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New vistas in Neotropical stream ecology—Preface

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Most of our current models for stream nutrient dynamics, decomposition, and regulation of community structure have been derived from extensive and detailed research on lotic systems in the temperate zone. We have scarcely researched even a small fraction of the extensive aquatic ecosystems in the tropics. The vast Neotropical region contains the greatest concentration of biodiversity (species) on planet Earth. Streams and rivers of tropical South America, Central America, and the Caribbean Islands encompass varied landscapes and biogeographic regions. Most streams in South America are part of large drainage basins, the largest being the Amazon, Paraná, and Orinoco. Streams draining Central America and the Caribbean islands have small drainage basins, generally steep gradients, and close proximity to the ocean. Regional environmental heterogeneity in the tropics is particularly influenced by patterns of precipitation (seasonal vs aseasonal, mesic vs arid) and soils/geology (e.g., acidic blackwaters vs neutral whitewaters). Neotropical streams may be nearly as environmentally diverse as the rich faunas and floras that they support.

This diversity of Neotropical streams stands in marked contrast to our limited knowledge of their ecology. An increase in effort has been evident since the status of tropical streams was reviewed in the symposium "Community Structure and Function in Temperate and Tropical Streams" held in 1987 (Stanford and Covich 1988). Despite the paucity of research, major advancements have been made in several areas, including the taxonomy of tropical stream invertebrates (e.g., caddiesflies: Holzenthal 1995, stoneflies: Zúñiga and Stark 2002, mayflies: Dominguez et al., in press), and documentation of stream biodiversity in some regions (e.g., Flowers 1991, Melo and Froehlich 2001). We also have seen advancements in our understanding of tropical stream biogeochemistry (e.g., Pringle et al. 1993, McClain et al. 1994, McClain and Elsenbeer 2001), foodweb interactions (e.g., Walker 1985, Walker et al. 1991, Winemiller 1990, Pringle and Hamazaki 1998), and human impacts on stream ecosystems (e.g., Biggs et al. 2004). This special series contains reports of new findings on these and other topics from studies of streams and rivers ranging from Caribbean islands to the Orinoco llanos and Amazonian rainforests.

Overall, the number of publications dealing with tropical lotic systems has been increasing steadily over the last decade. A quick search of the Web of Science® using the keywords "tropical stream" and "tropical river" provides clear evidence of this trend. The number of publications/y from 1993 to 1996 was <15 and, by 2004, that number had more than doubled (Fig. 1). Despite these gains, we are still lacking a clear picture of how tropical stream ecosystems function. All too often, we are forced to rely on information from other geographic regions to answer questions about the ecological integrity of streams or to interpret impacts of human activities. The need is pressing for more detailed research, both basic and applied, to inform management and conservation decisions. Moreover, potential reference streams and rivers are being impacted rapidly in most tropical regions. Thus, irreplaceable information that could guide restoration is being lost.

Basing management decisions for tropical streams on assumptions founded in temperate stream research

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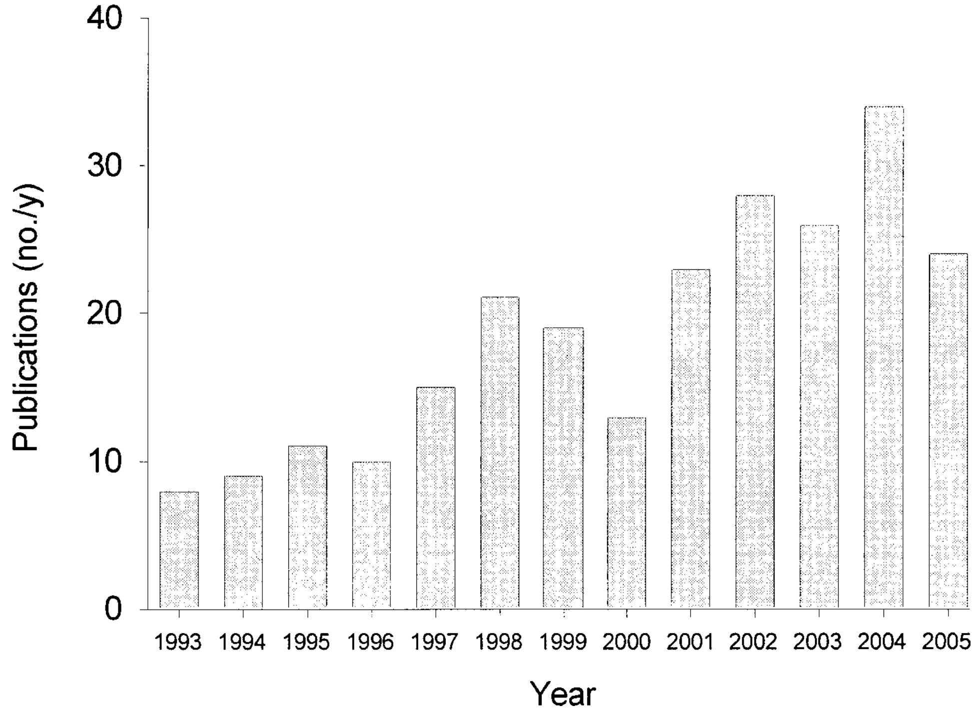

FIG. 1. Total annual publications (1993–2005) resulting from a search of the Web of Science® using the keywords "tropical stream" and "tropical river".

is a highly tenuous practice. Recent studies on the effects of nutrient loading in streams provide a good example. Cultural eutrophication affects freshwater and coastal ecosystems worldwide. Agencies currently are focused on the effects of nutrients on aquatic primary producers (typically algae) when setting standards for allowable nutrient concentrations. However, aquatic food webs may be supported by detritus (organic C from dead plant material, especially leaves and wood of allochthonous origin and associated bacteria and fungi). Studies of lowland streams in Costa Rica showed that an increase in nutrients can affect processes in detritus-based food webs at a landscape scale. Several factors, such as detritus processing rates (Rosemond et al. 2002) and insect production dynamics (Ramírez and Pringle 2006), respond dramatically to increases in stream P concentrations that are well within current water-quality standards. We remain poorly informed about the effects of nutrients on detritus-based food webs even as biogeochemical cycles of elements, such as P, change globally. Temperate streams tend to be affected by channelization and excessive nutrient runoff from fertilizers, whereas many tropical streams receive direct inputs of municipal sewage (Biggs et al. 2004) and sediments associated with land conversion (Mol and Ouboter 2004, Wantzen 2006). These trends imply the need for different management priorities and strategies for streams in these regions.

This special series is the result of recent efforts to advance understanding of Neotropical stream ecology. Initial findings from the studies presented here were reported during annual meetings of the Association for Tropical Biology and Conservation in Panama (2003), the North American Benthological Society in Athens, Georgia (2003), and the Ecological Society of America in Portland, Oregon (2004). Special sessions were convened to address tropical stream ecology with emphasis on the Neotropical region. Two overarching issues are addressed by the diverse contributions in this series: 1) the importance of spatial and temporal environmental variation for ecological processes and community structure, and 2) the functional role of species in ecosystem processes.

Spatial and Temporal Variation

Tropical regions do not have strong thermal seasonality, but most of them experience some degree of seasonality in rainfall. Rainfall, in turn, governs stream hydrology. In many of the studies in this series, important ecosystem patterns and processes, as well as patterns of community composition, show strong responses to seasonal precipitation. Seasonal ecological dynamics are pronounced in lowland South American rivers where rivers connect with aquatic floodplain habitats during annual flood pulses (Junk et al. 1989, Junk and Wantzen 2004). The Cinaruco River, a tributary of the Orinoco, is the subject of several of the studies in this series (Arrington and Winemiller 2006, Cotner et al. 2006, Montoya et al. 2006, Roelke et al. 2006, Winemiller et al. 2006). Located in the flat grasslands of the llanos, the Cinaruco undergoes gradual, yet major, water-level changes over the annual cycle of wet and dry seasons. In contrast, small streams in Central America and the Caribbean show less predictable patterns of annual hydrological variation in which discharge spikes follow rainy-season spates (e.g., Pringle and Hamazaki 1997). Small lowland floodplain streams in Amazonia show a mixed hydrological pattern between these extremes, with alternating phases of flashy and backflooded discharge (Rueda-Delgado et al. 2006). Even streams draining tropical humid forests display some degree of seasonality in their discharge patterns and associated ecological processes (Forti and Neal 1992). Seasonal changes in discharge influence substrates and periphyton (Pringle and Hamazaki 1997, Montoya et al. 2006). Aquatic fauna also respond to the habitat disturbance regime and patch dynamics (Flecker 1997, Arrington and Winemiller 2006, Blanco and Scatena 2006, Covich et al. 2006, Ramírez et al. 2006).

In addition to seasonal variation in water discharge, spatial variation strongly affects ecological processes in tropical streams as emphasized by several studies in this series. The importance of spatial variability is highlighted in relation to the presence of migratory barriers (e.g., waterfalls) that create predator-free environments (Covich et al. 2006), changes in water physicochemistry in relation to inputs from groundwater or the geological setting (Allan et al. 2006, Esselman et al. 2006, Ramírez et al. 2006), and differences between main-channel and floodplain habitats in providing resources for food webs (Cotner et al. 2006, Roelke et al. 2006).

The Role of Species in Ecosystem Processes

An ever-increasing amount of evidence highlights the important roles that metazoans play in ecosystem processes. Fishes, shrimps, and aquatic insects have strong effects on tropical stream ecosystems (Power et al. 1989, Pringle and Hamazaki 1998). Detritivorous and omnivorous fishes can profoundly influence benthic ecology by removing organic sediments and, in so doing, alter benthic communities (Flecker 1996). In the Cinaruco River, a system with strong hydrological seasonality, the role of large benthivorous fishes as bioturbators appears to be much stronger during the dry season than during the wet season (Winemiller et al. 2006).

A long-standing paradigm in tropical stream ecology identifies an apparent lack of shredding invertebrates. Leaf-litter decomposition and other ecosystem processes mediated by shredders in temperate streams may occur at faster rates in many tropical streams than in temperate streams, even without shredders. On the other hand, the slowest aquatic decomposition rates yet recorded were found in tropical streams (Rueda-Delgado et al. 2006). The role of shrimps and other benthic invertebrates in processing organic matter in streams is evaluated by several studies in this series (Crowl et al. 2006, Martínez and Rincón 2006, Rueda-Delgado et al. 2006, Wantzen and Wagner 2006). Macroinvertebrates seem to be more omnivorous in tropical than temperate streams. Shredder effects on leaf-litter decomposition vary strongly in relation to stream hydrology and geographic distributions of invertebrate and tree species.

The contributions included in this special series offer new insights into the function and structure of Neotropical streams. These studies cover a broad geographic spectrum of environmental and biotic diversity in the Neotropical region and offer new perspectives and hypotheses to be addressed by future research. By highlighting recent research in Neotropical streams, we hope this series stimulates further research that ultimately will provide technical and policy solutions for growing environmental problems in the tropics.

This special series is dedicated to the memory of Harald Sioli (1910–2004), the founder of Neotropical running-water ecology. During the preparation of manuscripts in this series, the authors were partially funded by the following sources: DFG grant WA 1612 and WW-DECOEX to KMW, Luquillo LTER program NSF grant DEB-0218039 to AR, and NSF grant DEB-0107456 to KOW. We thank Pam Silver for her indefatigable editing efforts.

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