MG). *Neotropical Biology and Conservation* 3: 149-158.

Pahl-Wostl C, Sendzimir J, Jeffrey P, Aerts J, Berkamp G, Cross K (2007) **Managing change toward adaptive water management through social learning**. *Ecology and Society* 12(2): 30.

Peres-Neto PR, Jackson DA (2001) **How well do multivariate data sets match? Evaluating the association of multivariate biological data sets: comparing the robustness of Mantel test and a procrustean superimposition approach**. *Oecologia* 129: 169–178.

R Development Core Team (2009) **R: A language and environment for statistical computing**. R Foundation for Statistical Computing, Vienna, Austria. [http://www.r-project.org/] Acessed 25 Feb 2010.

Restello RM, Penteado-Dias AM (2006) **Diversidade dos Braconidae (Hymenoptera) da Unidade de Conservação de Teixeira Soares, Marcelino Ramos, RS, com ênfase nos Microgastrinae**. *Revista Brasileira de Entomologia* 50(1): 80-84.

Roche KF, Queiroz EP, Righi KO, Souza GM de (2010) **Use of the BMWP and ASPT indexes for monitoring environmental quality in a neotropical stream**. *Acta Limnologica Brasiliensia* 22: 105-108.

Rosenberg DM, Resh VH (1993) **Introduction to freshwater biomonitoring and benthic macroinvertebrates**. In: Rosenberg DM, Resh VH (eds) *Freshwater biomonitoring and benthic macroinvertebrates*. 2 ed. Chapman and Hall, New York, pp. 1-9

Silvano RAM (2004) **Pesca artesanal e etnoictiologia**. In: Begossi A (ed), *Ecologia de Pescadores da Mata Atlântica e da Amazônia*. 1 ed. HUCITEC, São Paulo, SP, Brazil, pp. 185–220.

Silvano RAM, Udvardy S, Ceroni M, Farley J (2005) **An ecological integrity assessment of a Brazilian Atlantic forest watershed based on surveys of stream health and local farmers' perceptions: implications for management**. *Ecological Economics* 53: 369-385.

Silvano RAM, Silva AL, Ceroni M, Begossi A (2008) **Contributions of ethnobiology to the conservation of tropical rivers and streams**. *Aquatic Conserv: Mar. Freshw. Ecosyst.* 18: 241–260.

Siqueira AB (2012a) **Etnobiología en la Educación Básica**. *Revista de Educación en Biología* 15: 12-19.

Siqueira AB (2012b) **Etnobiologia e Educação: algumas reflexões**. In: Mendonça, Ana Waley; Siqueira, AB; Marcomin, FE (eds) Educação, Sociedade e Meio Ambiente no Estado de Santa Catarina: Múltiplas abordagens. 1 ed. Oikos, São Leopoldo, RS, pp. 123-136.

Socioambiental (2001) **Plano de Manejo do Parque Natural Municipal Teixeira Soares/RS**. Florianópolis, SC, Brazil.

Souto FJB, Alves, AGC (1999) **Etnolimnologia no açude Bodocongó (Campina Grande, Paraíba): percepção e utilização do cágado d'água *Phrynops spp*. (Testudinomorpha: Chelidae) por pescadores artesanais** (In: Seventh Brazilian Congress of Limnology). Federal University of Santa Catarina, Florianópolis, SC, Brazil.

Strang V (2004) **The meaning of water**. Berg Publishers, Oxford, UK.

Takeda AM, Fujita DS, Fontes HM (2004) **Perspectives on exotic bivalves proliferation in the Upper Paraná River floodplain**. In: Agostinho AA, L. Rodrigues L, Gomes LC, Thomaz SM, Miranda LE (eds) *Structure and functioning of the Paraná River and its floodplain*. 1 ed. EDUEM, Maringá, PR, Brazil, pp. 97-100.

Tompkins EL, Adger WN (2004) **Does adaptive management of natural resources enhance resilience to climate change?.** *Ecology and Society* 9(2):10.

Toussaint S (2008) **Kimberley friction: complex attachments to water-places in northern Australia**. *Oceania* 78:46–61.

Train S, Rodrigues LC (2004) **Phytoplanktonic assemblages**. In: Thomaz SM, Agostinho AA, Hahn NS (eds) *The Upper Paraná River and its floodplain: Physical aspects, ecology and conservation.* 1 ed. Backhuys Publishers, Leiden, pp. 103-124.

Trevisan A, Hepp LU (2007) **Chemistry compound dynamic of leaf-litter and fauna associated with breakdown process of arboreous species in a stream from North of Rio Grande do Sul, Brazil**. *Neotropical Biology and Conservation* 2(1): 54-60.

United Nations (1992) **Rio Declaration on Environment and Development. United Nations Conference on Environment and Development.** United Nations, New York, New York, USA.

Webb EL, Maliao RJ, Siar SV (2004) **Using local user perceptions to evaluate outcomes of protected area management in Sagay Marine Reserve, Philippines**. *Environmental Conservation* 31: 138-148.

World Resources Institute (2001) **Guía de Recursos Mundiales 2000-2001**. La gente y los ecosistemas: Se deteriora el tejido de la vida. Instituto de Recursos Mundiales, Washington, USA.