Don’t stressor the small stuff

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Freshwaters are subject to a multitude of threats, but complex interactions among stressors are context-dependant and less common than expected.

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It's no exaggeration to say that life on land would not exist without freshwater. As detailed in the Millennium Ecosystem Assessment[1], freshwater ecosystems service all aspects of human existence, yet are also increasingly degraded by our activities. In part, this sensitivity arises because surface waters lie at the bottom of the gravity well that drives the global hydrological cycle. Here lakes and rivers integrate the influx of energy (irradiance, heat, kinetic energy) and matter (water, solutes, suspended materials) arising from natural biophysical processes and human activities[2]. As such, freshwater ecosystems are sensitive sentinels of environmental change[3], impacted by a multitude of obvious and cryptic stressors. In this issue, Birk et al.[4] roll up their sleeves and get on with the messy and potentially frustrating task of determining when, how, and where stressors interact to affect biota in lakes and rivers by synthesizing around 175 studies of European freshwaters.

Protection of freshwaters is difficult in part because public and scientific perception of the main threats have changed during past century. Following on from ecosystem surveys during the early 1900s[5], freshwater science entered the global theatre during the 1960s and 1970s in response to widespread degradation of surface waters by nutrient pollution, a process called eutrophication[6] (Fig. 1). Over the next 70 years, challenges diversified to include acidic precipitation, food-web modification, UV radiation, biodiversity loss, invasive species, xenobiotic pollution, and climate change, among other more regionally-expressed stressors. While this diversification results in a sophisticated recognition of the complexity of threats to freshwaters, many mechanisms driving surface water degradation remain active[7]. In fact, even formerly vanquished foes, such as eutrophication, are rebounding in some regions[8,9] .

Birk et al.[4] define stressors as any external factor that causes a receptor to respond outside its normal operating range, and they identify six stressor categories; nutrient, hydrological, morphological, thermal, xenobiotic and 'other' chemical. Their comparative approach combines standardized manipulative experiments from a pan-European project (MARS)[10], whole-ecosystem studies, and cross-basin monitoring programs to quantify the linear interactions between all pairs of stressors, each selected to be locally relevant ('real life') in terms of identify and magnitude. By contrasting diverse biological responses of both primary producers (plankton, plants) and consumers (invertebrates, fish), they generalize their findings well beyond the normal expertise of individual laboratories or investigations.

The authors uncover many unexpected findings. For example, complex interactions among stressors are uncommon across Europe, with 39% of interactions controlled by a single factor and 28% suggesting simple linear addition of regulatory effects. Across all biological responses, this pattern is more marked for lakes (62% single factor) than for rivers (28%), even if comparisons are restricted to a single taxon such as fish (75% and 32% respectively). Critically, the importance of complex interactions increases with spatial scale in rivers, but not in lakes. In fact, statistical models perform better for rivers than lakes at all spatial scales, although those derived from highly-regulated experiments did the best at explaining biological responses in both ecosystem types.

Despite myriad threats to European freshwaters, Birk et al.[4] show that the effects of nutrient pollution on biota are usually paramount in lakes, even when matched against climatic factors such as warming or changes in water inflow. Although less singular, strong effects of eutrophication are seen in flowing waters, where animals are more sensitive to a wide range of stressors than are photosynthetic organisms. Of interest is the outlying observation that increasing colour of lakes due to influx of dissolved organic matter from land, a process termed brownification, may supress the worst of nutrient pollution effects, at least on phytoplankton which form the base of lentic food webs.

As often happens with provocative science, this study results in more questions than answers. Why are nutrient effects so pronounced? Would the same patterns be seen in other regions? Do invasive species modify findings? How will the next generation of stressors, such as microplastics, salt pollution, and novel xenobiotics, change the story? As noted by the authors, this study represents one of the first attempts to standardize and quantitatively contrast diverse threats to aquatic biota and, as such, is a combination of empirical observation and expert opinion from many of Europe's best freshwater scientists. Future studies will need to develop a mechanistic explanation for the key trends, as well as expand the analysis to include higher-order (three or more factors) or non-linear interactions. As well, there is a pressing need for a conceptual basis that would allow prediction of the outcome of stressor interactions.

Eutrophication remains a central threat to freshwater ecosystems world-wide[9], reflecting a shift from predominantly urban pollution 50 years ago to widely-distributed diffuse sources in recent decades[8]. Consequently, it is unclear whether the finding that lake biota respond mainly to nutrients arises because eutrophication remains the most potent stressor, such as seen in many aquatic ecosystems (e.g., Laurentian Great Lakes, Baltic Sea), or rather precisely because regulatory actions are starting to have an effect, thereby providing additional scope for damages in some European waters. What is clear from Birk et al.[4], however, is that a one-size-fits-all approach is unlikely to be effective in protecting European rivers[9] and that managers will require a bespoke strategy that considers the interaction between nutrients, river hydrology, basin modification (riparian and wetland habitats), food-web management (invasive species), and xenobiotic pollution.

Notwithstanding transient challenges, human population and global economy should continue to expand for at least 50 more years, possibly at rates which outstrip those of climate change. As these three factors together control the influx of energy and matter into all ecological systems[2,3], it seems likely that stressor interactions will intensify, both due to emergence of new challenges and return of historical processes. The work by Birk et al.[4] provides a launch pad to get ahead of this problem, as well as a solid roadmap for effective management of freshwaters.

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Competing interests

The author declares no competing interests.

Figure legend

Figure 1. Nutrient pollution of freshwaters leads to intense blooms of cyanobacteria in a process called eutrophication. Despite management since the 1960s, excess nutrient pollution is still the main stressor of biota in European lakes[4]. (Photo credit: Institute of Environmental Change and Society, Regina, Saskatchewan, Canada)