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Tropical freshwater sciences: an overview of ongoing tropical research

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Ecosystems within the tropics range from warm and humid lowland jungles to snow-covered mountains. The streams that drain these systems vary widely and provide a diversity of opportunities to test current theories or devise new ones. For some ecological phenomena, tropical studies have supported theories or models based on information from temperate regions. For example, the River Continuum Concept appears to be an appropriate framework within which to understand tropical streams (Greathouse and Pringle 2006). In other cases, the evidence is less conclusive, and new concepts might be necessary to describe observed tropical phenomena. For example, most temperate studies suggest a strong reliance of stream food webs on allochthonous C inputs, but several tropical studies have pointed toward autochthonous sources as the main energy source (Dudgeon et al. 2010) in low-order forested streams. For other ecological phenomena, tropical studies formed the basis for the theories or models. In these cases, the uniqueness of some tropical ecosystems inspired their selection as study sites and the resulting advances in research. For example, the flood-pulse concept was developed for large tropical rivers with strong hydrological seasonality (Junk 1999) and later applied to other systems with strong interactions between rivers and their floodplains.

Authors often argue that limited information is available from the tropics, but the number of publications from research conducted on freshwater systems in the tropics has increased significantly in recent years (Dudgeon 2008). We surveyed 2 journals (*Journal of the North American Benthological Society* [JNABS]/*Freshwater Science* [FWS] and *Freshwater Biology*) for articles about tropical ecosystems (Fig. 1). Fluctuations in the number of papers published annually are evident, but the percentage of articles dealing with the tropics ranges from 5 to 10% of

the total papers published in those journals since ~2000. In a similar survey, Ramírez and Gutiérrez-Fonseca (2014) found 500 papers on freshwater macroinvertebrates in Latin America published during the period 2000–2013. After an initial steep increase in publications, numbers have stabilized at ~50/y since 2006. Brazil, Colombia, Argentina, and Costa Rica were the most common study sites (Ramírez and Gutiérrez-Fonseca 2014). The recent increase in tropical studies is most evident in Latin America and Australia, but large areas of the tropics in Asia and Africa are not as actively researched and the number of publications from these regions is increasing more slowly. Dominguez and dos Santos (2014) studied coauthorship networks among researchers working on the taxonomy of Ephemeroptera in South America. They found an increase over time in papers authored by local taxonomists that coincided with decreasing work by nonresident taxonomists and increased international collaboration.

This special series is the 5th compendium of studies of tropical fresh waters published in JNABS/FWS. Previous special series were published in JNABS in 1988 (Stanford and Covich 1988), 1995 (Jackson and Sweeney 1995), 2006 (Wantzen et al. 2006), and 2009 (Boyero et al. 2009). Some of the previous special series arose from papers presented in special sessions at annual meetings of the North American Benthological Society, but we conceived the present special series as an effort to highlight ongoing freshwater research that is taking place in the tropics. Our main goal was to present a picture of ongoing efforts rather than to focus on a particular subject or region. The geographic distribution of the studies presented is a reflection of the uneven research activity around the tropics. Most contributions came from research conducted in Australia (6 papers), Latin America (5 papers), and Malaysia (2 papers). Research also was conducted at 1 site in Asia and 1 in Africa as part of

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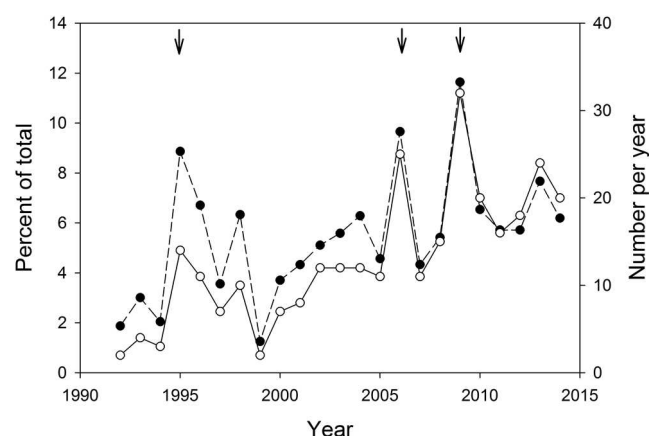


Figure 1. Number of publications related to the tropics published in the *Journal of the North American Benthological Society* (JNABS)/*Freshwater Science* (FWS), and *Freshwater Biology* since 1992. The dashed line (closed circles) represents the percentage of tropical publications per year and the continuous line (open circles) the number of tropical publications. Arrows indicate the tropical special issues published in JNABS/FWS. Papers were counted as tropical if they included the term “tropic” in the title, abstract, or key words.

a pantropical study. The collection of works included in this special series shows a strong emphasis on the study of natural systems, indicating the continued need for fundamental information on the ecology of tropical systems.

Complex life histories

Tropical fresh waters are inhabited by a large diversity of fauna, and many examples of unique and complex life histories are known from tropical regions. Coastal fauna often include groups of marine-derived organisms with life stages adapted to inhabit both environments. Many species of freshwater decapods and some fish species present this type of adaptation (McDowall 2007). In this issue, Novak et al. (2015) discuss the life history of a shrimp species from a large tropical river in Australia that follows this pattern. In addition, Crook et al. (2015) discuss how the study of otolith microchemistry can aid in understanding the life histories of fish species that inhabit coastal rivers.

Environmental and biotic controls over freshwater fauna

The roles of environmental and biotic factors in controlling the distribution of freshwater fauna in tropical environments are poorly studied. Several authors in this series emphasize this information gap in different tropical regions. The importance of environmental factors in controlling invertebrate assemblages is highlighted in studies from Australia (Davis et al. 2015) and Belize (Carrie et al. 2015). In both regions, environmental variations in space and time explain patterns in macroinvertebrate assemblage composition and abundance. In tropical dry–wet en-

vironments, seasonal changes in temperature affect aquatic fauna, such as fish (Wallace et al. 2015). As in freshwater ecosystems elsewhere, the strength of trophic interactions in northern Australia varies spatially (Garcia et al. 2015).

Aquatic fauna and the processing of organic matter

The process of leaf-litter breakdown is a major research focus in tropical streams, as it has been in temperate streams (Webster and Benfield 1986, Tank et al. 2010). Early studies in the tropics indicated that tropical streams might be shredder-poor environments, and this question continues to be explored now, by considering more complexity, such as changes in assemblage composition along elevation gradients. The relative importance of temperature and litter quality is explored across elevation gradients by Jinggut and Yule (2015). Martins et al. (2015) and Yule et al. (2015) use leaf-litter breakdown as a tool to understand how urbanization affects ecosystem function of tropical streams. Last, Boyero et al. (2015) present the results of a pantropical study that highlights the large amount of variability in this process within and among tropical regions.

Conservation issues

Like all freshwater ecosystems, tropical streams face a variety of anthropogenic impacts. The challenges created by these impacts are reflected in an increasing focus on conservation issues and on understanding the effects of threats, such as agriculture and urbanization, on tropical streams. This focus is highlighted by studies of the effects of urban land use on leaf-litter processing and ecosystem function of streams in central Amazonia (Martins et al. 2015) and in Malaysia (Yule et al. 2015), and the effects of agricultural activities on macroinvertebrates in Andean streams (Chará-Serna et al. 2015). King et al. (2015) analyze the consequences of water extraction on the hydrology and ecology of rivers in the Australian savannah, and their results provide insights of value for streams draining other savannahs. Invasive species, such as trout (Vimos et al. 2015) and armored catfish (Capps and Flecker 2015) in Latin America, also strongly affect the functioning of tropical stream ecosystems.

Syntheses

Freshwater research is progressing at different rates around the tropics, and the depth of research in some areas has led to reviews of particular topics (e.g., Dudgeon 2008). Last, a synthesis of research on the Queensland Wet Tropics provides in-depth understanding of this unique system and a better understanding of tropical freshwater ecosystems in general (Pearson et al. 2015).

The collection of studies in this special issue reflects the diversity of research taking place in the tropics. Much remains to be done, but tropical research is playing an important role advancing certain areas of stream ecology.

For example, our understanding of ecosystem processes, such as leaf-litter breakdown, is benefiting from tropical examples, where noninsect fauna (e.g., decapods) play important roles breaking down organic matter. Some of these groups have complex life cycles that make them particularly vulnerable to anthropogenic impacts. We expect similar contributions to become more common in other research areas, as researchers continue to use the tropics as laboratories to advance our understanding of freshwater ecosystems.

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