Context matters: An insider's view on freshwater ecosystem research in Latin America

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Abstract: Freshwater science has grown and evolved extensively since its inception in the late 1800s. Many of the models and conceptual frameworks developed for and used in freshwater research were originally proposed by researchers in the Global North to explain patterns and processes in temperate streams. This view of freshwater ecosystems has extended to research in Latin America, potentially limiting our ability to understand unique ecological and socioeconomic attributes of the watersheds found in our region. Recently, there has been an increase in freshwater research being conducted by Latin American scientists, who may be able to apply and validate more suitable models and conceptual frameworks given their personal experiences and insights about local realities. In this *BRIDGES* cluster, we feature the work of early career Latin American researchers who are addressing environmental concerns pertinent to the region through research that challenges some of the ideas developed for river networks in the Global North.
Key words: model, conceptual framework, extrapolation, transferability, Latin American scientists, ecology, stream ecosystem

Freshwater research has played an important role in advancing our understanding of general ecology, environmental health concerns, and socioecological systems. In the last 50 y, the number of articles published describing general patterns in freshwater ecosystems has rapidly increased (Minshall 1988, Thompson and Lake 2010). This knowledge laid the foundation for the development of numerous models and conceptual frameworks (MCFs) in freshwater ecology. Most MCFs that freshwater scientists employ when developing and framing their research questions were originally proposed, developed, tested, and validated by scientists based in the Global North (mainly western Europe, the United States [USA], and Canada) for systems in temperate climates. The MCFs developed in temperate watersheds in the northern hemisphere have been applied to freshwater research in other latitudes. However, using them outside of their region of development may be problematic because of key differences in social, economic, and ecological characteristics among regions (Moulton and Wantzen 2006).

Freshwater research in Latin America has been steadily increasing in the last few decades (Ramírez and Gutiérrez-Fonseca 2014). This progress is exemplified by the rising number of published articles (a 275% increase from

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2000–2013) and the establishment of national (e.g., Argentine Association of Limnology) and international (e.g., Macrolatinos@) scientific societies focused on freshwater science. Similar to research in the Global North, local socioeconomic and ecological conditions significantly shape the production of knowledge and the kinds of questions Latin American researchers seek to answer. However, freshwater research in Latin America has been strongly influenced and guided by MCFs that were originally proposed in the Global North. Applying MCFs developed elsewhere can be valuable because they may validate the original postulates and assumptions within new socioecological contexts. Furthermore, testing MCFs in Latin America may inspire new areas of research. In contrast, uncritical application of MCFs established in temperate northern watersheds to Latin American ecosystems may discourage critical thinking, lead to spurious conclusions, and impede the generation of new ideas in freshwater science.

To contribute to the growing body of knowledge on Latin American freshwater ecosystems, this *BRIDGES* cluster evaluates 2 MCFs that were developed in the Global North but have been applied to research in Latin America for decades. Marques and Cunico (2023) evaluated the postulates of the urban stream syndrome for streams in Latin America and emphasized the importance of wastewater flux and treatment in predicting the structure and function of urban streams. Cortelezzi and Paz (2023) examined how biological indices developed in the Global North for evaluating and quantifying the ecological condition of lotic systems have been applied in Latin America. In their discussion, the authors highlight major shortcomings in the application of biological assessments in Latin America, including a lack of taxonomic knowledge that underlies bioassessments, reliance on indices developed in different regions of the world, and a dearth of programs employing modern techniques that allow practitioners to estimate detection probabilities of different species.

TESTING MCFs IN LATIN AMERICA

Ecologists have documented several challenges and limitations in the predictive performance of MCFs when applied in areas outside of where models were initially developed. These issues can arise even on small spatial scales (e.g., within the same region). In addition to ecological differences, cultural, political, and socioeconomic differences can exacerbate challenges in the applicability of MCFs across geographies. Consequently, some models from the Global North have not been fully supported in freshwater ecosystems of Latin America. For example, Greathouse and Pringle (2005) tested the River Continuum Concept (RCC; Vannote et al. 1980) in Puerto Rican streams. Their findings supported the general postulates of the RCC and documented predicted longitudinal changes in the proportions of scrapers, shredders, and predators, but their findings about collector–filterers conflicted with the predictions of the concept. Their results suggest that biotic interactions (i.e., predation), rather than longitudinal changes in food sources, may most strongly affect the distribution of dominant filter feeders on tropical islands (i.e., shrimp). Thus, incorporating interactions between species seems to be important to the refinement of the RCC when extrapolated from one context to another.

Differences in the physicochemical environment also influence the applicability of MCFs to systems outside of northern temperate latitudes. For instance, low-order Pampean streams have been shown to have much higher nutrient uptake and metabolic rates than those observed for low-order streams in temperate regions of Europe and North America (i.e., USA and Canada). The difference is associated with the high nutrient retention efficiency of these South American streams (García et al. 2017, Martí et al. 2020). Similarly, the Southern Urban Hydrosystem Syndrome was recently adapted (see Wantzen et al. 2019) from the urban stream syndrome (Walsh et al. 2005) for use in Latin America and considers both the biophysical and the social contexts of Latin America. Marques and Cunico (2023) discuss some of these modifications in this *BRIDGES* cluster.

EVALUATING NEW AND ESTABLISHED MCFs

The MCFs proposed in the Global North are extremely valuable outside their original context because they can inspire the development of new research endeavors in regions that are understudied and provide strong foundations on which to develop and test hypotheses in new systems. Globalization and increasingly accessible analytical tools and technology will provide researchers from around the world the ability to test established MCFs in their own regions. Here, we propose a guide to evaluate and test new and established MCFs in regions outside of their origin (i.e., model transferability), including a workflow for local scientists to use to support the generation of contextually relevant findings. The transferability (i.e., the ability of a model to produce accurate and precise predictions for a new set of conditions that differ from those on which the model was calibrated) of MCFs has been discussed by various authors (e.g., Yates et al. 2018), but most proposed frameworks have focused on the application of species distribution models. We expand on the concept of transferability to capture not only ecological phenomena but also socioeconomic, cultural, and political differences between the Global North and the geographic region of interest.

Proposed workflow

We describe 4 phases that should be considered when evaluating new or established MCFs from the Global North in the Global South (Fig. 1).

Groundwork phase In this phase, researchers should consider the socioeconomic and ecological context in which

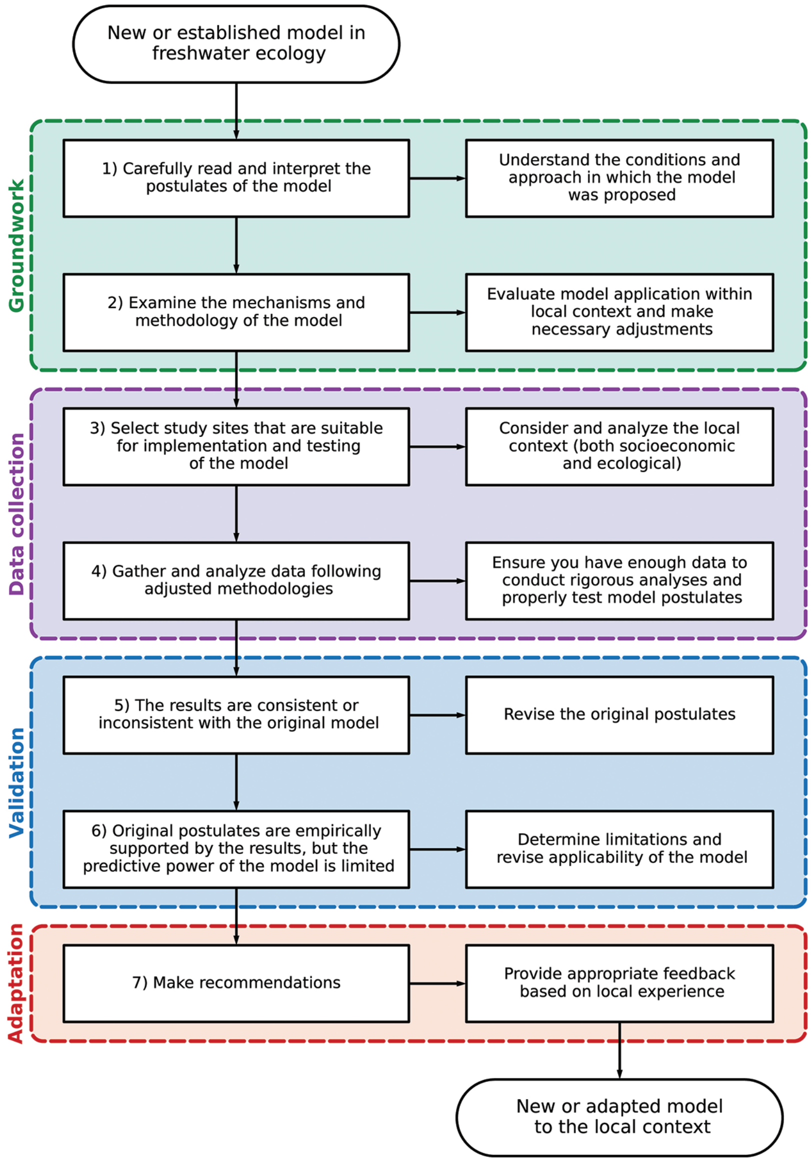

Figure 1. Workflow for researchers to consider when testing the transferability of models or conceptual frameworks (MCFs) to new regions or environmental settings. We describe 4 phases that should be considered for the transferability of MCFs: 1) the groundwork phase involves clearly understanding the postulates, assumptions, and mathematical characterization of the MCF of interest; 2) the data collection phase involves selecting suitable study sites and collecting appropriate data for testing the MCF; 3) the validation phase involves evaluating the data and determining which postulates were supported by the empirical evidence; and 4) the adaptation phase involves refining the MCF with contextually appropriate recommendations for its applicability in the region.

their study will take place. Explicitly stating the spatial, temporal, and ecological domains to which the MCF applies will be critical for the subsequent stages. The groundwork phase must also clearly describe the postulates, assumptions, and mathematical characterization of the MCF of interest.

Data collection phase In this phase, researchers must demonstrate that the selected study sites are appropriate for evaluating the proposed MCF. Moreover, enough data must be gathered to draw robust conclusions, allow rigorous testing of the postulates, and avoid spurious results associated with small sample size and low replication.

Validation phase In this phase, the results obtained through the data collection phase should be evaluated to determine which postulates were supported by the empirical evidence. In this phase, it is important to contrast study outcomes with the outcomes predicted by the original MCF to establish the MCF's generality, robustness, and possible limitations.

Adaptation phase In this phase, results should be used to refine the MCF with contextually appropriate recommendations for its applicability in the region. These recommendations could include modifying the variables, assumptions, or methods proposed in the original MCF.

OPPORTUNITIES AND FUTURE CONSIDERATIONS

National and international collaborations provide valuable opportunities for the advancement of science (Cullen et al. 1999). At present, there are several country-specific and regional societies dedicated to advancing freshwater science in Latin America. Collective research programs organized through these groups may be harnessed to test MCFs developed in the Global North and support the development of MCFs from within the Latin American research community (e.g., Sioli 1956, Junk et al. 1989).

Collaborations with researchers from other regions (e.g., Global North) can be highly beneficial for the development and growth of scientific research programs in Latin America. These scientific alliances can draw on the knowledge and experience of scientific societies with a long history of fostering collaborative research and innovation (e.g., Society for Freshwater Science). Researchers can benefit from sharing costs and tackling complex questions at broad geographic scales, enabling ecologists to move from local to global inferences. In addition, as collaborative publications are usually highly cited (Wojciechowski et al. 2017), the results from these collaborations can gain more visibility and extend to a wide variety of audiences.

We recognize that research in Latin America faces multiple challenges. For example, although the World Bank classifies most countries in the Global South as low to upper-middle income, financial support for environmental research—when available—tends to be low. Additionally, because of economic instability in some countries in Latin America, many research techniques are difficult to access and implement. For instance, funding available from the science agency in Argentina to large research groups is ~USD $40,000 and must be used in 3 y, while funding to early career researchers is ~USD $5000 and must be used in 2 y. This level of investment is likely higher than many other Latin American countries, but it does not adequately cover the costs of scientific equipment, staffing, and infrastructure needed for large-scale research projects. Thus, obtaining higher funding and recognizing the importance of the freshwater sciences are 2 of the most important issues to consider when attempting to validate established MCFs or develop new ones in Latin America.

Collectively, the manuscripts included in this *BRIDGES* cluster emphasize that MCFs developed in the Global North need to be evaluated carefully and critically before assuming they apply in Latin America. Differences in local context and the availability of the data and techniques needed to apply existing MCFs may compromise their applicability outside of the region for which they were designed. The guide we describe here may support future researchers in testing existing MCFs and developing new models that are locally and contextually appropriate. With these recommendations, we strive to build local knowledge and stimulate more collaborative research in Latin American freshwater science.

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