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LIMNOLOGY AND THE SUSTAINABLE USE OF WATER IN BRAZIL: VISIONS AND CHALLENGES

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Abstract: Brazil's wealth in water, its distribution, and losses, together with considerations on the challenges posed by the impacts of climate change, the precarious basic sanitation in the country, the demands of the agroindustry and the need to invest in new areas/themes through partnerships and integrated actions are the main points discussed in this article. The central proposal is to indicate new arrangements and possibilities for Limnology to face some of the problems that afflict humanity, especially those arising from climate change, loss of biodiversity and lack of basic sanitation, particularly critical challenges for Brazil.

Keywords: Brazil's waters; sustainable agriculture; water in mining; Covid-19

Brazil has *c.* 12 % of the planet's fresh water, an annual reserve estimated of *c.* 6,950 km^3. The historical series during the period 1985-2020 shows a trend of reduction in surface water in all Brazilian biomes: 10.4% in the Amazon, 17.5% in the Caatinga, 1.5% in the Cerrado, 1.4% in the Atlantic Forest, 68% in the Pantanal and 0.5% in the Pampa. Overall, 78% of surface water is in natural rivers and lakes and 22% in artificial reservoirs and dams (MapBiomas 2020).

Because of land use changes there is an interruption of water flows and a decrease in ecosystems connectivity, resulting in important changes in structure and functioning of the ecosystems and thus altering the maintenance of biota and ecosystem processes - the flow/biota/processes nexus - Palmer & Ruhi (2019). The river flow is directly responsible for the composition, structure and dynamics of communities and flow patterns dictate the structure and functioning of these ecosystems, in addition to the adaptation of a variety of aquatic and riverine species. Furthermore, the flow regime also influences ecosystem processes in the river and the floodplain, including primary production and nutrient cycling, and when the flow is altered, a combination of biotic and abiotic responses is triggered (Granit *et al.* 2017, Barbosa *et al.* 2019, Brito *et al.* 2021).

Water is an essential, strategic, and finite resource. Its use has grown 6 times in the last 100 years to *c.* 1 % per year since 1980s. Between 1990 and 2020, Brazil has lost 15.7 % of its surface water in 54 of the 76 sub-basins evaluated due to the conversion of forests to livestock/agriculture, reduction of water flow in rivers due to construction of dams for irrigation and animal watering and the increase in evapotranspiration from large reservoirs. Using human capital and available technologies to know the current and future availability of surface and groundwater resources in each region is an opportunity

to be undertaken with solid foundations of conservation and planning for the sustainable use of these resources. Likewise, participating in the implementation of public policies that favor monitoring, conservation, and good practices in the use of water resources, including alternative sources (reuse, rainwater) and multiple uses, creates opportunities for innovation and business and favors the quality of life and the country's sustainable development (ANE 2021, Barbosa & Ciminelli, 2022). This article intents to draw the attention of limnologists and decision makers to the great challenge of reversing this picture of degradation and neglect in relation to our aquatic ecosystems.

Freshwater ecosystems: importance and conservation status

Although total freshwater ecosystems cover < 1% of the planet's surface, they harbor *c.* 1/3 of known vertebrates and 10% of all known species (Strayer & Dudgeon 2010). Such importance is even increased when one observes the large number of endemism's present in freshwater ecosystems, as demonstrated, for example, for the fish species used in the definition of ecoregions (Abell *et al.* 2008) and for the offer of ecosystem services, particularly provision for billions of people (Linch *et al.* 2016). However, freshwater ecosystems remain underestimated, including the investment of resources for their protection and sustainable use, enabling a significantly higher level of threats than other ecosystems. Among the 29,500 species dependent on freshwater ecosystems evaluated for the IUCN Red Book, 27% are threatened with extinction: turtles (62%), gastropods (47%), mammals (42%), amphibians (33%), decapod crustaceans (30%), fish (28%), birds (20%), (IUCN 2019, Tickner *et al.* 2020).

The conservation of aquatic biodiversity and its sustainable use is a task of the highest priority. However, judging by the increasing degree of threats and the strong worldwide decline demonstrated for the case of freshwater fish, this importance has not been fully recognized, as demonstrated by the report 'The World's Forgotten Fishes' produced by scientists linked to Cardiff University and 12 more conservation organizations (Tickner *et al.* 2020). They formed the "Alliance for life in freshwater" which draws attention to the diversity of freshwater fish that represent > 50% of known fish species. However, one in three species are threatened with extinction, a rate twice as high as those recorded for terrestrial and marine environments.

To the extent that Limnology expands its insertion and provides relevant technical-scientific contributions to decision-making related to water and its resources at the municipal, state, and national scales (water governance), its professionals need to be prepared to act in the urban environments and contribute with other segments of society, in order to guarantee the supply of water, effective proposals for the control of eutrophication and pollution of water sources.

Climate change and its effects on aquatic ecosystems: challenges

The interdependence between climate, ecosystems, biodiversity, and people is very clear. Equally clear, should be the integration of knowledge from natural, social, and economic sciences, which demonstrate, through these interactions, the bases of the risks arising from climate change, ecosystem degradation and loss of biodiversity (IPCC-AR6 2022). Some data from this report are staggering: i) about half of the world's population already faces water shortages for at least part of the year, with consequent exposure to food insecurity; ii) the highest lethality from droughts, floods and storms in vulnerable areas of poor countries was *c.* 15 times higher than that observed in regions of richer countries; iii) probable extinction risk of 9-14% of species in all ecosystems if global warming is 1.5ºC – the planet has already warmed 1.1ºC and 55% of the extinction of local populations has happened in tropical regions against 39% in tempered regions; iv) increased population displacements driven by climate and extreme events; v) the emergence of animal and human diseases in new areas particularly transmitted by climate-sensitive aquatic pathogens and toxic substances from cyanobacteria (cyanotoxins); vi) 40 % of the world's population live in risk zones that are highly susceptible to climate change. In summary, climate change affects all natural and created ecosystems through interference in natural processes – rainfall, availability of water/

food, human and wild populations health, and the economy.

A special emphasis is placed on water scarcity, that afflicts almost half of the world's population and exposes millions of people to food insecurity. Such impacts constitute an opportunity and a clear indication for the definition of priorities for limnological research and the proposition of public policies aimed at adapting to ongoing changes. Of concern is the lack of studies on ecosystem health, which should include human and wildlife health – an association relegated to a low level of interest by the narrow view of the concept of human health as the absence of disease. Thus, as direct causes of the increase in diseases, the report points to the increase in temperature, rainfall, and floods, which increased the occurrence of pathogens in the water (*e.g. Vibrio cholera*). Another example is the consequences on mental health in regions with the highest occurrence of extreme weather events and an indication that anxiety and stress are expected to increase in scenarios of greater warming, particularly among young and old people.

It is worth noting an alert issued by > 115 aquatic scientific societies around the world: "The world's aquatic resources are now under their greatest threat in human history. Human-caused climate change is accelerating the degradation of aquatic ecosystems and the services they provide. Aquatic ecosystems are among the most affected worldwide (*e. g.*, in case of freshwater ecosystems, one measure of biodiversity, the freshwater living planet index for species populations, declined by 83% from 1970 to 2014, while up to 90% of coral reefs will disappear by mid-century if the current trends continue". The alert also draw attention to the need to continue to share data/findings with the public and particularly with public policy and decision makers, stressing the seriousness of these threats and the urgency of implementing actions. It was also emphasized that, based on the assessment of global risks carried out by the Global Economic Forum, for the first time, the impacts of climate change, the loss of biodiversity and the water crisis were ranked among the 5 greatest risks for the next decade. Human migrations forced by conflicts of various natures, including climate change, are a reality: between 2008 and 2016 more than 20 million people had to migrate due to extreme weather events. In 2017 alone, according to the UN, water was the main factor of conflict between 45 countries (European Commission, 2020). These are examples, motivation, and theoretical bases for limnologists to strive to implement studies that allow not only the assessment of the impacts of climate change on aquatic ecosystems, but also studies aimed at proposals for mitigation and assessment of adaptations of aquatic biota to these impacts. Equally important shall be the investment in "citizen science", for which we need to develop new ways of communicating our findings and discussing with society new ways of facing and adapting to climate change.

Limnology and the agrobusiness: the search for a sustainable agriculture

It seems still modest the direct involvement of Brazilian limnologists with the initiatives of agriculture/agribusiness and that their potential interactions are not yet fully explored. Brazilian agriculture is a world reference and traditionally, the area has been ruled by Agricultural Sciences/ Agronomy although, this picture has been changing and successful collaborations emerged (*e. g.* ecology of microorganisms, biogeochemistry/ soil nutrition and soil-water interactions). To strengthen this situation, it is essential to understand the centrality and importance that water plays in agribusiness, that uses, on average, 70% of the available freshwater on Earth (The World Bank, 2020).

Irrigation is key to the success of modern agriculture. It accounts for 40% of food production covering only 20% of the global cultivated area (Molden *et al.* 2010, The World Bank 2020). However, it should be questioned the preference for using the central pivot irrigation system – in Brazil it covered 1.6 million ha in 2020 – a system that admits losses of 50-60% of water in addition to the high energy consumption. Moreover, it is estimated that the world will need to produce 60% more food to meet the increase in world population by 2050 (FAO 2017a) and to meet this demand irrigation is expected to grow > 50%, reducing by *c.* 30% underground water resources (Rickey *et al.* 2015). These data open new fronts, in partnership, for studies and research for Limnology, particularly related to water economy and conservation and its sustainable use. Furthermore, a sustainable

agriculture will have to invest in evaluating the "virtual water" – that water used in food production and that is exported without having its volume quantified and that has an international economic connotation as exported water and that involves a value in commercial exchanges" (Hoekstra & Chapagain 2007). It is an important environmental service (water provisioning) that needs to be quantified and priced in the context of agribusiness. In addition to assessments of the "ecological footprint of water" in food production, it is necessary to invest in the reduction of the high consumption of water. The challenge is to demonstrate to agribusiness that water is not just a commodity, but an essential element of nature without which productivity gains of agribusiness would not be maintained. Limnology needs to position and qualify as a partner also in this field.

Limnology and the mining supply chain: opportunities for partnerships

Mining in Brazil has expanded its area of occupation > 6 times, from 31,000 ha to 206,000 ha, in the period 1985-2020, being 72.5% of this area in the Amazon (MapBiomas 2020). You can't do mining without water and this resource is present in practically all stages of the mining industry's production chain. Important to note that, to reach the vein to be mined, it is often necessary to lower the water table, thus altering the distribution and availability of water besides bringing risks of contamination of this water.

Two major uses of water in mining deserve attention: that used to wash the ore and that used to transport it - pipeline miner water, in considerable amounts (*e.g.* 2,105 m^3h – ore pipeline, 68% of solids), connecting the 529 km between Conceição do Mato Dentro, in Minas Gerais and São João da Barra, in Rio de Janeiro – (https://brasil.angloamerican.com/pt-pt/imprensa/noticias/year2014/18-12-2014). This water, usually new and good quality water that, despite providing an invaluable service, is not included in the final costs of the ore, despite the legal provision for charging for its use, nor is it seen as an essential and finite natural resource, clearly demonstrating the non-sustainability of conventional mining. The environmental impact studies required for these areas should, necessarily, support the plans for the recovery of degraded areas and, in fact, allow a step forward, be a reference for restoration programmes to be executed at the end of mineral exploration. Limnology should consider here an opportunity to propose studies and environmental restoration projects, following the impact assessment studies, including assessment of acute and chronic toxicity for different groups of the biota.

With the increment of mining area there will be more production and jobs, but also more transformations and impacts. This shall be an opportunity for interactions and investments in the conservation of biodiversity and environmental quality, if the mining sector consider its insertion in the circular economy, for what it is necessary to invest in new technologies, conservation, reuse of water, assessment, and sustainable use of biodiversity and, hopefully, less expenditures in environmental compensation. We are talking in a paradigm shift: leaving behind the idea that the mining impacts are concentrated on the "mine pit" (*e.g.* Sonter *et al.* 2018) to incorporate a new approach - the mineral resources landscape – MRL (Giurco & Cooper 2012).

This new vision, besides considering distinct spatial scales, allows to incorporate social, economic, cultural, and environmental impacts thus enabling the establishment of connections (*e.g.* EIA/RIMA and PRAD), the anticipation of impacts and the integration between use, management, and conservation of natural resources, to reconcile mining and other sectors/activities of society, besides promoting a shared responsibility among these sectors (Barbosa 2022). The MRL associated with the incorporation of new technologies (*e.g.* phyto mining, phytoremediation, big data, scenario modeling) and investments in recovery/restoration of degraded areas is the way for mining to bring real benefits to people and the places where they live, redeem itself and contribute to the implementation of the SDGs.

Limnology, Covid-19, and other pandemics: perspectives/adaptations in the new normal

Some changes in science, academic life and society in general have already been noticed and measured because of Covid-19 pandemic at a global scale, including the expansion of e-commerce, intensification of remote work and particularly of distance learning, and opening of new markets.

Maybe this pandemic has contributed to a slowdown in globalization (globalization minus, *sensu* Bruno Latour 2017) and it has increased the level of solidarity between people. For sure, it caused significant changes in people's life.

An expected adaptation in the case of Brazilian Limnology is its greater involvement and contributions to the water and sewage sector, including public supply, sewage treatment and water and sewage recycling, particularly in relation to water quality and biodiversity conservation. A promising example has been monitoring the spread of SarsCov-2 through sewage, as for example the project "Monitoramento Covid Esgotos" a joint initiative of Federal and State Agencies and Sustainable INCT-ETEs (ETES Sustentáveis, INCT 2022) which offers a series of opportunities, including the development of new technologies, monitoring of pandemics and professional training, expanding the possibilities of partnerships.

Limnology in the "New Normal" must prioritize local/regional problems and opportunities, investing in studies and projects with real contributions to solving problems related to basic sanitation, for what it can bring contributions to be used, for example, by river basin committees, notably for the review of National Plan of Water Resources (Ministery of the Environment and National Water Agency - http://www.participa.br/recursoshidricos/pnrh/o-plano-nacional-de-recursos-hidricos), besides invest in water education. Furthermore, there is the opportunity to invest in monitoring environmental health, adopting practices such as those proposed by the One Health platform (American Veterinary Medical Association 2008). To contribute to these new fronts, Limnology must expand its technical-scientific horizons and contribute to the elaboration of proposals for the political agenda of the water and sanitation sector, supporting and contributing to the consolidation of the New Legal Framework for Basic Sanitation (Law no. 14026/2020; ANA 2021). It is essential to understand and contribute to the cross-cutting relationships of sustainable development goals, particularly SDGs 6 and 13. Limnology must innovate.

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