Limnetica, 42(2): 279-290 (2023). DOI: 10.23818/limn.42.20
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Doing Science in Ecology. Does river flow show a path?

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Received: 17/08/22 Accepted: 25/11/22

ABSTRACT

Doing Science in Ecology. Does river flow show a path?

Rivers are submitted to deep and irreversible changes concerning their physical integrity (habitat simplification and loss) and water quantity (forcing of the global water cycle). The horizontal and hierarchical structure of river networks facilitates that impacts caused at the local scale may become relevant at higher scales, and therefore we face impacts which trespass the background of river ecologists. While we have progressed by incorporating many aspects of physical, chemical, and biological components of river ecosystems, the new challenges ahead imposed by global change complicate achieving operational predictions. I propose enhancing our connection to other experts, such as chemists, engineers, or land planners, to expand our current paradigms. I see that enforcing multidisciplinary collaboration is deemed essential to disentangle challenges that humankind has regarding river ecosystems. I assume that this will return as a progress and improvement of common scientific knowledge and applicability, stronger and more valuable for the sake of the conservation of our rivers.

Key words: river, Ecology, science, multidisciplinary, global change

RESUMEN

Hacer ciencia en ecología. ¿Muestra el camino el flujo fluvial?

Los ríos están sometidos a cambios profundos e irreversibles en cuanto a su integridad física (simplificación y pérdida de hábitat) y cantidad de agua (forzamiento del ciclo global del agua). La estructura horizontal y jerárquica de las redes fluviales facilita que los impactos producidos a escala local puedan ser relevantes a escalas superiores, por lo que nos enfrentamos a impactos que traspasan el bagaje de la ecología fluvial. Si bien hemos incorporado muchos componentes físicos, químicos y biológicos de los ecosistemas fluviales en ecología fluvial, los nuevos desafíos impuestos por el cambio global complican las predicciones operativas. Propongo mejorar nuestra conexión con otros expertos, tales como químicos, ingenieros o urbanistas, para expandir nuestros paradigmas actuales. Veo esencial promover estas colaboraciones multidisciplinares para desentrañar efectivamente los desafíos que la humanidad afrenta y que conciernen a los ecosistemas fluviales. Esto podrá facilitar el avance y perfeccionamiento del conocimiento científico común y de su aplicabilidad, redundante en la mejor conservación de nuestros ríos.

Palabras clave: *río, Ecología, ciencia, multidisciplinariedad, cambio global*

INTRODUCTION

"The steady construction and reconstruction of science is, and I hope it will remain, a never-ending enterprise"

(Margalef 1997)

The title and intention of this paper is to provide some thoughts on our current understanding of river structure and functions, and how this knowledge matches the challenges ecology face as an integrative science. I will use the analogy of the path followed by water throughout the river course, since rivers are not linear but collect progressively larger tributaries to the joint enterprise of draining the basin to the sea, as science needs to do (see Margalef's citation above) to achieve its goals. Throughout their course, rivers expand and contract, form meanders or floodplains, and shift naturally between sections of faster and slower waters. The river path is, therefore, as complex as the path science has carved through history, and still does (Fuller, 2004).

I depart from some aspects that in my understanding are important for river science, and which have been of my interest through the last 20 years. Many of these aspects relate to main questions river ecologists have collectively explored in the recent past. I take as a basis those raised in the Freshwater Imperative (Naiman et al., 1995), summarised on ecological restoration and rehabilitation; maintenance of biodiversity; modified hydrologic flow patterns; ecosystems goods and services; predictive management; and solving future problems. Some of these issues have gained actuality and complexity, as a consequence of the continued pressure we humans exert on every natural system.

Aspects such as the "Modified Hydrologic Flow Patterns" or "Maintenance of Biodiversity" connect with the ones I will discuss on in this paper as the backbone story, namely, *water scarcity*, and the overall *effect of global change on ecosystem structure and functio*n. My reflection addresses our ability to predict their effects on river ecosystems, which is essential for improved conservation and management.

THE SCIENCE OF RIVER ECOLOGY

Rivers were outliers in the study of freshwaters up to the 1970s. Limnology started with the study of lakes, which were seen as self-contained systems relatively easy to assess. In contrast, rivers were uneasy to study because of their physical structure and their changing contact between land and water. In fact, rivers were rarely considered in mainstream limnology, deserving at most a few chapters in Limnology manuals (see e.g., Kalff, 2002; Wetzel, 2001). Constructing river ecology was a slow process, likely benefited by the confluence of multiple perspectives. The interest on organisms and how they assemble in communities, as well as their potential value as indicators, came first (Margalef, 1960). In parallel, geomorphologists described the dynamism of sediments throughout the river, and interpreted it as a process of multiple solutions (Leopold, 1994). Ecologists constructed early conceptual models of structural and functional processes (Cummins, 1974), thus depicting the basis of the matter and energy transfer in the system.

Summing up on these, in 1975 Noel Hynes convincingly exposed the complexity of rivers as aquatic systems connected to land. He did so by presenting the Edgardo Baldi Memorial in the SIL in Stuttgart to an audience of non-river specialists. That lecture was the highest honour the *Societas Internationalis Limnologiae* gave to a scientist at that time. The relevance of the lecture was even more significant considering the prevalent role SIL had then in world's limnology. Hynes advocated in his paper "to look at streams not as purely aquatic phenomena, as one can with lakes, but rather to view them as parts of the valleys that they drain" (Hynes, 1975). Making an echo to his paper's title, he concluded that "in every respect the valley rules the stream". His lecture came as a shock to challenge the ongoing understanding of rivers, which up to then were merely considered as flowing lakes. River scientists were more concerned on classifying river zones (e.g., Illies and Botosaneanu, 1963) than on looking at rivers as ecosystems. Hynes convincingly showed that rivers were heterotrophic systems, a result of the organic matter entering the channel from the basin. He established that the connection between terrestrial and aquatic compartments was driven by water flow, what made possible the transport of dissolved inorganic and organic matter, processes which remain at the base of the river food web.

Hynes was exemplary not only because of his conceptual breakthrough in a world of sceptics, but also for his courage in trespassing disciplinary boundaries. A trained zoologist and specialist on river invertebrates (what could indeed provide a certain bias to his overall vision of river ecosystems, as he himself recognized; Hynes 1970), he moved from his knowledge zone to entangle with those of American geomorphologists (such as Leopold) and ecologists (such as Cummins). When interactions were more mature, the most complete unifying concept was provided by a group of American ecologists describing the River Continuum Concept (the RCC; Vannote et al., 1980), which triggered the present view on river ecology. New concepts have incorporated then since, to understand the elementary budget of river basins (Likens et al., 1977), the nutrient spiralling dynamics (Mulholland et al., 1985), or the metacommunity perspective of river biota (Heino et al., 2015).

RIVERS FLOW THROUGH AS MUCH AS HUMANS ALLOW

The above story illustrates how river science took impulse after a first rather awkward start. Likely, a distinctive element of this construct was the fruitful interconnection of scientists coming from different disciplines, which made possible a synthesis, crystallized in concept. Surely, this exemplary breakthrough shows the path to follow in our effort to make river ecology a more predictive science in the present context of global change.

Hynes and American ecologists focused mainly on pristine or near pristine systems of the temperate zone, with little consideration of other biomes or of more complex realities. This indeed triggered an immediate wave of debate and data (e.g., Statzner, 1985; Winterbourn, 1981; Greathouse and Pringle, 2006; Webster, 2007), which profiled the validity and extent of the RCC.

Nowadays, and making a necessary twist on river ecology, we face the reality that river basins are submitted to deep and irreversible changes, and that pristine systems are gone in many areas of the world. Human actions drive multiple physical and biological elements of the basin, and rivers are affected by multiple interests derived from human needs and services, which connect with the so-called human well-being (Bennett et al., 2015). Here, it might be relevant to recall that the so-called ecological integrity (or ecosystem health or ecological status, to use the different terms around the same concept) has a non-linear relationship with ecosystem services. Citizen needs and economic decisions may become antagonist to the conservation of river ecosystems when prioritizing pressures on water resources or (and) large transformation of land uses. Consequently, making extensive use of ecosystem services may affect ecosystem's health, and we are rarely aware of this paradox (Silvertown, 2015).

Mostly in Europe (though less in other parts of the world) watercourses have been strongly modified to fit human needs since very old times (Fagan, 2011). Channels have been simplified and basins register a growing number of stressors of diverse nature (Sabater et al., 2019). Ramon Margalef was sensitive to this situation since his early works (e.g., Margalef, 1960), with arguments that he later developed in different manuscripts and interviews. He suggested that the main problems faced by river ecosystems were the channelization and modification of watercourses, with implications in physical integrity (*habitat deterioration*) and water quantity (the *forcing of the global water cycle*). As a visual expression of this modification, meanders, lagoons, and oxbows are currently eliminated from many floodplains, and water transfer between basins is a common practice in many territories. These actions may be seen as steps toward the irreversible simplification of river ecosystems, which in extreme cases are transformed from complex channels into simple pipes. This physical and hydrological modification of river networks may start locally but extends toward the whole river network in basins where human density or activity is high.

Once this point reached, it is necessary to differentiate the physical structure of river ecosystems from those in other ecosystems. Lakes, oceans, and forests are largely organized in a vertical dimension, with production and respiration

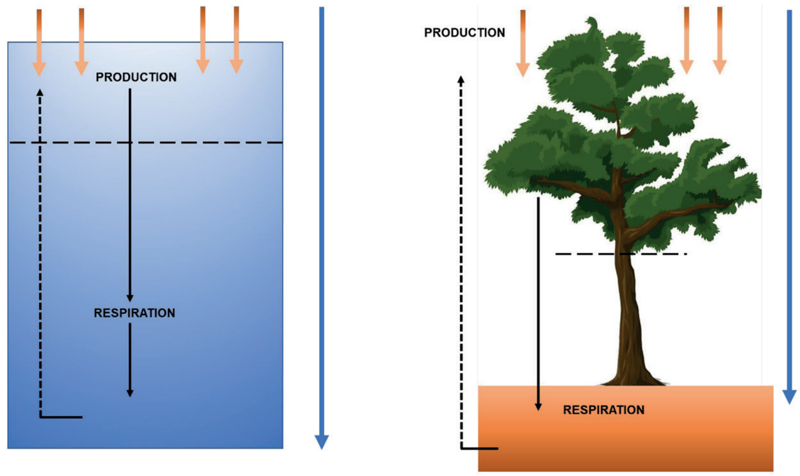

Figure 1. The vertical axis (blue arrows) dominates the processes in lakes and oceans (left) and terrestrial ecosystems (right). Production and respiration remain separated in space as defined by the availability of light (yellow arrows) and the force of gravity (black arrows), and external energy is required to transport the mineralized elements, back to the photic zone (delimited by the interrupted horizontal line). Adapted from Margalef (1997). *El eje vertical (flechas azules) domina los procesos en lagos y océanos (izquierda) y en los ecosistemas terrestres (derecha). La producción y la respiración permanecen separadas en el espacio definido por la disponibilidad de luz (flechas amarillas) y la fuerza de la gravedad (flechas negras), y se requiere energía externa para transportar los elementos, una vez mineralizados, hasta la zona fótica (delimitada por la línea horizontal interrumpida). Adaptado de Margalef (1997).*

segregated through space (Margalef, 1997; Fig. 1). Regardless of their obvious differences in size and structural components, production in these systems occurs in the upper layers, associated to the availability of light (photic zone), whereas the respiration mainly occurs in the bottom (soils, sediments), where the dead organic material accumulates. This vertical separation requires moving the materials back toward the production zone, a process that depends on external energy (wind, evapotranspiration) since these systems are ruled by gravity. Rivers, on the other hand, are not organized in a vertical dimension, but horizontally driven by water flow from headwaters to the mouth, which configures river networks as transport systems from the land to the sea. River networks are organized dendritically from headwaters to middle and lower segments, building a hierarchical pattern of transport of water, sediments, organic materials, and organisms. Because of the changing nature of the river network in the upstream-downstream direction, transport processes are asymmetric. There is asymmetry in the interaction between the water and the terrestrial ecosystem it drains, and there is asymmetry in the intensity of transport from upstream to downstream (Margalef, 1990). Rivers therefore are horizontal structures operated by water flow (Fig. 2), and this makes them unique. In this horizontal disposition, production and respiration alternatively dominate reaches along the channel, this shifting pattern depending on the amount of organic matter stored or the light entering the system (Thorp et al., 2006).

It is this horizontal and hierarchical structure that spreads impacts performed at the local scale to achieve relevance at higher scales. As an example, excessive water withdrawal performed in upstream sections does affect the area locally, but also concerns the hydrological pattern and habitat availability of downstream sections. Effects can be even more important when constant pressures spread over large areas of the basin. This situation of water scarcity affects the global residence time of circulating waters, leading to higher "aging" of the waters (Vörösmarty et al., 2010), and river segments shift from lotic to lentic (which I termed as *lentification*, Sabater, 2008). Consequences include the alteration of the biogeochemistry of elements, with especial reference to the carbon cycle

(Proia et al., 2019), limitations to the dispersal of biological communities (Sabater et al. 2018), and a shift in the metabolism of river systems from heterotrophic (del Giorgio & Williams, 2004) to autotrophic (e.g., Kemp et al., 1997). Long-term water scarcity conditions produce irreversible effects, as has been recently confirmed in Australian river ecosystems (e.g., Peterson et al., 2021).

Margalef's concern on the habitat's deterioration was part of another more general, which he expressed in his last lectures as "*the inversion of the topographic landscape*", where a landscape dominated by natural or semi-natural habitats, with some scattered urban areas, is progressively converted to transformed landscape with a few remaining fragments of natural ecosystems We may observe this effect in many river basins submitted to strong human pressure. The Onyar River basin (Girona, NE Spain) provides an example of this transformation. This middle-size basin has a large and growing impact of irrigation and industry (Gabriela Córdoba, in progress), which has caused land uses to change swiftly in 30 years. In this period, forest cover has increased from 33 % to 42 % of the total surface area because of land abandonment, irrigated areas have increased from 8.3 % to 10 %, and urban areas have also increased from 3.7 % to 8.4 %. Tributaries and even main sections that were once permanent are nowadays intermittent. The decreasing water flow associated to this shrinking process favors the massive growth of filamentous algae and macrophytes, which occupy most of the river channel during summer. Many sections in mid summer appear fully vegetated with terrestrial plants, as the outcome of the terrestrialization process (Harvolk et al., 2015). Further, not only the total surface area in the Onyar has changed, and the systems have become more intermittent, but the fragmentation of the remaining natural areas and that of the permanent-intermittent sequence in the river network has increased. Overall, the system is hydrologically, and chemically stressed, and long-term observations may lead us to assume that this is already a chronic situation.

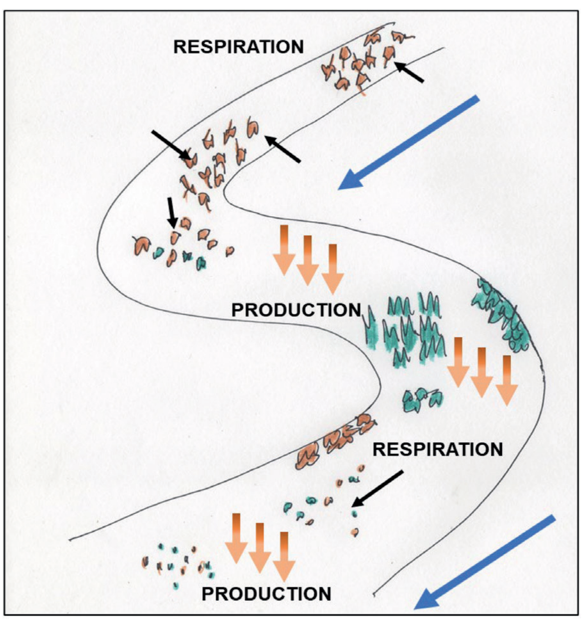

Figure 2. The horizontal axis (blue arrows) dominates the transport dynamics in river systems. Production- and respiration-dominated areas are scattered in space because of the storage of organic matter (black arrows), or of the availability of light (yellow arrows). *El eje horizontal (flechas azules) domina la dinámica del transporte en los sistemas fluviales. Las áreas dominadas por la producción y la respiración están dispersas en el espacio como consecuencia del almacenamiento de la materia orgánica (flechas negras) o de la disponibilidad de luz (flechas amarillas).*

Fragmentation, loss, and impairment of habitats is common in river basins, as much as it is in other ecosystems, either terrestrial or aquatic. Habitat alteration has been recognized as a driver of biotic homogenization elsewhere since it mostly affects the less tolerant biota (known as habitat specialists) and favours the most tolerant (habitat generalists). This is a general trend observed in ecosystems such as coral reefs (Graham, 2007; Pratchett et al., 2012) or grasslands (Botham, 2015; Assandri et al., 2019) as much as in rivers (Benstead et al., 2003; Herbert & Gelwick, 2003; Leboucher et al., 2019). Physical and chemical homogenization are associated to a replacement of specialists by generalists and to a general loss of beta diversity (Leboucher et al., 2019). This shift may affect the resistance of communities to disturbances, since specialists are the better adapted (Lyons et al., 2005; Bracken & Low, 2012). In rivers, the combined impact of habitat impairment and the stress associated to water scarcity may challenge the whole structure and functions of biological communities, and therefore directly impact on their biodiversity (e.g., Cuffney et al., 2010).

A further expression of the changes associated to human pressure in river basins is the arrival of new materials, which enter the stream channels in a growing number and diversity. The RCC recognized the relevance of inorganic and organic materials entering the river from the basin, and that these materials were at the base of the food web structure. Indeed, inputs of nutrients and organic matter (dissolved fraction), and those from the particulate fraction (in the form of leaves and other organic debris) have not stopped flowing in, unless in extreme cases where the basin is fully urbanized (Walsh et al., 2005; Wegner et al., 2009). But the human intervention of the basin causes a whole new set of materials to enter the system, including organic pollutants from different sorts (pesticides, pharmaceutical products, industrial products), as well as nanomaterials and plastics (Petrovic et al., 2011; Freixa et al.; 2018, Wang et al., 2021). Some of these materials have toxic properties, but the implications for the biota are barely known for many others. Our knowledge on the interaction between these materials and those naturally reaching the river is scarce, and we do not know which might be their co-occurrent effect in the biota. Previsic et al. (2021) observed that some endocrine disruptors and pharmaceutical products bioaccumulated in caddisfly larvae and adults, with remarkable high concentrations. This provides evidence that noxious materials do not simply concern the channel biota itself because of the transference of materials toward the terrestrial compartment (Baxter, 2005). However, potential effects on the organism's fitness, particularly when inputs are persistent, are yet unknown. We remain far to comprehend the whole implications the new materials may have for the biodiversity and functioning of river systems, mostly when we deal at the large scale of the river basin.

RIVERS – AND RIVER SCIENCE AT THE EDGE OF CHANGE

Doing science in river ecology demands some understanding of multiple physical, biogeochemical, and biological processes operating in river ecosystems. Although in principle this seems rather impressive, requirements do not differ much from those necessary in other ecosystems, such as oceanic or terrestrial. All ecologists face the challenge of addressing the new paradigm of human intervention. Our skills may not be sufficient to produce robust scientific outputs but demand complementary expertise.

Peters, in his controversial book "A critique for Ecology" (1991), discussed many of the difficulties we face for making science in ecology. He listed in the preface of his book a list of items which -he felt- impaired our full connection to scientific requirements (Table 1). Some aspects in the list are likely no longer an issue after 30 years, while others have long-lasting relevance and remain as actual as ever. For instance, low research budgets or lack of employment opportunities are as pressing now as then, particularly in what concerns to early career researchers. On the contrary, "failure to harness modern technology" maybe nowadays lies in the other extreme, since many ecologists do prioritize managing sophisticated tools, which they feel are useful to produce outcomes unimaginable in the recent past.

Apart from these more incidental aspects, other issues of the list are fundamental to our development as scientists, in particular those criticisms pointing out that we ecologists fail to predict the outcomes of ecosystems, and by doing so our performance diverges from other scientific disciplines. Peters put down that we ecologists prefer measuring and describing facts than contributing to theory. And it is true that developing theory involves a collegial procedure and a collective will to do so. Margalef (1997) adhered on some of Peters 'concerns. "One feels an utter lack of general theory that could provide a link throughout many disparate concepts… (this) reflects a considerable reluctance to face nature in its complexity." It might be indeed the case that our predictive ability is challenged by the complexity and variability of ecosystems, and that this makes uneasy the comparability between studies.

Taking these criticisms positively may lead us to improve our collective development as scientists. River ecology has enormously progressed as a science on incorporating so many aspects of the physical, chemical, and biological template of rivers. We indeed remain in the middle of a necessary expansion of basic knowledge and the obligation to assertively respond to challenges related to the several pressures which rivers receive. In the positive side, we have advanced on understanding general patterns of diversity (e.g., Gutiérrez-Canovas et al., 2013), the contribution of greenhouse gases emitted from dry riverbeds or reservoirs to the global carbon imbalance (e.g., Arce et al., 2021), or debated on the delicate equilibrium between social and ecological systems (e.g., Diaz et al., 2015), to name a few. But beyond these successful developments, we remain unprecise to define the impacts of multiple stressors on a community, or on predicting the expected trajectory of a population under global change, or in upscaling the biological response observed in several sites to a basin-wide pattern of response. Providing reliable answers to any of these questions demands us to be ready to uptake complementary expertise while not diluting ours. I contend that we need to expand our knowledge and toolboxes if we aim to enhance our own understanding of river ecosystems.

If we may agree on this need to expand our natural field of knowledge, the point may be how to perform this in a fair interaction with other disciplines (Table 2). Hynes plainly stated in his seminal paper of 1975, most likely cheating on himself and on his peers, that "some of our most important recent discoveries have been of the existence of hydrologists, foresters and soil scientists, which perhaps says something of our innocence". Possibly, in an analogous manner, we might admit that we must discover the contribution of engineers, chemists, land planners, or social scientists, if we really aim to make the best of our predictable river ecology. For that, we can make use of the opportunities provided by science policies and funding, but the most secure track is to remain open to new, emergent issues, as well as to previously understudied aspects. This is indeed associated with thinking carefully about our own frontiers and how we may overcome these limitations.

Understanding others' expertise is an initial step for us to progress on our predicting ability. Ideas may flow into us from others, therefore making a positive imbalance for river science. Sydney Brenner (1997) expressed that "progress depends on the interplay of techniques, discoveries, and new ideas, probably in that order of decreasing importance". Applied to the theme of this paper, and making an echo of many ongoing multidisciplinary endeavors, we may consider that enlarging ideas and increasing knowledge of techniques from other disciplines may indeed enhance our joint predictive capacity on the fate and conservation of river systems.

Table 1. Some weaknesses in ecology as described in Peters (1991). *Algunas debilidades en la ciencia de la ecología, como se describe en Peters (1991).*

- Lack of scientific rigor
- Weak predictive capacity
- Failure to harness modern technology
- Lack of testable theory
- Low research budgets
- Lack of employment opportunities
- Proliferation of uncontrolled and non-coordinated studies
- Poor contacts with specialists of other disciplines
- A tendency for demagogy and polemics
- Rarity of interactions between ecologists and planners

Making this connection to others' expertise may improve our manner to deal with river science but does not necessarily imply that we fully assimilate the paradigms of engineers, chemists, economists, or social scientists. As in many human endeavors, for a connection to be fruitful, it is necessary to permeate with the other, involving both their skills as well as ours in the interaction. As an example, engineers producing drinking waters are proficient to provide the best treatment, but usually do not consider the functional contribution of river ecosystems to water purification. Engineers mostly see rivers (and other water resources) as water providers (Sedlak, 2014). But engineers have developed sensors and monitoring techniques that may be extremely helpful to understand the complex hydrology of heavily humanized rivers and have a precise idea on what to improve to achieve the final product. We may learn from interacting with them on the techniques and the manner they use, and they may learn from us on the best use of the naturalness of systems to decrease costs for water depuration. This example may illustrate a win-win situation between disciplines and experts, with good returns for the two in terms of a better diagnosis (conservation, our interest), as well as in lower requirements for treatment (and lower cost, their interest).

Incorporating the knowledge and techniques of others should not be done at the expenses of sacrificing our views as ecologists concerned in conservation. We ecologists may perform as "jacks of all trades, but masters of none" (Cherret, 1989), but we need to impose limits regarding the "trades" and the techniques associated to these. The acquisition and mastering of some skills remain close to our main background in freshwater ecology, while others remain far apart from our expertise. Margalef invited his students to master on groups of organisms (at their own will), as a prime start of their thesis. Knowledging Cladocera, oligochaetes, algae, or butterflies (to name a few) was conceived by him as a useful introduction to the natural world, its complexity, and further, to the system (river, lake, reservoir, forest) where the student was willing to initiate his or her expertise. This Margalefian tradition of a basic naturalistic knowledge of groups of organisms, in my view still valid, opened the curiosity to the role of species in communities, and from there on their role in the ecosystem.

However, since so many aspects may now capture our interest, we may be tempted to be proficient on techniques- while forgetting our main background. Statistical methods, modelling, barcoding, or sophisticated chemical analyses, to name some of the most popular, raise our interest because of their powerful connection with different aspects of our job. While any of these techniques may be useful for our research purpos-

Table 2. Non-exhaustive items that constitute river structure as we understand them now (left), new challenges imposed by human intervention (center) and complementary expertise potentially useful to achieve predictive value. *Algunos elementos que constituyen la estructura del río tal como los entendemos ahora (izquierda), nuevos desafíos impuestos por la intervención humana (centro), y experiencia complementaria potencialmente útil para lograr valor predictivo.*

Water flow is contributed by tributaries throughout the river network, and it is expected to increase towards the mouth	Water flow may be intercepted through abstraction or damming. Water is contributed by WWTP Flow may not reach the river mouth	Hydrology Modelling Engineering
Sediments follow dynamics of erosion-transport-sedimentation which organize the geomorphological structure of the river channel	Sediment transport is disrupted because of changes in the basin (urbanization, afforestation) and river regulation	Hydrology Geomorphology Geographical Information Systems
Concentration of chemicals (inorganic nutrients, DOC) increases from the headwaters to the mouth	Point and diffuse sources throughout the river blur the pattern of progressive increase	Inorganic chemistry Biogeochemistry
Organic particulate materials from nearby terrestrial ecosystems enter the channel and make up most of the edible materials	Particulate materials of human origin also enter the river (industrial materials, plastics) Loss or simplification of riparian forest – shifts in community composition	Organic chemistry Engineering Land planning
Dissolved organic molecules enter the river channel and are transformed through the microbial loop	Organic contaminants (pharmaceutical products, industrial products, pesticides) also enter the river	Organic chemistry Engineering Molecular biology Microbiology

es, it may not be necessarily useful for the advancement of science if our dedication is not balanced toward ideas- and construction of theory. I am not meaning that promoting the knowledge of a technique is unnecessary, but that it should go together with the adequate contemplation of scientific advancements in the literature, and the formulation (or contrast, if existing) of concepts which are at the base of our common scientific advancement. Since time is limited, accurate decisions need to be done, particularly at the onset of a career research. And collaboration with complementary partners from several disciplines (see Table 2) is indeed an alternative to expand on techniques and visions.

In conclusion, it is necessary we incorporate complementary regards to our current paradigms to achieve the better diagnosis and prediction of river ecosystems. This exercise does not necessarily require mastering approaches and techniques of others. Instead, we may enforce a much-needed general view. Enforcing collaboration is deemed essential to progress in science, and river science requires of an increasing professional regard and new perspectives. This should not only mean collaborative works, now very much in fashion, but also to achieve proper cooperation efforts, across disciplines, to disentangle challenges that humankind has ahead. By no means this is avoiding us onto the much necessary task to dialog with society in general, as much as with managers and policymakers, to show the advantages of a better science for the conservation of our river systems. I indeed assume that this will return as a progress and improvement of common scientific knowledge and its applicability, stronger and more valuable for the sake of the conservation of our rivers.

ACKNOWLEDGMENTS

I am indebted to mentors and colleagues from whose interaction I profiled my way of looking at rivers. Among the firsts, Professor Ramon Margalef marked the path to follow for me and many others, and Professor Joan Armengol, friend, and supporting supervisor in crucial moments. Among the colleagues, the list is indeed very large, and includes former students as well as peers throughout these years, particularly, and in alphabetical order, Vicenç Acuña, Joan Artigas, Wim Admiraal, Ramon Batalla, Damià Barceló, Susana Bernal, Laurie Boithias, Nuria Bonada, Nick Bond, Carles Borrego, Andrea Butturini, Miriam Colls, Natàlia Corcoll, Cliff N Dahm, Jhon Donato, Concha Duran, Arturo Elosegi, Claudia Feijoó, Anna Freixa, Emili Garcia-Berthou, Ainhoa Gaudes, Adonis Giorgi, Nora Gómez, Juan-David González-Trujillo, Manuel Graça, Stan Gregory, Helena Guasch, Núria Ivorra, Sam Lake, Julio Cesar Lopez-Doval, Eugènia Martí, Rafel Marcé, Jordi-René Mor, Isabel Muñoz, Enrique Navarro, Claudia Pascóal, Mira Petrovic, Gilles Pinay, Lorenzo Proia, Montserrat Real, Anna M Romani, Ferran Romero, Albert Ruhí, Francesc Sabater, Jim Sedell, Juan Soria, Jan Stevenson, Xisca Timoner, Elisabet Tornés, Elisabet Vilalta, Daniel Von Schiller, Gemma Urrea, and Lluis Zamora. Special thanks are given to Arturo Elosegi and Isabel Muñoz who provided comments and ideas to this manuscript.

This paper reflects the main contents of my plenary lecture at the SIBECOL-AIL Meeting 2022, where I received the Iberian Association of Limnology Trajectory Award, as a recognition of my scientific career. My gratitude to the AIL board for this recognition, and to the editors of Limnetica for inviting me to give this paper.

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