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CLASSIFYING THE HIERARCHY OF WATERCOURSES FOR ECOLOGICAL STUDIES

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Abstract. The hierachical classification of a watercourse is fundamental in the field of ecology and other sciences, as it facilitates, for example, communication about the characteristics of the environment to be studied (or previously studied). Generally, for ecological studies of lotic ecosystems, many authors use classification by order, as proposed by Arthur N. Strahler in 1954 (widespread from 1957), or magnitude, a concept idealized by Ronald L. Shreve published in 1967. In this article, we advocate that, from a logical perspective, the use of Shreve's method makes more sense in studies on the ecology of freshwater biodiversity. In addition, we call attention to the fact that (if possible) authors should also consider the type of environment (i.e., perennial, intermittent, and ephemeral) in their classification.

Keywords: non-perennial; order; Shreve; Strahler; stream

INTRODUCTION

What is a watercourse? It is a waterbody that flows from its origin (generally a source) to its outlet in other watercourses, lakes, seas or other receiving bodies. A good definition is "a natural channel in which water flows regularly or intermittently" (Act 1998, p. 16). A watercourse is one of the basic components of a hydrographic basin. It is the morphological component for conveying water from one region to supply another.

Existing watercourses may be categorized into three basic types: (i) perennial, which maintains in its channel a continuous and lasting flow (Allen et al. 2020); (ii) intermittent, which spatially or temporally loses its regular water flow (Busch et al. 2020); and

(iii) ephemeral, which may be considered a non-perennial watercourse and, generally, flows in the channel after rainfall (Busch et al. 2020). These three types of watercourses are important for maintaining freshwater biodiversity (e.g., Benstead et al. 2003, Stubbington et al. 2017, Tickner et al. 2020, Steward et al. 2022, Sánchez-Montoya et al. 2023) and, therefore, for implementing conservation actions.

The hierarchical classification of a watercourse is fundamental in freshwater ecology and other sciences, as it facilitates, for instance, communication about the characteristics of the study environment. Generally, for ecological studies of lotic ecosystems, most authors use the classification proposed by Strahler (1954) apud Strahler (1957), which is also detailed in this latter study. However, from an ecological perspective, we believe that the use of Shreve's (1967) method is more appropriate.

In this essay, we advocate that future studies on ecology should employ Shreve's method and, ideally, apply it considering perennial, intermittent, and ephemeral watercourses. Although the term watercourse can refer to both artificial and natural channels, here, we will focus on natural systems commonly referred to as streams, creeks, and rivers.

STRAHLER AND SHREVE METHODS

The analysis of the hydrological hierarchy involves classifying stretches (also called segments or reaches) of a watercourse in different sections of a watershed. To this end, different approaches have emerged from the scientific literature of fluvial geomorphology. However, the most widely used methods for determining watercourse hierarchy in ecological studies are those proposed by Strahler (1957) and Shreve (1967). The approaches proposed by these authors have been used in studies across diverse riverine ecosystems globally (e.g., Cao et al. 2015, Naumov et al. 2017, Vorste et al. 2017, Correa et al. 2025, Zhang et al. 2025, Stack et al. 2026).

The concept of hierarchy proposed by Arthur N. Strahler was first presented at the "International Geological Congress (1952, Algiers, Algeria)" (Strahler 1954 apud Strahler 1957). However, it was likely Strahler's (1957) publication, cited over 9,100 times (according to Google Scholar on 02 May 2026), that led to the widespread recognition of his watercourse classification. Strahler (1957, p. 914) considers different types of watercourses, clearly mentioned as "intermittent and permanent". According to Strahler (1957, p. 914), "(...) smallest finger-tip tributaries are designated Order 1. Where two first-order channels join, a channel segment of Order 2 is formed; where two of Order 2 join, a segment of Order 3 is formed; and so forth".

Alternatively, Ronald L. Shreve, in his 1967 study, cited 828 times (according to Google Scholar on 02 May 2026), explicitly explained his classification system based on watercourse magnitude. According to Shreve (1967, p. 179): "(1) Each exterior link has magnitude 1. (2) If links or magnitude $\mu 1$ and $\mu 2$ join, then the resultant link downstream has magnitude $\mu 1 + \mu 2$". For example, a stream that has just started (at its source) and flows into another should be considered of magnitude 1, and if two streams of magnitude 1 connect, the section immediately downstream should be considered of magnitude 2. In other words, the method is the cumulative sum of watercourses.

STRAHLER VERSUS SHREVE METHODS

Classifying watercourse stretches according to Strahler (1957) presents limitations. Watercourses of order higher than first-order are not readily comparable or accurately interpretable by readers. For example, under Strahler's method, a second-order watercourse may receive several first-order tributaries (Figure 1a), whereas another watercourse, also classified as second-order, may result from the confluence of just two first-order watercourses, without any additional tributary (Figure 1b). Along the same lines, Gutierrez et al. (2022) argued that this method is unfeasible to adequately show the fluvial hierarchy in a hydrographic basin. We agree with them.

The problems raised above are clearly solved using the method of Shreve (1967). For example, a second-magnitude watercourse, in all cases, is the result of the connection of only two first-magnitude watercourses. This allows both comparison of ecological aspects with others of similar hierarchy and unequivocal characterization (Figure 1c-d). Therefore, if used, Shreve's method, as also mentioned by Gutierrez et al. (2022) in their article, seems more appropriate for application in freshwater ecological studies.

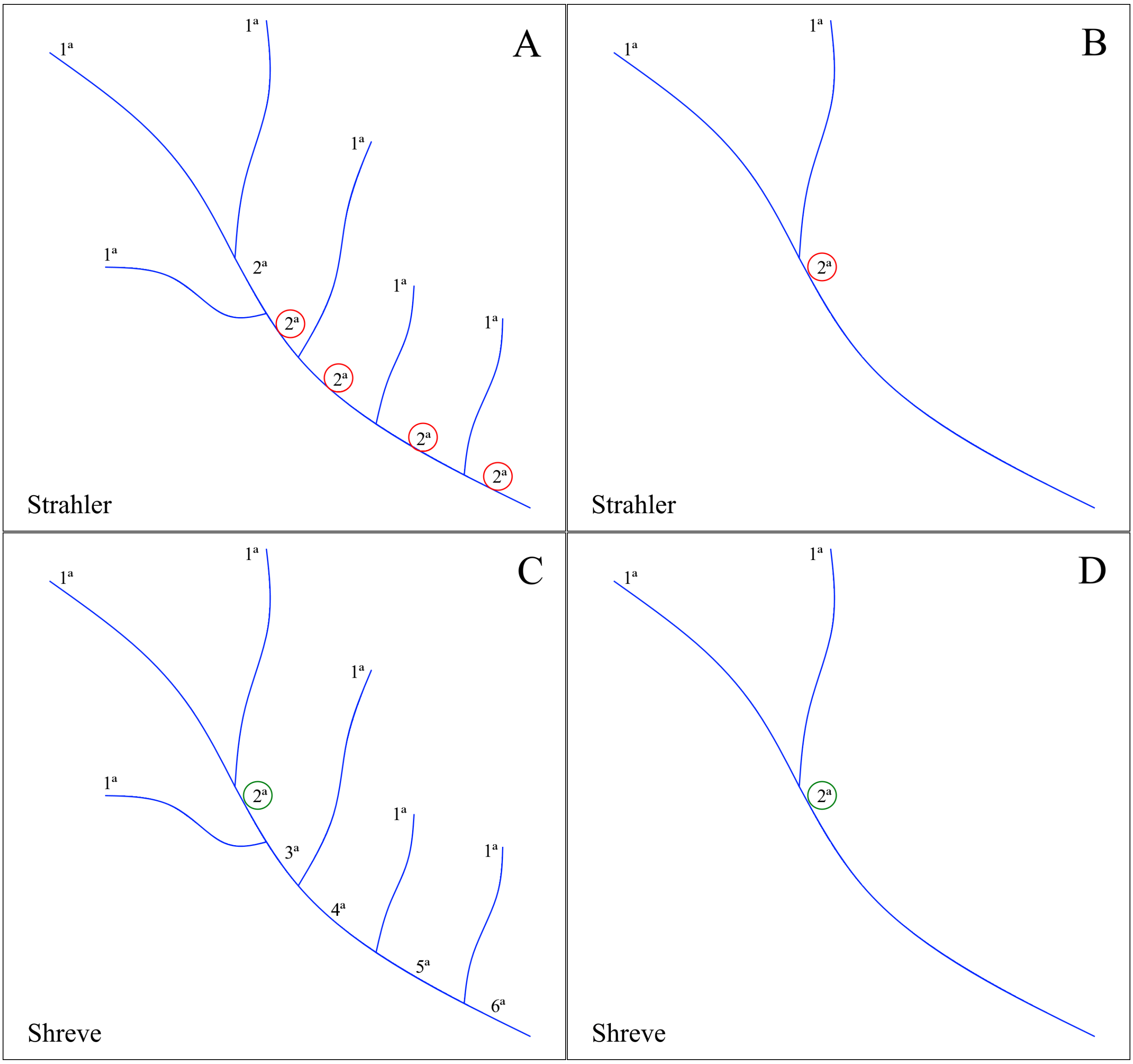

Figure 1. Hypothetical hydrographic basin showing the differences between Strahler's (1957) and Shreve's (1967) methods: A and B are not equivalent second-order watercourses (red circle); C and D are equivalent second-magnitude watercourses (green circles).

HOW TO APPLY THE SHREVE METHOD?

The application of Shreve's (1967) method should consider all types of watercourses (i.e., perennial, intermittent, and ephemeral) in the existing ecosystem. However, we recognize that, in many cases, it is very difficult to determine certain categories of watercourses (e.g., ephemeral) in ecological and other types of studies. For instance, some channels may not be visible during non-rainy periods. In these cases, we suggest that authors clearly state their use of the Shreve method. Afterward, they may explain that no differentiation of watercourse types occurs in their classification. Alternatively, authors may use the Shreve method and consider only perennial ones, but this last piece of information also should be mentioned to the readers to facilitate their understanding and reproducibility. Generally, several authors do not mention the type of watercourse considered in their classification of the hydrological hierarchy (e.g., Casatti et al. 2001, Castro et al. 2003, Azevedo-Santos et al. 2020, Stahl et al. 2023). This should be avoided in the future for the reasons we explained previously.

WHERE TO APPLY THE SHREVE METHOD?

The method we advocate can be applied in various contexts. For example, it is useful in studies that compare ecological aspects (e.g., species richness) in watercourses of equivalent hierarchies. It serves to efficiently communicate the hierarchy of a watercourse that is to be (or has been) sampled in different types of studies, such as inventories or surveys, community ecology, population ecology, ecotoxicology, biogeography (e.g., to better understand organism dispersal patterns) and even in taxonomic studies (e.g., when describing the type locality of a species). Furthermore, it appears to be a viable alternative to Strahler's method for use in new biogeographical and ecological approaches (e.g., the iPODfish proposed by Duarte et al. 2022), as well as in restoration and other conservation strategies (e.g., FitzHugh 2005). It can potentially be used to distinguish a stream from a river for ecological purposes. Finally, it can be included in databases (e.g., Ottocoded Hydrographic) that are potentially used in ecological studies.

CONCLUSIONS

The classification approach we advocate enhances clarity in communicating watercourse hierarchies to readers. Furthermore, it will make it possible to compare the biodiversity among equivalent watercourses. We reinforce that, if possible, authors should apply Shreve's method considering the different existing types of watercourses (i.e., perennial, intermittent, and ephemeral). This has important implications for applications by scientists and technicians studying freshwater biodiversity.

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