ENVIRONMENTAL IMPACTS

No clean coal for stream animals

Societal activities carry environmental costs, which can be mitigated to restore ecosystem function and services. A meta-analysis demonstrates strong negative effects of coal mining on stream biota and limited recovery after restoration.

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Humans affect the environment in many ways, a necessary consequence of living that is exacerbated by our numbers, now approaching eight billion, and lifestyles. Efforts to recognize those effects, reduce our footprint, and repair or offset damages, are a central focus of policy and regulation in many countries[1]. This is particularly relevant for fossil fuel extraction and energy production. For example, coal accounts for approximately a third of all energy used worldwide, and the effects of coal combustion on air pollution and greenhouse gases are well known. However, the impacts of coal production arise long before the coal is burned. In this issue, Giam and co-authors[2] report on their synthesis of field studies on the responses of stream animals — fish, salamanders and invertebrates — to coal mining in the United States, and demonstrate that the abundances and diversity of this biota are greatly reduced by coal mining and that restoration efforts fail to rebuild them.

You might think that quantifying effects of environmental impacts would be simple — all you have to do is 'look'. But natural systems vary notoriously from one site to another and from one time to another. The challenge is to discern effects of the activity of interest (for example, coal mining in a specific locale) from other factors that drive variation in, for example, biodiversity or species' population sizes. Ideally, sites would be sampled before and after some activity of interest, such as mining, and these would be compared with samples from 'control' sites to infer causation and quantify effects[3,4]. 'Before' data are often not available, though, so any single study that compares a downstream site with a control is likely to give a biased result that confounds natural spatial variation with effects of mining. Put simply, any two sites, such as streams in a mining region, will be different even in the absence of mining. An alternative approach uses a collection of 'after-only' studies to determine if the pattern of effects is consistent across studies. In this case, the challenge lies in properly combining results from disparate studies, and that is the purpose of a technique called meta-analysis[5,6].

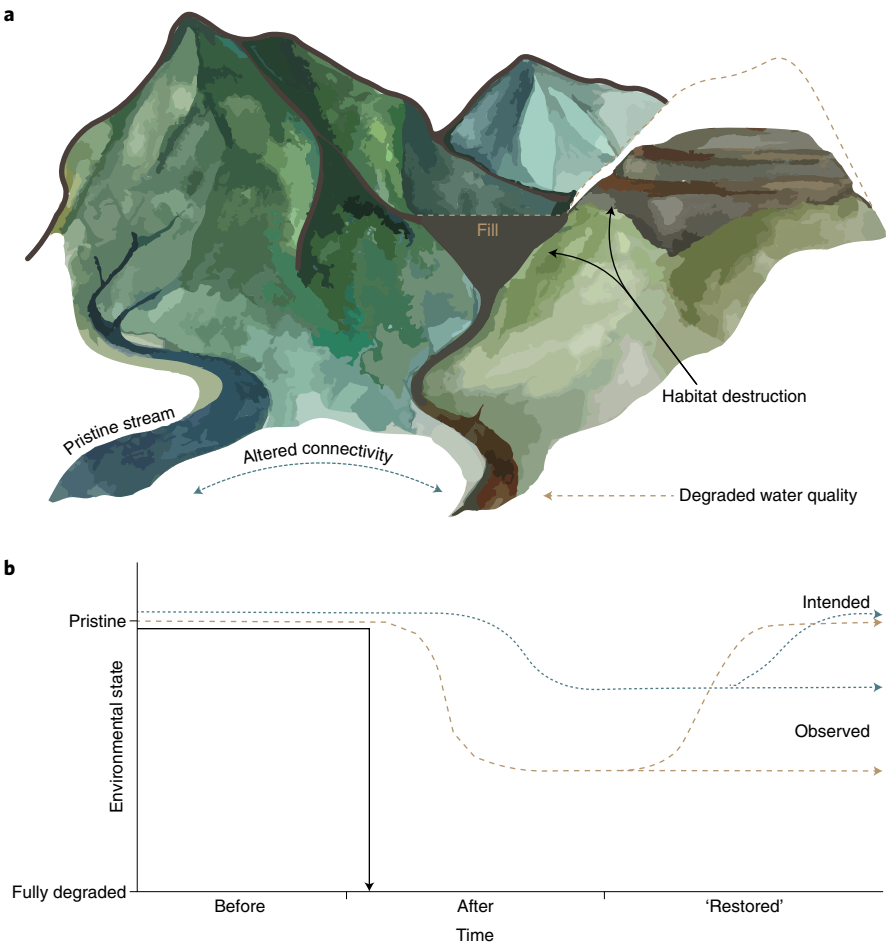

Fig. 1 | Coal mining affects stream biota through three pathways. a, Coal mining using the mountain-top mining/fill valley method causes: habitat destruction; degraded water quality (the focus of Giam et al.[2]); and reduced connectivity between degraded and non-degraded sites. **b**, These effects have different temporal dynamics. There is an immediate loss of headwater habitats with little opportunity for recovery (solid black line). Downstream habitats persist, but impacts accumulate through time (dashed brown line). The decreased density of organisms in the affected stream(s) reduces the densities and biodiversity of streams that are not directly affected by mining (dotted blue line)[8]. Although restoration should lead to recovery ('intended'), the data contradict that expectation ('observed')[2]. Note: spatial and temporal variability due to other processes has been ignored for clarity, as have effects on public health, the terrestrial environment, and the atmosphere. Illustration and figure by Rebecca Atkins.

Giam and his collaborators used meta-analysis to synthesize data from 13 field studies to estimate effects of coal mines on stream biota. Mining can alter downstream

biota by elevating concentrations of heavy metals and other contaminants or by increasing sediment loads or water acidity[7,8]. However, effects on populations of stream organisms, such as fish and aquatic insects, have varied across studies, and so far this variation had not been synthesized systematically. By comparing the biota downstream of mining activities with those in control streams, Giam et al. determined that densities of aquatic insects, fish and salamanders declined on average by >50% and that the number of species in affected streams fell by about 35%. Importantly, even after restoration of the habitat, or 'reclamation', these effects persisted; there was no demonstrable evidence that abundances or diversity had recovered[1,2].

While compelling, Giam and collaborators' meta-analysis focused on only one type of effect that coal mining might have on stream biota. In general, mining affects stream ecosystems by: (1) destroying habitat, for example, mountain-top mining-valley fill methods remove or bury headwater streams, and restoration is not possible; (2) degrading downstream environments (as studied by Giam et al.); and (3) reducing connectivity to other streams — because many populations rely on migration from other sites, reduced numbers at a mined site are likely to reduce the populations in nearby, pristine streams[9] (Fig. 1). Of course, burning coal also contributes to air pollution and climate change, which could further affect stream biota away from the mining site. As a result of these diverse impacts, the effects estimated by Giam et al. should be viewed as conservative — it's likely they underestimated the overall effects of coal mining on stream-dwelling organisms.

Coal mining is forecast to remain a major source of energy for at least the coming several decades. Giam et al. therefore identified regions in the US where future coal production was most likely and those where impacts of mining are likely to be most severe (for example, regions with high biodiversity or many threatened or geographically restricted species). The overlap defined two regions of greatest conservation concern: Appalachia and the Colorado Plateau. How society weighs the economic pressure to mine coal-rich regions against their ecological and recreational value is anyone's guess, but the Trump administration's recent changes to environmental policy suggest mining interests may hold the most sway, at least for now in the United States. However, effects of mining extend far beyond stream biota and include impacts on public health and human life expectancy; indeed, effects on human longevity alone exceed the economic benefits of coal production[10]. Adding in the costs associated with quality of life, health care, tourism, climate change, and recreational fishing only make the case for coal more tenuous[11]. Data speak. Who is listening? ❐

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