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Use of ecosystem health indicators for assessing anthropogenic impacts on freshwaters in Argentina: a review

Luciana Rocha · Cecilia Hegoburu · Ana Torremorell · Claudia Feijoó · Enrique Navarro · Hugo R. Fernández

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Abstract Indicators of ecosystem health are effective tools to assess freshwater ecosystem impairment. However, they are scarcely used as a monitoring tool by local environmental agencies in Argentina. Here, we review the literature to analyze the use of ecosystem health indicators in freshwaters from Argentina. We found 91 scientific articles relating to the use of ecological indices to assess the impact of different environmental stressors in aquatic environments published between 1996 and 2019. We generated Google Earth map where we deployed the sampling sites and type of indices reported by each article. As biological indices were the most used, we also surveyed bioindication experts to gather information on their application. We found that most studies were concentrated mainly in Pampas (34%), Dry Chaco (20%), Espinal (12%), and Patagonian Steppe (10%) ecoregions. Biological indices (mainly with invertebrates) were more used than geomorphological or physico-chemical indices. Indices resulted useful to evaluate the impact of stressors in 63% of cases, being land use the most studied stressor. However, sampling design varied greatly among studies, making their comparison difficult. The information compiled here could help to the design of monitoring protocols, the adoption of regional indices, and the creation of a national inventory of ecosystem health status, which are mandatory to propose well-grounded conservation and management policies for freshwaters in Argentina.

Keywords Integrity · Stressor · Monitoring · Indices · Aquatic ecosystems

L. Rocha (✉)
Aquatic Ecology Group (GIEA), INEDES (CONICET-UNLu), Departamento de Ciencias Básicas, Universidad Nacional de Luján, Luján, Buenos Aires, Argentina
e-mail: rochaluciana17@yahoo.com.ar

C. Hegoburu
Freshwater Biogeochemistry Programme (BED), INEDES (CONICET-UNLu), Luján, Buenos Aires, Argentina

A. Torremorell · C. Feijoó
Ecology Program of Protists and Fungi (PEPHON), INEDES (CONICET-UNLu), Luján, Buenos Aires, Argentina

E. Navarro
Pyrenean Institute of Ecology, Spanish National Research Council (IPE-CSIC), 50059 Zaragoza, Spain

H. R. Fernández
Facultad de Ciencias Naturales e Instituto Miguel Lillo, IBN (CONICET-UNT), San Miguel de Tucumán, Argentina

Introduction

Governments are nowadays facing the tremendous challenge posed by anthropogenic impacts on safe and healthy water for their populations and ecosystems. The search for better ways to identify ecosystem impairment drove to intensive works to find the most complete indicators (Jørgensen 2005). Today, we can identify two concepts in relation to ecosystem condition assessment: the ecological integrity and the ecosystem health. Both have been already presented and discussed during the last three decades (Karr 1991, 1996; Karr and Chu 2000; Vugteveen et al. 2006; Vollmer et al. 2018).

The term ecological integrity is defined as the dimension of health that reflects the ability of an ecosystem to maintain their organization (structure and function) (Karr 1992). The term is used in an ecological sense to refer to the natural evolution of the ecosystem without being affected by human influence (Nielsen 1999; Wicklum and Davies 1995). Moreover, it implies a non-deteriorated condition compared to the original condition (Campbell 2000), or the quality of being complete or undivided (Karr 1992).

Ecosystem health is a characteristic of complex natural systems, which implies that the ecosystem can maintain its structure and function over time and space (sustainability), maintaining its dynamic nature and changing slowly (Wells 2005). Health is the ecological resilience (Rapport et al. 1980) and describes the "preferred state" of sites modified by human activity. These sites do not have integrity in an evolutionary sense but can be considered "healthy" (Karr 1996). Hence, an ecosystem is impaired when its capacity of assimilating stress is exceeded (Loeb 1994).

Some authors use the terms "ecosystem health" and "ecological integrity" indistinctly, because both describe the current condition or state, a short-term view, how well the ecosystem is composed and functioning now, while other authors use the terms in relation to the level of biological organization (i.e., an individual organism is healthy or unhealthy, while a biological community has or lacks integrity) (Karr 1996; Wells 2005). We used the term "ecosystem health" because it refers more to a condition, which have to measure with certain indicators to establish corrective measures in terms of satisfying a social need. Furthermore, we believe that under this approach, ecological issues can be conveyed to agencies or the general public in a recognizable format.

The concept of ecosystem health and its evaluation involves researchers from quite different perspectives (e.g., biology, chemistry, economics, modeling, etc.), which use multiple indicators to determine the "disease" of the system. Vugteveen et al. (2006) introduce the River System Health concept to integrate ecosystem health with the health of the socio-economic system. In that sense, a Freshwater Health Index has been recently proposed to relate human uses of water, freshwater ecosystems, and governance to achieve an integral management of aquatic environments (Vollmer et al. 2018). Under this approach, we refer to freshwater health as the capacity of freshwater ecosystems to maintain ecological function, biodiversity, and the provision of ecosystem services.

In South America, there exist considerable studies of environmental impacts that use unimetric ecological indices (biotic indices, mainly), but almost all are published in non-commercial form (e.g., government reports, policy statements and issues papers, conference proceedings), and there is a lack of standardized protocols (Prat et al. 2009). Catchment disturbances such as water use, intensive agriculture, mining, deforestation, and afforestation were identified as main causes of threat for South American freshwater ecosystems (Torremorell et al. in press). They also remarked the lack of adequate legislation that may aggravate the situation of freshwater ecosystems in many regions of the continent.

In Argentina, impairment of aquatic environments was recognized since the Colonial period (18th century) when tanneries and slaughterhouses were established in the margin of rivers in Buenos Aires (Brailovsky and Foguelman 1991). Recently, Torremorell et al. (in press) identified watershed level stressors (mainly land use impacts) as the worst ones affecting Argentinian rivers, even more than alterations in flow regime and channel modifications. This explains why scientists are still interested in finding more comprehensive and integrative indicators for freshwaters ecosystems in Argentina (Domínguez et al. 2020).

It is well stablished that Gualdoni and Corigliano (1991) is the first bioindication reference using macroinvertebrates in Argentina. Later, many others from different Argentinian regions were published by different authors (Vallania et al. 1996; Domínguez and Fernández 1998; Miserendino and Pizzolón 1999; Rodrigues Capítulo et al. 2001, 2003). The study of Gualdoni and Corigliano, it is possible to infer the influenced of the Ghetti group from Italy; others were influenced by English (e.g., Wilhm 1975), French (e.g., Tuffery 1979), Italian (e.g., Ghetti and Bonazzi 1980), or Spanish groups (e.g., Alba-Tercedor and Sánchez-Ortega 1988).

Despite the information generated on ecological indicators by research groups in Argentina, they are not currently used as a monitoring tool by local environmental agencies (Fernández 2015). However, there is a raising concern among managers and citizens about the ecological state of fluvial ecosystems and thus on the implementation of appropriate monitoring tools (Loiselle et al. 2016). This review aims at establishing the state of the art on ecosystem health assessment in aquatic ecosystems throughout Argentina, as a part of a collaborative project between Latin American and Iberian countries (Iberoamerican Network for the Development of Protocols for the Ecological Assessment, Management and Restoration of Rivers: IBEPECOR). To this end, we review the use of indices to assess ecosystem health in freshwaters throughout Argentina, considering different types of environments (rivers, lakes, lagoons, etc.) and ecoregions. We examine the type of indices applied, the problems evaluated by them, and whether they were validated or not using additional parameters. We also conducted a survey to experts in biomonitoring to analyze the practical application of biological indices in the country.

Material and methods

Literature dataset

We conducted a systematic evaluation of the peer-reviewed literature relating to the use of ecological indices to assess the impact of different environmental stressors in aquatic environments from Argentina. We performed a literature search in three databases: the Web of Science (WoS; http://apps.webofknowledge.com), Scientific Electronic Library Online (Scielo; https://www.scielo.org), and Online Regional Information System for Scientific Journals from Latin America, the Caribbean, Spain and Portugal (Latindex; https://www.latindex.org), using the following keywords combination: ("ecological quality" OR "ecological condition" OR "environmental conditions" OR "environmental monitoring" OR "water quality" OR pollution OR indices OR indicators) AND (Argentina OR "land use"). The search was done in January 2020 and we selected articles that use ecological indices to analyze some local problematics or stressors. The review process resulted in a total of 91 papers matching our study criteria (Appendix 1). These articles were written in English or Spanish and published between 1996 and 2019.

Articles were categorized by the ecoregion/s where the study was performed, according to Burkart et al. (1999): (1) High Andes, (2) Puna, (3) Monte of hills and valleys, (4) Yungas forest, (5) Dry Chaco, (6) Humid Chaco, (7) Paraná forest, (8) Iberá Marshes, (9) Subtropical grasslands and savannas, (10) Paraná Delta, (11) Espinal, (12) Pampas, (13) Monte of plains and plateaus, (14) Patagonian steppe, (15) Patagonian forest, (16) South Atlantic Islands, (17) Argentine Sea, and (18) Antarctica. Concerning the number of samplings, the articles were grouped into four categories: (1) once, (2) several samplings in one year, (3) several samplings in two or more years, and (4) non-specified. When more than one sampling was made (N = 70), we further categorized the articles considering sampling frequency: (1) monthly or bi-monthly, (2) seasonal, (3) variable, and (4) non-specified. We also classified the articles considering the validation of the index ((1) Yes, (2) No) with additional parameters and the result of this validation: (1) Positive, (2) Negative, (3) Positive/negative, (4) Non-specified.

We distinguished six types of indices (Logan 2001; Agéncia Catalana de l'Aigua 2006a, 2006b; Vugteveen et al. 2006): (1) physico-chemical, which include those indices that evaluated variables such as pH, dissolved oxygen, conductivity, and nutrients, (2) biological, which include metrics of different communities such as fish, invertebrates, macrophytes, algae and amphibians, and indicators, such as richness, biodiversity, and biotic quality indices, (3) hydrological (alteration of the hydrological regime or fluvial connectivity), (4) geomorphological, related to the riparian zone, (5) functional, which encompass ecosystem functional processes (nutrient spiraling, decomposition, metabolism), and (6) multimetric, which uses different kind of metrics to evaluate the ecological condition.

Articles were also categorized into seven groups of environmental stressors that were analyzed using the indices: (1) non-specific factors (note that this broad term incorporates evaluation of ecological or ecosystem health, biological integrity, and water quality, without specifying a particular problematic), (2) aquatic pollution (organic and inorganic pollution), (3) morphological alteration (dredging and channelization), (4) natural disasters (as volcanic eruptions), (5) mining and oil spill, (6) tourism and recreation (to evaluate the quality of recreation services and/or to assess the impact of tourism on aquatic environments), and (7) land use (impact of different land uses, such as urbanization, agriculture, livestock, industries). Studies that addressed more than one topic were classified to more than one category (e.g., to both non-specific factors and land use).

Based on the validation of the indices, studies were further grouped into two categories: (1) yes (the index was validated using additional parameters), and (2) no (the index was not validated). Articles where the index was validated ($N = 83$) were categorized by the result of the validation: (1) positive (when the index was useful to evaluate the impact of the stressor), (2) negative (when the index was not useful), (3) positive/negative (if the validation was positive with one index and negative with another index in the same article, or when the same index represented the conditions predicted by one parameter but not by other one), and (4) non-specified. Only one category was assigned to each publication.

We uploaded the sampling sites of each article ($N = 89$) on Google Earth. These points were identified through (1) geographical coordinates (when they were provided), (2) specific indications of the localization when they were explicit, and (3) visual localization using as reference the morphology of net drainage and the satellital image, which was compared with the localization map presented in each article. This was supported by the distance measured from reference points (e.g., roads, bridges, etc.) using the map scale, and (4) other elements like photos loaded on Google Earth by users and labels of places that were referenced in the article. We used different symbols to categorize sampling points according to the type of index employed. Sampling sites from two articles (Dos Santos et al. 2011; Hunt et al. 2017) could not be located on Google Earth due to the lack of precision on the localization of sampling points. Points dataset was saved as a kml file (Keyhole Markup Language, Appendix 2) and later converted into a shapefile using QGIS version 2.4.0. This shapefile was combined with one containing the ecoregions proposed by Burkart (available at https://groups.google.com/forum/#!topic/scgis-latino/J6FtFxdFRTk); both were projected in the coordinate reference system World Geodetic Survey 1984 (WGS 1984).

Survey analysis

Given that biological indices were the most used in our literature review, a survey was performed to evaluate the application of this type of index in sampling protocols. A questionnaire was sent to 17 experts that currently use biological indices and that belong to research groups of reference for the topic in Argentina. That questionnaire gathered their experience in the performance and application of ecological indices, including the applicability and present use of indices by environmental agencies in Argentina (Appendix 3).

Results

Literature dataset

Our literature review identified 91 papers published between 1996 and 2019 that used ecological indices in Argentine aquatic environments (Appendix 1). The number of publications progressively increased since 1996 and peaked in 2012, when a special number on the topic was published by a local journal. After 2012, the number of publications was the same as in previous years, around four papers per year (Fig. 1).

Pampas region was the most studied region (34% of the papers), followed by Dry Chaco (20%), Espinal (12%), and Patagonian steppe (10%) (Figs. 2 and 3). Other regions like Patagonian and Yungas forests were poorly represented in the literature (9% and 7%, respectively), while some regions like Puna, High Andes, and Parana forest were not represented at all. Other ecoregions such as Monte of plains and plateaus, Monte of hills and valleys, Subtropical grasslands and savannas, and Parana Delta have only been studied in one paper.

The number of sampling greatly varied among studies. Considering the whole sampling period, 57.5% of the papers reported several samplings within one year, while 30% reported several samplings in two or more years. Only one sampling was reported in 15 papers (18.75%) while 6 papers did not specify it. Sampling frequency was also highly variable. Most studies (72.7%) reported seasonal samplings, while monthly or bimonthly samplings were performed in 21.2% of the publications, and variable (nor systematic) samplings in 8 publications (12%).

Concerning the type of indices, more than 63% of the studies used biological indices (626 sampling points), followed by geomorphological (17%, 260 sampling points) and physico-chemical indices (15%, 88 sampling points). Multimetric indices were poorly represented (only 4 papers, 16 sampling points), while hydrological and functional indices were not applied (Fig. 4). It was also verified that most of the articles that report a

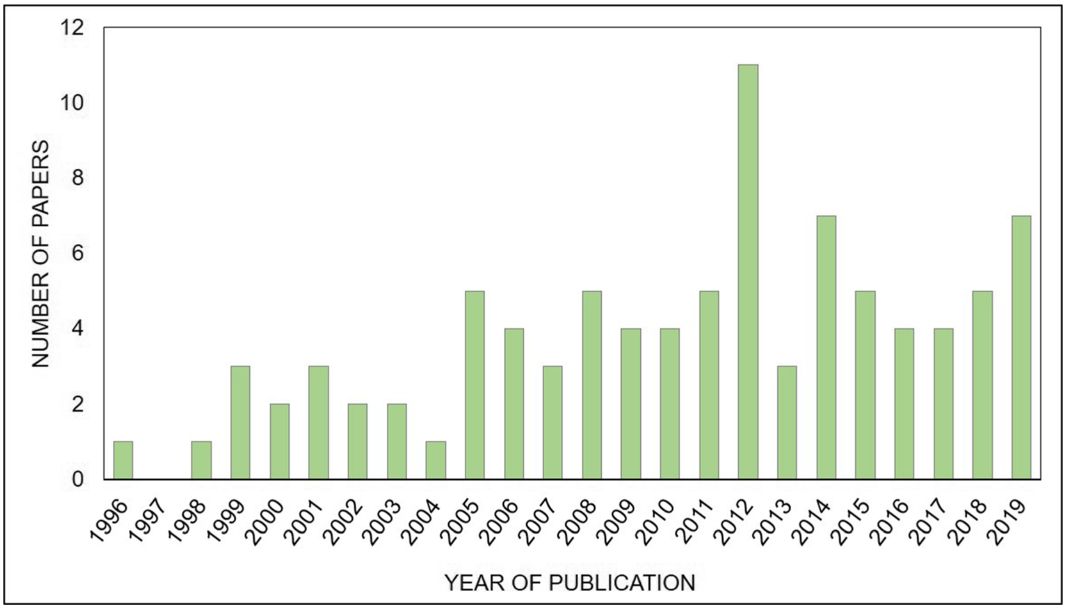

Fig. 1 Number of papers published per year, where ecological indices were applied

significant relation between environmental stressors and a biological index used the invertebrates as response variable. They represented 73% of the total, followed by the algae (16%), fish and amphibians (4% each). The macrophytes accounted for less than 3% of the articles (Fig. 4). When considering environmental stressors that were significantly related to the invertebrate community, we found that 54.5% of the articles reported land use, 37.5% pollution, and 8% included both the effect of pesticides and volcanic eruption.

Most studies (41%) applied ecological indices to assess the impact of land use (mainly urbanization, agriculture, cattle grazing, and industry) on

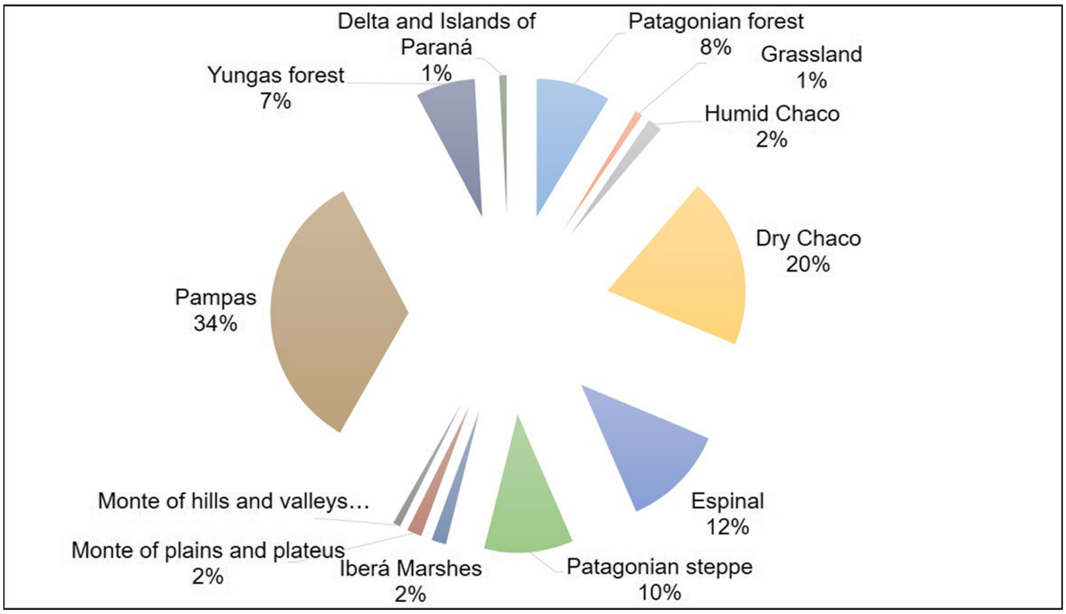

Fig. 2 Distribution of the aquatic environments considered in the literature across ecoregions

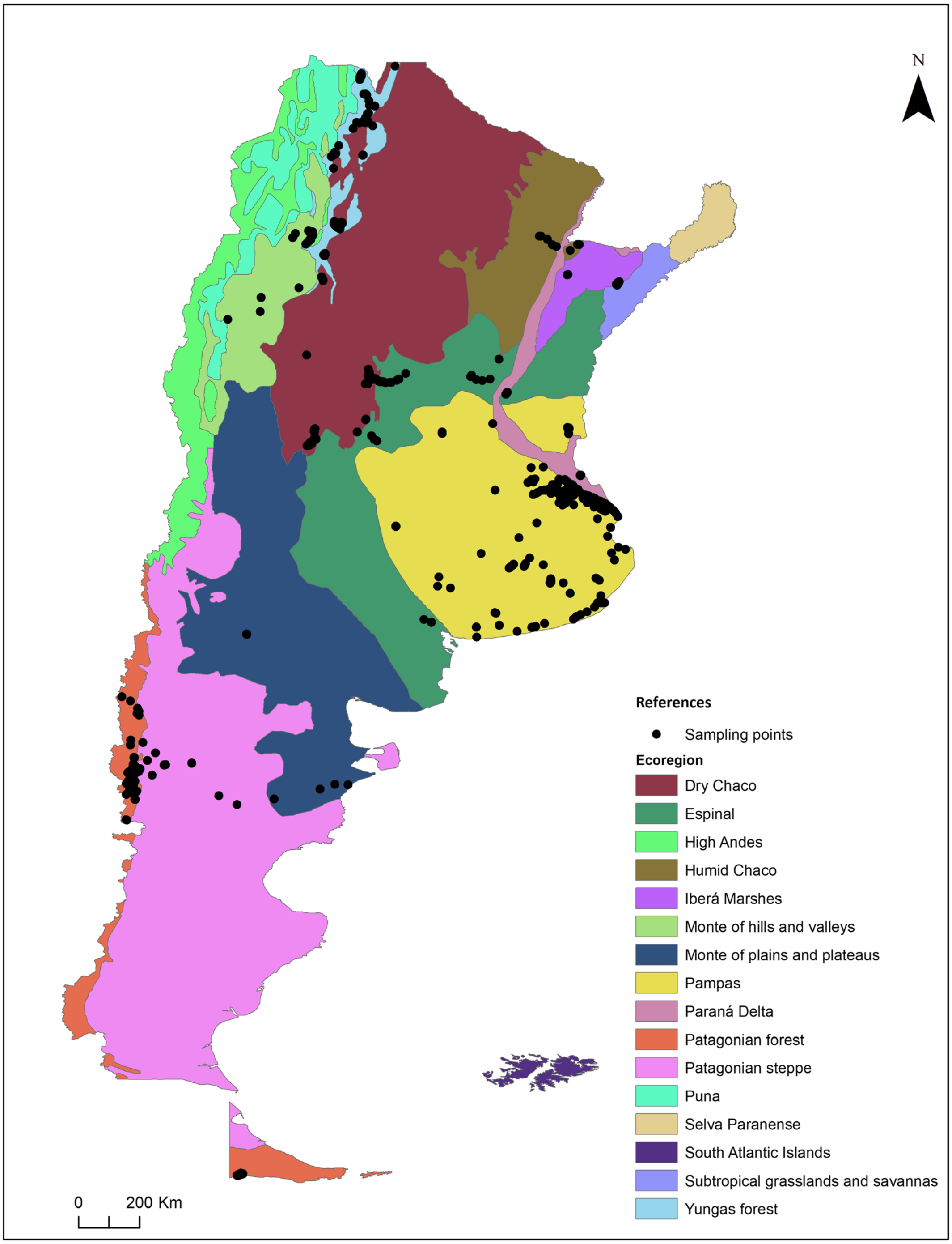

Fig. 3 Distribution of the sampling points considered in the literature across ecoregions

ecosystem health. Twenty-six percent of the studies evaluated non-specific factors in broad sense, without specifying the type of impact, while 23% considered the impact of the aquatic pollution. Other stressors like morphological alteration, natural disasters, mining and oil spilling, and tourism and recreation were examined in 10% of the publications (Fig. 5).

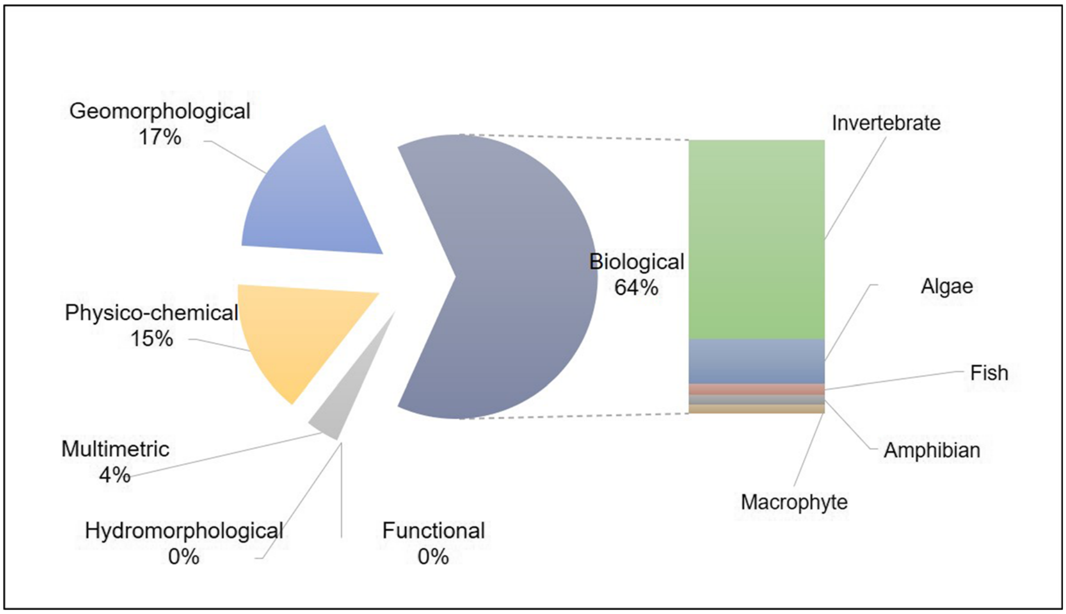

Fig. 4 Type of indices used in the reviewed literature

Concerning the validation of the ecological indices using additional parameters, we found that 80 papers (88%) included some kind of validation. Moreover, authors reported that the index was useful to assess the impact of the stressor in 86% of the papers (Fig. 6).

Survey analysis

The questionnaire designed to examine the practical application of biological indices in assessment protocols (Appendix 2) was answered by 14 researches. Most of them (57.1%) reported > 6 years of expertise

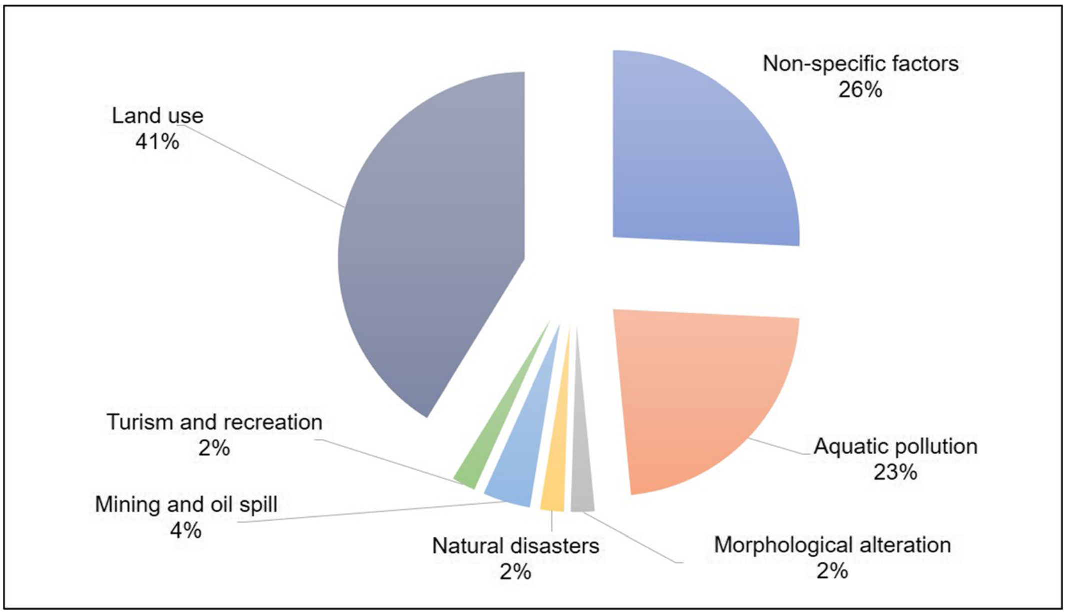

Fig. 5 Type of environmental stressors addressed in the literature

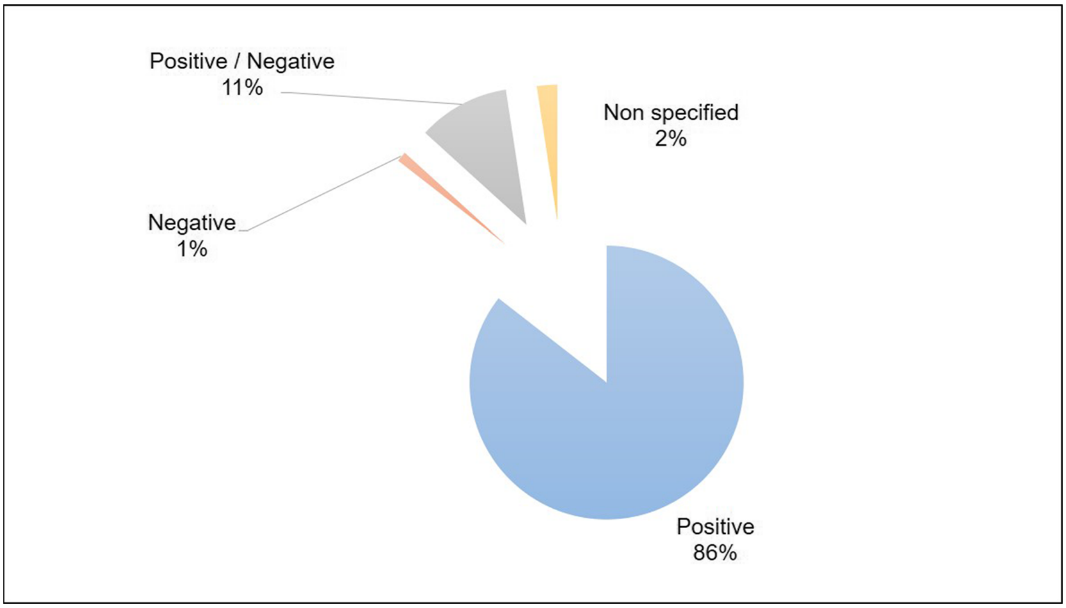

Fig. 6 Results of the validation of the index: positive (when the index was useful to evaluate the impact of the stressor), negative (when the index was not useful), positive/negative (if the validation was positive for one index and negative for other index in the same article, or when the same index represented the conditions predicted by one parameter but not by other one), and non-specified

using biological indices, while the rest of interviewers were equally divided between ≤ 2 years and 3–6 years of expertise. Indices based on species assemblages were most used (44%), followed by diversity and richness (28%), multimetric (16%), and functional (6%) (Fig. 7).

Concerning the applicability of biological indicators, 87% of interviewers asserted that indices

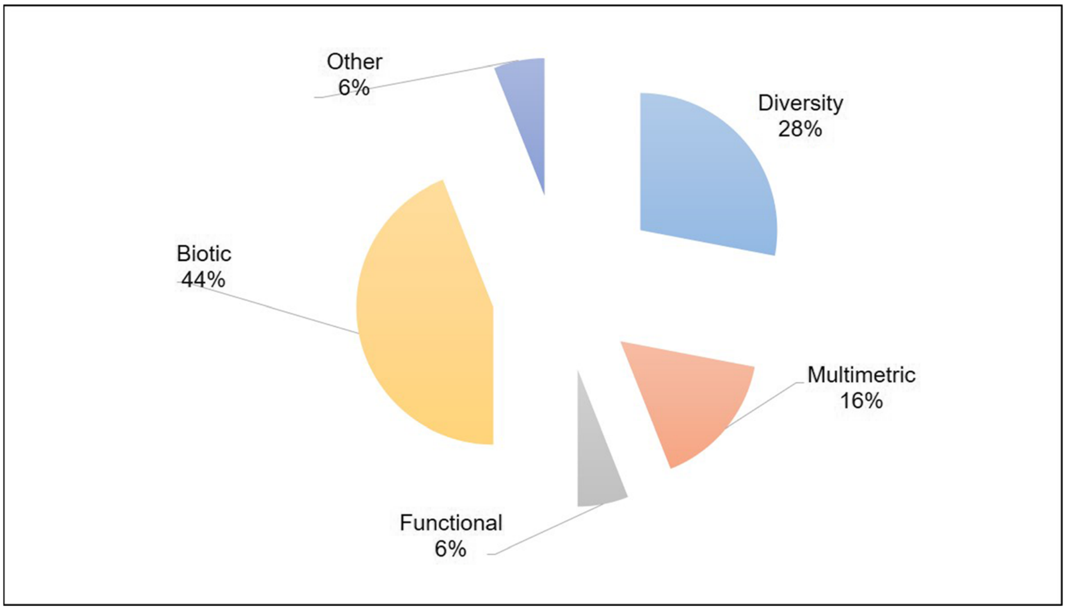

Fig. 7 Results of questionnaire to researchers about use of indices

can be used without difficulties by non-scientific staffs after a training period ≤ 3 months (33%), between 4 and 6 months (58%), or > 6 months (8%). However, most researchers acknowledged that biological indices were never used by public environmental agencies (69% of cases). Application of indices by local agencies on one occasion or > 1 occasion was reported with the same proportion (15%).

Discussion

We found 91 papers published between 1996 and 2019 where ecosystem health was assessed in aquatic environments of Argentina. Number of papers tended to increase slightly but continuously through years, and we observed a peak in 2012, when a special number on ecological quality was published by Biología Acuática, a local journal (Fig. 1). This suggests a sustained interest on this issue by the scientific community, despite of the lack of exhaustive monitoring strategies by local, regional, and national agencies (Torremorell et al. in press).

Among all ecological indices, biological indices were the most applied, being the invertebrates the most widely used group of organisms to evaluate the freshwater ecosystem health in Argentina (Fig. 4). Greater knowledge in biological indices is also confirmed by the fact that most researchers reported > 6 years of expertise using these indices. When conducting studies that relate aquatic communities to environmental stressors, an important factor is selecting the taxonomic group that will be the response variable (that is, only a taxon, several taxonomic groups, the entire community, more than one community), considering their specificities in relation to the environmental conditions (Brasil et al. 2020). The high representativeness of studies applying invertebrate indices could be related to the wide distribution of these taxa and their important role as bioindicators in freshwater ecosystems. Worldwide studies have demonstrated that anthropogenic activities exert a significant effect on the diversity of sensitive invertebrates (Mehari et al. 2014; Chi et al. 2017), being this community the most investigated in river quality evaluations in Europe (European Environmental Agency 2016). Thus, we consider that the invertebrate indicators can be a suitable tool for water quality assessment in Argentina. Invertebrates are more simple to evaluate ecosystem health than chemical conditions or other communities like fish, amphibian, or algae, which require more specialized equipment and professional expertise to conduct assessments. Therefore, this study can serve as an initial step in implementing biomonitoring protocols to determine the freshwater ecosystems health in Argentina. Regionally appropriate bioindicators, such as the BMPS (Biotic Monitoring Patagonian Stream, Miserendino and Pizzolón 1999), IMRP (The Macroinvertebrate Index for Pampean Rivers, Rodrigues Capítulo et al. 2003), and BMWP´(Biological Monitoring Working Parting adapted for Yungas forest ecoregion, Domínguez and Fernández 1998), are not only ecologically meaningful, but they could also be integrated into citizen science approaches (Penrose and Call 1995; Nerbonne and Vondracek 2003; Edwards 2016; Rae et al. 2019) and thereby enhance dialogue between science and society (Wenger et al. 2009). The United Nations has called for increased public participation in scientific research, to benefit professionals, the public, and the planet (Quinlivan et al. 2020).

Geomorphological and physico-chemical indices were less represented (< 35% of papers), and they were generally used as complements of the biological indices. Hydrological and functional indices were not used at all, remarking the lack of studies that develop monitoring tools for specific impacts on flow and functional ecosystem properties in the reviewed literature. Assessment of ecosystem health requires the integration of multiple and complementary attributes, including chemical, hydrogeomorphological, biological, and functional metrics (Vugteveen et al. 2006; Woodward et al. 2012; von Schiller et al. 2017). However, we only found 12 papers where two types of indices were used. This highlight the need to perform monitoring protocols that complement structural and functional measures to fully understand the impact of multiple stressors on fluvial ecosystem health.

Our literature review revealed that most of the studies (76%) were developed in a few ecoregions (Pampas, Dry Chaco, Espinal and Patagonian Steppe). The rest of ecoregions were underrepresented or not represented at all, including large ecoregions as Humid Chaco, Monte of hills and valleys and Monte of plains and plateaus, and indeed ecoregions that sustain high biological diversity (like Patagonian Forest, Iberá Marshes, Yungas Forest, and Parana Forest). Hence, geographical distribution of studies did not obey to the interest of monitoring regions based on an ecological criterion, such as high conservation value or threats that they are facing. For instance, deforestation is the main cause of deterioration of streams and rivers, especially in the northeast portion of Argentina (Torremorell et al. in press); however, the number of studies performed in Paraná, Yungas, and Patagonian forests is relatively low (19 articles). Actually, the geographical distribution of studies is related to the presence of research groups in the region. For instance, there are many research groups in the Pampas ecoregion that focus on the ecology of freshwaters and water quality, including INEDES (Institute of Ecology and Sustainable Development), University of Buenos Aires, ILPLA (Institute of Limnology Dr. Raúl A. Ringuelet), the National University of Mar del Plata, MACN (Museo Argentino de Ciencias Naturales Bernardino Rivadavia), the National University of Center of Buenos Aires Province, and the National University of La Pampa. Studies in Dry Chaco, Espinal, and Yungas forest are mainly performed by the National University of Córdoba, National University of Río Cuarto, National University of San Luis, National University of Litoral, and National University of Tucumán, while the CIEMEP (Centro de Investigación Esquel de Montaña y Estepa Patagónica), National University of Patagonia San Juan Bosco, and National University of Comahue study ecosystems from Patagonian steppe and forest.

Among the analyzed stressors, land use impact was the most studied (41% of the articles), while the assessment of factors without specifying an explicit environmental problem was the second most studied. Unexpectedly, the effect of inorganic and organic water pollution was less evaluated despite its potential risk for people and aquatic biota. Most of the studies focused on the assessment of ecosystem health from a broad perspective, integrating physical, chemical, hydromorphological and biological impacts of human activities on fluvial ecosystems. The aquatic communities can be influenced by the scale which anthropogenic environmental changes occur (Allan 2004). We identified three scales in the analyzed studies: (1) punctual sewage inputs that occur within freshwater systems; (2) impacts in a riparian zone, and (3) changes in land use in a region that drains into a freshwater system (regional scale).

We found that indices were validated using additional parameters in 88% of articles and that they resulted useful to evaluate the impact of stressors in 63% of the cases. In addition, 87% of the interviewed researchers considered that biological indices could be easily used by non-scientific staffs after a relatively short period of training (≤ 6 months for 91% of respondents). Hence, our results stressed the usefulness of ecological indices to assess freshwater ecosystem health in Argentina, as it was stressed by several authors in other countries (Logan 2001; Burger 2006; Zhang et al. 2018).

However, despite the advantages of indices reported by the reviewed literature and the survey, two main concerns arose from our results. First, sampling frequency was greatly variable among studies. For instance, only 30% of the articles reported samplings that exceeded one year to capture interannual variability. Moreover, in 18.75% of the studies, only one sampling was made. Even most authors tried to include seasonal variability (seasonal or monthly and bimonthly samplings were reported in 94% of the papers), disparity in sampling protocols may prevent comparisons of methodologies and data. The second concern is the scarce application of indices by environmental agencies. Sixty-nine percent of researchers indicated that biological indices were never used, which suggests a lack of interaction between researchers and managers. This fact may be related to the unrecognized importance of ecosystem approaches to the management. As occurred in many other countries (Derocles et al. 2018), local environmental agencies in Argentina preferred some specific ecological indices because their technicians or employees are familiarized with them. Some agencies use water quality indices like ICA (Berón 1984), while others sporadically perform ecotoxicological tests or biological monitoring. The use of different protocols to assess freshwater quality creates a confusing landscape of situations around "freshwater quality" in Argentina, preventing the establishment of a common (and comparable) monitoring system.

The European Union has established the Water Framework Directive to achieve good qualitative and quantitative status of all European waterbodies (WFD 2000/60/EC). It aims to reconcile and limit existing differences in the mechanisms for ecological monitoring of waterbodies, favoring the implementation of common protocols for establishing freshwater quality. In Latin America, the lack of such common policies in the field of ecological monitoring is undoubtedly a problem for the maintenance of the ecological integrity of freshwaters (Fernández 2015). To overcome this problem, a net of researchers was created recently to develop a national monitoring system (Net of Assessment and Monitoring of Aquatic Systems or REM.AQUA). The objectives of the REM-AQUA are to organize the existing information, establish reference conditions in the different ecosystems, and define biological groups and metrics for ecoregions (Gómez 2020). This review may contribute to these objectives by providing a summary and systematic organization of the results obtained through long years of experience in the field of freshwater ecosystem monitoring in Argentina.

Conclusions

It is necessary that societies begin to track the condition of their waters as they track the status of local and national economies. The increase in knowledge on the ecological status and biodiversity in different ecoregions is urgently needed to apply prioritized conservation strategies. However, in Argentina, we face several problems to meet this target and implement suitable environmental policies. Despite there is enough data on fluvial ecosystem health assessment, this information is scarcely used by managers. The recent creation of REM.AQUA, which depends on the National Ministery of Ambient and Sustainable Development, is an important step to solve this problem. In addition, watersheds are managed by different political administrations in the country, resulting in an overlap of functions at the national, provincial, and local levels. To overcome this problem, basin committees were created to provide advice and collaboration for sustainable environmental management. However, several committees are still inactive. Institutions such as universities should be the platform to facilitate the communication among researchers and water managers. In this sense, practical application of biological indices could be quickly reachable in the country using universities capacities to train technician.

Our results shown that there is a lack of standardization of monitoring programs, which would avoid for comparing and integrating databases from different research groups and monitoring organisms. The temporal sampling frequency might be determined by the characteristics of the metrics used; however, as a general recommendation, we consider that seasonal samplings will be adequate in most cases.

Human activities as deforestation, mining, expansion of agriculture and livestock, channelization and alteration of discharge, and introduction of exotic species are increasingly threatening the ecosystem health of fluvial systems in Argentina. These problems will be exacerbated by changes in temperature and regime of rainfall predicted by climatic models at regional scale. Design of monitoring protocols and creation of an inventory of ecosystem health status at the national level is mandatory to propose conservation and restoration policies for freshwater ecosystems. Information compiled here can serve as a basis to attain these goals, help to identify priorities and gaps in research areas, and finally, will contribute to preserve biodiversity and ecological function of freshwater ecosystems in Argentina.

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Appendix 1

Table 1 List of articles reviewed relating to the use of ecological indices to assess the impact of different environmental stressors in aquatic environments from Argentina

Authors	Title	Journal	Publ year	Volume	BP	EP	DOI / URL
Almeida, C.A., Quintar, S., González, P., Mallea, M.A.	Influence of urbanization and tourist activities on the water quality of the Potrero de los Funes River (San Luis - Argentina)	Environmental Monitoring and Assessment	2007	133	459	465	doi:10.1007/s10661-006-9600-3
Almeida, C., Oliva González, S., Mallea, M., González, P.	A recreational water quality index using chemical, physical and microbiological parameters	Environmental Science and Pollution Research	2012	19	3400	3411	doi:10.1007/s11356-012-0865-5
Basílico, G.O., De Cabo, L., Faggi, A.	Adaptación de índices de calidad de agua y de riberas para la evaluación ambiental en dos arroyos de la llanura pampeana	Revista del Museo Argentino de Ciencias Naturales Nueva Serie	2015	17	119	134	http://revista.macn.gob.ar/ojs/index.php/RevMus/article/view/411
Bazán, G.I., Dalmaso, M.G., Álvarez, S.B., Martínez de Fabricius, A.L.	Contribución al conocimiento ficológico y calidad de agua de la laguna La Arocena (Pcia. de La Pampa, Argentina)	Biología Acuática	2012	27	17	27	http://www.bacuatica.org/BA_ant/ba27.pdf
Bertora, A., Grosman, F., Sanzano, P., Rosso, J.J.	Composición y estructura de los ensambles de peces en un arroyo pampeano con uso del suelo contrastante	Revista del Museo Argentino de Ciencias Naturales Nueva Serie	2018	20	11	22	http://revista.macn.gob.ar/ojs/index.php/RevMus/article/view/545
Boccolini, M.F., Oberto, A.M., Corigliano, M.C.	Calidad ambiental en un rio urbano de llanura	Biología Acuática	2005	22	59	69	http://www.bacuatica.org/BA_ant/ba22.pdf
Brand, C., Miserendino, M.L.	Testing the Performance of Macroinvertebrate Metrics as Indicators of Changes in Biodiversity after Pasture Conversion in Patagonian Mountain Streams	Water, Air, & Soil Pollution	2015	226			doi:10.1007/s11270-015-2633-x
Calderon, M.R., González, P., Moglia, M., Oliva Gonzáles, S., Jofré, M.	Use of multiple indicators to assess the environmental quality of urbanized aquatic surroundings in San Luis, Argentina	Environmental Monitoring and Assessment	2014	186	4411	4422	doi:10.1007/s10661-014-3707-8

Table 1 (continued)

Authors	Title	Journal	Publ year	Volume	BP	EP	DOI / URL
Calderon, M.R., Moglia, M.M., Nievas, R.P., Colombetti, P.L., González, S.P., Jofré, M.B.	Assessment of the environmental quality of two urbanized lotic systems using multiple indicators	River Research and Applications	2017	33	1119	1129	doi:10.1002/rra.3160
Calderon, M.R., Almeida, C.A., González, P., Jofré, M.B.	Influence of water quality and habitat conditions on amphibian community metrics in rivers affected by urban activity	Urban Ecosystems	2019	22	743	755	https://doi.org/10.1007/s11252-019-00862-w
Castañé, P.M., Sánchez-Caro, A., Salibián, A.	Water quality of the Luján river, a lowland watercourse near the metropolitan area of Buenos Aires (Argentina)	Environmental Monitoring and Assessment	2015	187	1	14	doi:10.1007/s10661-015-4882-y
César, I.I, Martín, S.M., Colla, F.M.	The Use of Littoral Benthic Macroinvertebrates of the Martín Garcia Island Nature Reserve as Indicators of Water Quality	Annual Research & Review in Biology	2019	32	1	22	DOI: 10.9734/ARRB/2019/v32i130077
Cochero, J., Cortelezzi, A., Tarda, A.S., Gómez, N.	An index to evaluate the fluvial habitat degradation in lowland urban streams	Ecological Indicators	2016	71	134	144	doi:10.1016/j.ecolind.2016.06.058
Colla, M., César, I., Salas, L.	Benthic insects of the El Tala River (Catamarca, Argentina): longitudinal variation of their structure and the use of insects to assess water quality	Brazilian Journal of Biology	2013	73	357	366	doi:10.1590/s1519-69842013000200016
Corigliano, M. d. C.	Indices bióticos: aplicaciones y alcances	Revista de la Sociedad Entomológica Argentina	1999	58	193	201	https://biotaxa.org/RSEA/article/viewFile/32769/29094
Corigliano, M. d. C.	Indices para evaluar la calidad ambiental en ríos serranos urbanos mediante indicadores	Revista de la Universidad Nacional de Río Cuarto	2008	28	33	54	https://www.academia.edu/821295/%C3%8DNDICES_PARA_EVALUAR_LA_CALIDAD_AMBIENTAL_EN_R%C3%8DOS_SERRANOS_URBANOS_MEDIANTE_INDICADORES
Cortelezzi, A., Armendáriz, L.C., López van Oosterom, M.V., Cepeda, Rodrigues Capítulo, A.	Different levels of taxonomic resolution in bioassessment: a case study of oligochaeta in lowland streams	Acta Limnologica Brasiliensia	2011	23	412	425	doi:10.1590/s2179-975x2012005000020

Table 1 (continued)

Authors	Title	Journal	Publ year	Volume	BP	EP	DOI / URL
Cortelezzi, A., Sierra, M.V., Gómez, N., Marinelli, C., Rodrigues Capítulo, A.	Macrophytes, epipelic biofilm, and invertebrates as biotic indicators of physical habitat degradation of lowland streams (Argentina)	Environmental Monitoring and Assessment	2012	185	5801	5815	doi:10.1007/s10661-012-2985-2
Cortelezzi, A., Barranquero, R.S., Marinelli, C., Fernández San Juan, M.R., Cepeda, R.E.	Environmental diagnosis of an urban basin from a social–ecological perspective	Science of The Total Environment	2019	678	267	277	https://doi.org/10.1016/j.scitotenv.2019.04.334
Crettaz, M., Juárez, R., Aguer, I., Borro, E.	Aplicación de índices de calidad de agua en un arroyo pampeano utilizando macroinvertebrados bentónicos como bioindicadores (Gualeguaychú, Entre Ríos, Argentina)	Biología Acuática	2014	30	93	105	https://www.bacuatica.org/index.php/bacuatica/article/view/25/14
Damborsky, M.P., Poi, A.G.	Aplicación de índices bióticos utilizando macroinvertebrados para el monitoreo de calidad del agua del río Negro, Chaco, Argentina	Facena	2015	31	41	52	revistas.unne.edu.ar/index.php/fce/article/download/650/561
Di Prinzio, C.Y., Casaux, R.J., Miserendino, M.L.	Effects of land use on fish assemblages in Patagonian low order streams	Annales de					Limnologie-International Journal of Limnology
2009	45	267	277				doi:10.1051/limn/2009030
Díaz, O., Colasurdo, V., Guzmán, L., Grosman, F., Sanzano, P.	Aspectos preliminares de la calidad del agua del arroyo Tapalqué en la ciudad de Olavarría, Provincia de Buenos Aires	Biología Acuática	2012	27	71	80	http://www.bacuatica.org/BA_ant/ba27.pdf
Dos Santos, D.A., Molineri, C., Reynaga, M.C., Basualdo, C.	Which index is the best to assess stream health?	Ecological Indicators	2011	11	582	589	doi:10.1016/j.ecolind.2010.08.004
Esquiús, K.S., Escalante, A.H., Solari, L.C.	Algas epífitas indicadoras de calidad del agua en arroyos vinculados a la Laguna de los Padres	Biología Acuática	2008	24	95	102	http://www.bacuatica.org/BA_ant/ba24.pdf

Table 1 (continued)

Authors	Title	Journal	Publ year	Volume	BP	EP	DOI / URL
Feijoó, C., Gantes, P., Giorgi, A., Rosso, J.J., Zunino, E.	Valoración de la calidad de ribera en un arroyo pampeano y su relación con las comunidades de macrófitas y peces	Biología Acuática	2012	27	113	128	http://sedici.unlp.edu.ar/bitstream/handle/10915/68944/Documento_completo.pdf-PDFA.pdf?sequence=1&isAllowed=y
Fernández, H.R., Romero, F., Vece, M.B., Manzo, V., Nieto, C., Orce, M.	Evaluación de tres índices bióticos en un río subtropical de montaña (Tucumán - Argentina)	Limnetica	2002	21	1	13	https://www.limnetica.com/es/evaluaci%C3%B3n-de-tres-%C3%ADndices-bi%C3%B3ticos-en-un-r%C3%ADo-subtropical-de-monta%C3%B1a-tucum%C3%A1n-argentina
Fernández, H.R., Romero, F., Domínguez, E.	Intermountain basins use in subtropical regions and their influences on benthic fauna	River Research and Applications	2009	25	181	193	https://doi.org/10.1002/rra.1114
Frau, D., Medrano, J., Calvi, C., Giorgi, A.	Water quality assessment of a neotropical pampean lowland stream using a phytoplankton functional trait approach	Environmental Monitoring and Assessment	2019	191			https://doi.org/10.1007/s10661-019-7849-6
Gallardo, L.I., Coronel, J.M., Poi, A.S.G.	Urban rain-fed lakes: macro-invertebrate assemblages associated with Egeria najas as indicators of biological integrity in wetlands of Corrientes Province (Argentina)	Biodiversity and Conservation	2019	28	1549	1568	https://doi.org/10.1007/s10531-019-01742-7
García, M.E., Rodrigues Capítulo, A., Ferrari, L.	El ensamble de invertebrados y la calidad del agua: indicadores taxonómicos y funcionales en arroyos pampeanos	Biología Acuática	2009	26	109	120	http://www.bacuatica.org/BA_ant/ba26.pdf
Giorgi, A., Rosso, J.J., Zunino, E.	Efectos de la exclusión de ganado sobre la calidad ambiental de un arroyo pampeano	Biología Acuática	2014	30	133	140	http://www.bacuatica.org/index.php/bacuatica/issue/view/5
Gómez, D., Molineri, C.	Crop landscapes reduced taxonomic and functional richness but increased evenness of aquatic macroinvertebrates in subtropical rivers	Environmental Monitoring and Assessment	2019	191			https://doi.org/10.1007/s10661-019-7864-7

Table 1 (continued)

Authors	Title	Journal	Publ year	Volume	BP	EP	DOI / URL
Gómez, N.	Use of epipelic diatoms for evaluation of water quality in the Matanza-Riachuelo (Argentina), a pampean plain river	Water Research	1998	32	2029	2034	doi.org/10.1016/S0043-1354(97)00448-X
Gómez, N.	Epipelic diatoms from the Matanza-Riachuelo river (Argentina), a highly polluted basin from the pampean plain: Biotic indices and multivariate analysis	Aquatic Ecosystem Health & Management	1999	2	301	309	doi:10.1080/14634989908656966
Gómez, N., Licursi, M.	The Pampean Diatom Index (IDP) for assessment of rivers and streams in Argentina	Aquatic Ecology	2001	35	173	181	doi.org/10.1023/A:1011415209445
Gómez, N., Licursi, M., Bauer, D.E., Ambrosio, E.S., Rodrigues Capítulo, A.	Assessment of Biotic Integrity of the Coastal Freshwater Tidal Zone of a Temperate Estuary of South America through Multiple Indicators	Estuaries and Coasts	2012	35	1328	1339	doi:10.1007/s12237-012-9528-5
Gómez, N., Cochero, J.	Un índice para evaluar la calidad del hábitat en la Franja Costera sur del Río de la Plata y su vinculación con otros indicadores ambientales	Ecología Austral	2013	23	18	26	http://ojs.ecologiaaustral.com.ar/index.php/Ecologia_Austral/article/view/321
Granitto, M., Rosso, J.J., Boveri, M.B., Rennella, A.M.	Impacto del uso del suelo sobre la condición de ribera en arroyos pampeanos y su relación con la estructura de la comunidad de peces	Biología Acuática	2016	31	19	27	http://www.bacuatica.org/index.php/bacuatica/issue/view/6
Gualdoni, C.M., Duarte, C.A., Medeot, E.A.	Estado ecológico de dos arroyos serranos del sur de Córdoba, Argentina	Ecología Austral	2011	21	149	162	http://www.scielo.org.ar/scielo.php?script=sci_arttext&pid=S1667-782X2011000200003&lng=es&nrm=iso
Hankel, G.E., Emmerich, D., Molineri, C.	Macroinvertebrados bentónicos de ríos de zonas áridas del noroeste argentino	Ecología Austral	2018	28	435	445	doi:10.25260/ea.18.28.2.0.645
Horak, C.N., Assef, Y.A., Miserendino, M.L.	Assessing effects of confined animal production systems	Agricultural Water Management	2019	216	242	253	https://doi.org/10.1016/j.agwat.2019.01.026

Table 1 (continued)

Authors	Title	Journal	Publ year	Volume	BP	EP	DOI / URL
	on water quality, ecological integrity, and macroinvertebrates at small piedmont streams (Patagonia, Argentina)						
Hued, A.C., Bistoni, M.D.L.Á.	Development and validation of a Biotic Index for evaluation of environmental quality in the central region of Argentina	Hydrobiologia	2005	543	279	298	doi:10.1007/s10750-004-7893-1
Hunt, L., Bonetto, C., Marrochi, N., Scalise, A., Fanelli, S., Liess, M., Lydy, M.J., Chiu, M.C., Resh, V.H.	Species at Risk (SPEAR) index indicates effects of insecticides on stream invertebrate communities in soy production regions of the Argentine Pampas	Science of The Total Environment	2017	580	699	709	doi:10.1016/j.scitotenv.2016.12.016
Juárez, R., Crettaz-Minaglia, M.C., Aguer, I., Juárez, I., Gianello, D., Ávila, E., Roldán, C.	Aplicación de índices bióticos de calidad de agua en cuatro arroyos de la cuenca del río Gualeguaychú (Entre Ríos, Argentina)	Intropica	2016	11	35	46	doi:10.21676/23897864.1859
Kutschker, A., Brand, C., Miserendino, M.L.	Evaluación de la calidad de los bosques de ribera en ríos del NO del Chubut sometidos a distintos usos de la tierra	Ecología Austral	2009	19	19	34	http://www.scielo.org.ar/scielo.php?script=sci_arttext&pid=S1667-782X2009000100002
Lallement, M.E., Juárez, S.M., Macchi, P.J., Vigliano, P.H.	Puyehue Cordón -Caulle: Post-eruption analysis of changes in stream benthic fauna of Patagonia	Ecología Austral	2014	24	64	74	http://ojs.ecologiaaustral.com.ar/index.php/Ecologia_Austral/article/view/38
Licursi, M., Gómez, N., Donadelli, J.	Ecological optima and tolerances of coastal benthic diatoms in the freshwater-mixohaline zone of the Río de la Plata estuary	Marine Ecology Progress Series	2010	418	105	117	doi:10.3354/meps08865
Licursi, M., Gómez, N.	Aplicación de índices bióticos en la evalución de la calidad del agua en sistemas lóticos de la llanura pampeana	Biología Acuática	2003	21	31	49	http://www.bacuatica.org/BA_ant/ba21.pdf

Table 1 (continued)

Authors	Title	Journal	Publ year	Volume	BP	EP	DOI / URL
	Argentina a partir del empleo de diatomeas						
Macchi, P., Loewy, R.M., Lares, B., Latini, L., Monza, L. Guiñazú, N., Montagna, C.M.	The impact of pesticides on the macroinvertebrate community in the water channels of the Río Negro and Neuquén Valley, North Patagonia (Argentina)	Environmental Science and Pollution Research	2018	25	10668	10678	https://doi.org/10.1007/s11356-018-1330-x
Maggioni, T., Hued, A.C., Monferrán, M.V., Bonansea, R.I., Galanti, L.N., Amé, M.V.	Bioindicators and biomarkers of environmental pollution in the Middle-Lower basin of the Suquía river (Córdoba, Argentina)	Archives of Environmental Contamination and Toxicology	2012	63	337	353	doi:10.1007/s00244-012-9785-0
Mauad, M., Miserendino, M.L., Risso, M.A., Massaferro, J.	Assessing the performance of macroinvertebrate metrics in the Challhuaco-Ñireco System (Northern Patagonia, Argentina)	Iheringia, Série Zoologia	2015	105	348	358	DOI: 10.1590/1678-476620151053348358
Mercado, L.M.	Evaluación de la calidad de las aguas de seis sistemas lóticos pampásicos mediante el estudio de variables fisicas y químicas	Revista del Museo Argentino de Ciencias Naturales Nueva Serie	2000	2	27	35	http://revista.macn.gov.ar/ojs/index.php/RevMus/article/view/121
Merlo, C., Abril, A., Amé, M.V., Argüello, G.A., Carreras, H.A., Chiappero, M.S., Hued, A.C., Wannaz, E., Galanti, L.N., Monferrán, M.V., González, C.M., Solís, V.M.	Integral assessment of pollution in the Suquía River (Córdoba, Argentina) as a contribution to lotic ecosystem restoration programs	Science of The Total Environment	2011	409	5034	5045	doi:10.1016/j.scitotenv.2011.08.037
Mesa, L.M.	Effect of spates and land use on macroinvertebrate community in Neotropical Andean streams	Hydrobiologia	2010	641	85	95	doi:10.1007/s10750-009-0059-4
Mesa, L.M.	Influence of riparian quality on macroinvertebrate assemblages in subtropical mountain streams	Journal of Natural History	2014	48	1153	1167	doi:10.1080/00222933.2013.861937
			1999	11	137	148	

Table 1 (continued)

Authors	Title	Journal	Publ year	Volume	BP	EP	DOI / URL
Miserendino, M.L., Pizzolón, L.A.	Rapid assessment of river water quality using macroinverterbrates: A family level biotic index for the patagonic andean zone	Acta Limnologica Brasiliensia					http://ablimno.org.br/acta/pdf/acta_limnologica_contents1102E_files/Artigo%2011_11(2).pdf
Miserendino, M.L.	Macroinvertebrate functional organization and water quality in a large arid river from Patagonia (Argentina)	Annales de					Limnologie-International Journal of Limnology
2007	43	133	145				doi:10.1051/limn:2007008
Miserendino, M.L., Brand, C., Di Prinzio, C.Y.	Assessing urban impacts on water quality, benthic communities and fish in streams of the Andes mountains, Patagonia (Argentina)	Water, Air, & Soil Pollution	2008	194	91	110	doi:10.1007/s11270-008-9701-4
Miserendino, M.L., Masi, C.I.	The effects of land use on environmental features and functional organization of macroinvertebrate communities in Patagonian low order streams	Ecological Indicators	2010	10	311	319	doi:10.1016/j.ecolind.2009.06.008
Miserendino, M.L., Casaux, R., Archangelsky, M., Di Prinzio, C.Y., Brand, C., Kutschker, A.M.	Assessing land-use effects on water quality, in-stream habitat, riparian ecosystems and biodiversity in Patagonian northwest streams	Science of The Total Environment	2011	409	612	624	doi:10.1016/j.scitotenv.2010.10.034
Miserendino, M.L., Archangelsky, M., Brand, C., Epele, L.B.	Environmental changes and macroinvertebrate responses in Patagonian streams (Argentina) to ash-fall from the Chaitén Volcano (May 2008)	Science of The Total Environment	2012	424	202	212	doi:10.1016/j.scitotenv.2012.02.054
Miserendino, M.L., Kutschker, A., Brand, C., La Manna, L., Di Prinzio, C.Y., Papazian, G., Bava, J.	Ecological Status of a Patagonian Mountain River: Usefulness of Environmental and Biotic Metrics for Rehabilitation Assessment	Environmental Management	2016	57	1166	1187	doi:10.1007/s00267-016-0688-0
			2006	112	271	281	doi:10.1007/s10661-006-1078-5

Table 1 (continued)

Authors	Title	Journal	Publ year	Volume	BP	EP	DOI / URL
Momo, F.R., Casset, M.A., Gantes, P., Torremorell, A.M., Perelli, R.M.	Relationship between micro-invertebrates and macrophytes in a wetland: Laguna Iberá (Corrientes, Argentina). Implications for water quality monitoring	Environmental Monitoring and Assessment					
Monferrán, M.V., Galanti, L.N., Bonansea, R.I., Amé, M.V., Wunderlin, D.A.	Integrated survey of water pollution in the Suquía River basin (Córdoba, Argentina)	Journal of Environmental Monitoring	2010	13	398	409	doi:10.1039/c0em00545b
O'Farrell, I., Lombardo, R.J., De Tezanos Pinto, P., Loez, C.	The assessment of water quality in the Lower Luján River (Buenos Aires, Argentina): Phytoplankton and algal bioassays	Environmental Pollution	2002	120	207	218	doi:10.1016/S0269-7491(02)00136-7
Ocón, C.S., Rodrigues Capítulo, A., Paggi, A.C.	Evaluation of zoobenthic assemblages and recovery following petroleum spill in a coastal area of Río de la Plata estuarine system, South America	Environmental Pollution	2008	156	82	89	doi:10.1016/j.envpol.2007.12.035
Ocón, C.S., Rodrigues Capítulo, A.	Assessment of water quality in temperate-plain streams (Argentina, South America) using a multiple approach	Ecología Austral	2012	22	81	91	https://digital.bl.fcen.uba.ar/download/ecologiaaustral/ecologiaaustral_v022_n02_p081.pdf
Olguín, H.F., Puig, A., Loez, C.R., Salibián, A., Topalián, M.L., Castañé, P.M., Rovedatti, M.G.	An integration of water physicochemistry, algal bioassays, phytoplankton, and zooplankton for ecotoxicological assessment in a highly polluted lowland river	Water, Air, & Soil Pollution	2004	155	355	381	doi:10.1023/B:WATE.0000026538.51477.c2
Oliva González, S., Almeida, C.A., Calderón, M., Mallea, M.A., González, P.	Assessment of the water self-purification capacity on a river affected by organic pollution: application of chemometrics in spatial and temporal variations	Environmental Science and Pollution Research	2014	21	10583	10593	doi:10.1007/s11356-014-3098-y
	Impacto de la contaminación orgánica sobre el	Ecología Austral	2017	27	437	448	https://doi.org/10.25260/EA.17.27.3.0.579

Table 1 (continued)

Authors	Title	Journal	Publ year	Volume	BP	EP	DOI / URL
Padulles, M.L., Conforti, V.T.D., Nannavecchia, P., O'Farrell, I.	fitoplancton de un arroyo de la llanura pampeana						
Paggi, A.C., Ocón, C., Tangorra, M., Rodrigues Capítulo, A.	Response of the zoobenthos community along the dispersion plume of a highly polluted stream in the receiving waters of a large river (Rio de la Plata, Argentina)	Hydrobiologia	2006	568	1	14	doi:10.1007/s10750-005-0010-2
Pavé, P.J., Marchese, M.	Invertebrados bentónicos como indicadores de calidad del agua en ríos urbanos (Paraná-Entre Ríos, Argentina)	Ecología Austral	2005	15	183	197	https://digital.bl.fcen.uba.ar/download/ecologiaaustral/ecologiaaustral_v015_n02_p183.pdf
Pesce, S.F., Wunderlin, D.A.	Use of water quality indices to verify the impact of Córdoba City (Argentina) on Suquía river	Water Research	2000	34	2915	2926	doi.org/10.1016/S0043-1354(00)00036-1
Pizzolón, L., Miserendino, M.L.	The performance of two regional biotic indices for running water quality in Northern Patagonian Andes	Acta Limnologica Brasiliensia	2001	13	11	27	http://www.ablimno.org.br/acta/pdf/acta_limnologica_contents1301E_files/Artigo%202_13(1).pdf
Rautenberg, G.E., Amé, M.V., Monferrán, M.V., Bonansea, R.I., Hued, A.C.	A multi-level approach using Gambusia affinis as a bioindicator of environmental pollution in the middle-lower basin of Suquía River	Ecological Indicators	2014	48	706	720	doi:10.1016/j.ecolind.2014.09.025
Rodrigues Capítulo, A., Tangorra, M., Ocón, C.	Use of benthic macroinvertebrates to assess the biological status of Pampean streams in Argentina	Aquatic Ecology	2001	35	109	119	doi:10.1023/A:1011456916792
Rodrigues Capítulo, A., Ocón, C.S., Tangorra, M.	Una visión bentónica de arroyos y ríos pampeanos	Biología Acuática	2003	21	1	18	https://revistas.unlp.edu.ar/bacuatica/issue/view/504
Rosso, J.J., Cirelli, A.F.	Effects of land use on environmental conditions and macrophytes in prairie lotic ecosystems	Limnologica	2013	43	18	26	doi.org/10.1016/j.limno.2012.06.001

Table 1 (continued)

Authors	Title	Journal	Publ year	Volume	BP	EP	DOI / URL
Sánchez Caro, A., Giorgi, A., Doyle, S., Piccinini, M.	La calidad del agua del río Luján (Buenos Aires) y el potencial aporte del biofilm para su evaluación	Biología Acuática	2012	27	191	208	http://www.bacuatica.org/BA_ant/ba27.pdf
Sirombra, M.G., Mesa, L.M.	A method for assessing the ecological quality of riparian forests in subtropical Andean streams: QBRy index	Ecological Indicators	2012	20	324	331	doi:10.1016/j.ecolind.2012.02.021
Taglioretti, V., Rossin, M.A., Timi, J.T.	Fish-trematode systems as indicators of anthropogenic disturbance: effects of urbanization on a small stream	Ecological Indicators	2018	93	559	570	doi.org/10.1016/j.ecolind.2018.05.039
Tripole, E.S., Corigliano, M. del C.	Acid stress evaluation using multimetric indices in the Carolina stream (San Luis –Argentina)	Acta Limnologica Brasiliensia	2005	17	101	114	http://ablimno.org.br/acta/pdf/acta_limnologica_contents1701E_files/Acta17,1(10).pdf
Tripole, S., González, P., Vallania, A., Garbagnati, M., Mallea, M.	Evaluation of the impact of acid mine drainage on the chemistry and the macrobenthos in the Carolina stream (San Luis-Argentina)	Environmental Monitoring and Assessment	2006	114	377	389	doi:10.1007/s10661-006-4941-5
Tripole, S., Vallania, E.A., Corigliano, M.d.C.	Benthic macroinvertebrate tolerance to water acidity in the Grande river sub-basin (San Luis, Argentina)	Limnetica	2008	27	29	38	http://www.limnetica.org/Limnetica/Limne27/L27a029_Tolerance_macroinvertebrate_acidification.pdf
Vallania, E.A., Garelis, P.A., Trípole, E.S., Gil, M.A.	Un índice biótico para las sierras de San Luis (Argentina)	Revista de la Universidad Nacional de Río Cuarto	1996	16	129	136	
Vignolo, A., Pochettino, A., Cicerone, D.	Water quality assessment using remote sensing techniques: Medrano Creek, Argentina	Environmental Management	2006	81	429	433	doi:10.1016/j.jenvman.2005.11.019
von Ellenrieder, N.	Composition and structure of aquatic insect assemblages of Yungas mountain cloud forest streams in NW Argentina	Revista de la Sociedad Entomológica Argentina	2007	66	57	76	https://www.biotaxa.org/RSEA/article/view/31508/0

Table 1 (continued)

Authors	Title	Journal	Publ year	Volume	BP	EP	DOI / URL
Zagarola, J-P.A., Martínez Pastur, G., López, M.E., Anderson, C.B.	Assessing the effects of urbanization on streams in Tierra del Fuego	Ecología Austral	2017	27	45	54	
Zambrano, M.J., Rautenberg, G.E., Bonifacio, A.F., Filippi, I., Amé, M.V., Bonansea, R.I., Hueda, A.C.	Effects of water quality on aspects of reproductive biology of C*nesterodon decemmaculatus*	Science of The Total Environment	2018	645	10	21	https://doi.org/10.1016/j.scitotenv.2018.07.084
Zilli, F., Gagneten, M.	Efectos de la contaminación por metales pesados sobre la comunidad bentónica de la cuenca del arroyo Cululú (Río Salado del Norte, Argentina)	Interciencia	2005	30	159	165	http://www.scielo.org.ve/scielo.php?pid=S0378-18442005000300009&script=sci_arttext&tlng=pt

Appendix 2

Representation of the different types of index used in the sampling sites from each peer-reviewed studies (kml file)

Appendix 3. Survey on the use of biological indices in Argentina

1 How much experience do you have in bioindication?

   a ≤ 2 years
   b Between 3 and 6 years
   c > 6 years

2 What method do you use the most?

   a Biotic index
   b Diversity and derivatives
   c Multimetric
   d Functional
   e Others

3 The use of these methods was used by some application agency?

   a Yes

      i Once
      j More than one ocassion

   b No

4 Would you recommend to a colleague the method used?

   a Yes
   b No

5 Would you recommend to the application agency the method used?

   a Yes
   b No

6 Is it possible its application by a technician or non-scientific personnel?

   a Yes
   b No

7 If the answer was yes in the previous question, how long would it take to train them?

   a < 3 months
   b Between 4 and 6 months
   c > 6 months

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