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Climate change is reshaping US fish communities

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Standfast:

Rising temperatures and the introduction of non-native fishes are linked to rapid changes in the native fish communities across the US.

Rivers are some of the most biodiverse ecosystems yet are heavily exploited by humans, regulated for water supply and flood defence, and impacted by a range of other factors including climate change and invasive species¹. This results in sobering statistics about the state of freshwater biodiversity e.g. [2], albeit interspersed with some more positive news (e.g. recovery of many European rivers from gross sanitary pollution since the late 20th century³). Changes in river invertebrate diversity over recent decades have been widely documented from national to global scales [e.g. 3-4], but equivalent studies of fishes are less common, despite their economic importance in fisheries and for recreation. In this issue, Rumschlag *et al.*⁵ address this gap, tracking fish communities in rivers across the conterminous US. They show striking changes since the early 1990s which they relate to rising water temperatures and the impacts of non-native fish species.

The US has diverse native and non-native fish faunas⁶, which have been monitored for decades by electrofishing surveys carried out by the US Environmental Protection Agency and US Geological Survey⁵. Electrofishing is a widely used approach where fish are temporarily stunned by an electric current passed through the water, allowing them to be identified and counted. Rumschlag *et al.* analysed data from roughly 4500 of these surveys collected between 1993 and 2019 at nearly 3000 locations spread across the conterminous US. This differs from many long-term biodiversity studies in having few repeat surveys at each location; instead, similar rivers were sampled each year, allowing change through time to be assessed, whilst providing a more detailed geographical picture of changes across the US. Previous large scale fish studies have often been restricted to species lists for major river catchments⁷ due to the limited availability of such spatially extensive, standardised data looking at the whole fish community. This reflects the more intensive focus of much fish research, looking at subsets of species or river types, or particular river catchments.

In the first part of the study, Rumschlag *et al.* looked at how the richness (number of species) and total abundance (number of individuals of all species combined) of fish changed in relation to historical average summer temperatures. For convenience results were often presented for ‘cold’, ‘intermediate’ and ‘warm’ streams, defined by a simple split of the observed water temperature range. The most striking result is the magnitude of the estimated changes and contrast between cold and warm streams; richness and abundance declined by 32% and 53% respectively in cold water streams, but increased by 16% and 71% in warm streams. ‘Opportunistic’ species – typically small, short-lived, fecund species that respond rapidly to changes in their environment – increased in the warmer streams but decreased in cooler ones, whilst larger, longer-lived species which have more variable, ‘periodic’ reproductive success showed the reverse pattern. The headline figures need to be treated with some caution because the three-way temperature split, whilst helpful for communicating the results, is essentially arbitrary: classifying rivers into wider or narrower temperature bands would alter the percentage change figures. Nevertheless, this reveals major changes in fish communities since 1993, affecting large swathes of US rivers, and adds greatly to our understanding compared to coarser-grained analyses comparing major river basins [e.g. 7]. Moreover, it illustrates the value of drilling deeper into biodiversity trends, because the contrasting changes in warm and cold streams would tend to cancel one another out, disguising major biodiversity changes.

In the second part of the study, Rumschlag *et al.* focus on rising temperatures and non-native fish, which are two of the main factors degrading freshwater ecosystems⁸. Non-native encompassed species introduced for recreational fishing (‘game’ fish) as well as those introduced accidentally or for other purposes. The potential for two or more factors (‘multiple stressors’) to interact, accentuating or moderating each other’s effects, often complicates human impacts upon ecosystems. Rumschlag *et al.* found that rising temperatures and non-native fish abundance are generally synergistic, magnifying each other’s impacts upon the native fish community, as widely predicted for freshwater systems⁸. An interesting extension here would be to separate game fish from other introductions to ask whether game fish management in particular has made the system more climate sensitive. To minimise future climate impacts, should the focus be on biosecurity or does game fish management need revisiting?

Moving from descriptions of biodiversity change to causal understanding of the drivers is a generic challenge in ecology. Rumschlag *et al.* provide convincing evidence of the association between climate, nonnative species and biodiversity changes, but confirming underlying causal relationships will be much harder, not least because many global change impacts on rivers co-occur¹. As the authors note, even confirming a relationship with rising temperatures can be tricky, as temperature could be a proxy for

other climate-related phenomena (e.g. drought frequency) rather than temperature *per se*. The authors offer thoughtful explanations of their results, but resolving the mechanisms will require detailed follow on work.

Rumschlag *et al.* portray a rapidly changing river environment. Their analysis didn't extend to a nonlinear approach, so doesn't explicitly indicate whether changes are continuing at a similar pace, or have accelerated or slowed. Either way, their findings reinforce widespread management recommendations to reduce thermal impacts on rivers (e.g. via management of riparian vegetation to increase channel shading⁹) and minimise nonnative fish introductions⁸. More controversially, although not specifically highlighted by the authors, the latter could include game fishes, an area of potential conflict between management for biodiversity and ecosystem services.

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