Rivers and streams of the world’s cities are usually much less healthy than their rural counterparts. When urban land use degrades rivers and streams, there is a decrease in biodiversity. Many studies have shown that urban streams are marked by the loss of many species including frogs, salamanders, platypus, fish, and the most diverse group of animals—invertebrates (insects, crustaceans, and worms).

Stormwater drainage and the removal of forest cover from riparian zones impact streams at different scales, but both factors are cited as leading causes for decline in stream species in urban areas. Urban stormwater is a problem that can extend across the entire watershed of a stream. While a building or a road may sit at the top of the hill, a great distance from the nearest stream, it is likely to drain to a stormwater drain that takes all the water that runs off these surfaces (and all the pollutants it picks up on the way) straight to the stream. On the other hand, the influence of forests on streams tends to be strongest nearest the stream, so loss of forest next to the stream would likely have a much stronger effect on animals in the stream than would the loss of forest further up the hill.

This study used measures of urban stormwater runoff and forest cover—these measures may account for different scales of effect—to test how well they explain the distributions of macroinvertebrates (invertebrates larger than 0.25 mm) in streams across the large metropolitan region of Melbourne, Australia. For urban stormwater runoff we used attenuated imperviousness (AI), an estimate of the area (as a proportion of the watershed area) of roofs and roads that are connected to streams by stormwater pipes. For forest cover, we used a similar measure, attenuated forest cover (AF), which weighs areas of forest by how far they are from the stream and how far upstream they are from a sampling site.

The Melbourne region spans strong gradients in rainfall, geology, elevation and vegetation across approximately 200 kilometers (124 miles [mi]), resulting in large natural variation in the types of streams and the species that they support. We chose a modeling approach that allowed us to test how the effects of urban stormwater runoff, forest cover, and natural gradients interact with each other to predict distributions of macroinvertebrate families (groups of closely related species). We developed individual models for 60 families that are common in the region.

Of the 60 families, 51 showed a negative response to AI, most with a steep decline from 0% AI, with 24 families predicted to be near-absent in streams with more than 4% AI. Six families, including those of invasive and exotic species, had a positive response to AI. Of the 477 genera/species in these families, 340 were near absent from streams with more than 4% AI, so family analysis underestimates the loss of biodiversity resulting from urban stormwater impacts.

Others have predicted that stream species should have some resistance to small amounts of urban stormwater, but we found no such evidence. Frequent polluted runoff from less than 0.5% of a watershed’s area (i.e., 10,000 square meters [2.47 acres (ac)] of road in a two square kilometer [494 square ac] watershed, Figure 1) would likely be enough to stress or kill many sensitive species, if the runoff is piped straight to the stream. Such an effect could explain negative effects at very low levels of AI.

![Figure 1.](image)
The effect of urban stormwater runoff (as indicated by AI) was the same across the region, and not modified by forest cover for most families (none of the 24 highly sensitive families). Interactions that suggested a change in biological response to one variable (e.g., AI) as a result of change in another (e.g., AF) were uncommon. For four tolerant families (i.e., negatively correlated with AI, but found in sites with more than 4% AI), the effect of AI was reduced in streams with high AF. So for these few families, shading, and perhaps leaf and wood fall from streamside trees, may counter some of the broader impacts associated with urban stormwater runoff.

For 10 tolerant families, the effect of AI was reduced in streams in dry parts of the region or after very dry antecedent conditions, suggesting that inputs from the water supply system could reduce the stress of low flows in some urban streams (Figure 2). But for most families, neither forest cover nor additional flows during dry conditions show any sign of mitigating the broader impacts of urban stormwater runoff (Figure 3). So, to protect most species of invertebrates in streams of urban areas, the first priority should be to ensure that runoff from roofs and roads is retained in the catchment and either used or filtered slowly to the stream. The positive effects of forest cover along streams will be stronger if urban stormwater is adequately managed.

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