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EDITORIAL

Using Different Data Sources for Addressing Multiple Environmental Challenges in Our Anthropocene World

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As the global population grows and humans continue to pollute and overexploit the planet's natural resources, our children and grandchildren are being left with a daunting environmental legacy. Humans should be reminded of the growing environmental crises facing humanity. Promises continue to be made; tangible progress continues to be elusive.

We live in a multiple stressor world that gets more complicated every day. For example, the industrial production of synthetic chemicals, which was recently estimated at about 10 million new compounds each year (i.e., > 1,100 every hour or 19 per minute), is far outpacing our abilities to determine potential negative impacts. Sadly, the onus continues to be on scientists and environmental groups to demonstrate impending harmful effects before any action is taken, often many years after a compound has been released to the environment, rather than using a precautionary approach forcing industries to demonstrate the safety of their new compounds. The effects of many of these stressors are interactive with additive or even multiplicative effects, often resulting in unpredictable interactions leading to ever more complex problems. With rules like these, there is no surprise we are living with a multitude of environmental crises. In simple terms, our world is getting more difficult to predict.

Despite the challenges these issues pose, most jurisdictions are decreasing their commitments to environmental monitoring, thus making it even more difficult to identify issues requiring mitigation. Environmental assessments typically pass through three stages. Stage 1 determines if indeed a problem exists. Stage 2 attempts to identify the cause(s) of any problem (i.e., Who/what is to blame?). Finally, Stage 3 attempts to mitigate the problem. Here we will focus on the first two critical stages, which of course also inform the 3rd stage.

A fundamental and global issue with Stage 1 is that we typically lack continuous, long-term environmental monitoring programmes, which severely hampers our ability to determine if a problem exists and, if so, what the cause is. This is especially true for the many environmental problems that develop slowly, incrementally, and often "under the radar", which would be missed without decades of observations. To add further complexity, the effects of many environmental problems may not be apparent until a threshold or tipping point is reached and then, much like the fall of Rome, a change that at first occurred slowly suddenly changes very quickly. Society is woefully unprepared for surprises and rapid changes.

Given the lack of direct monitoring, it is time to more fully embrace other approaches that can be used to reconstruct these missing data sets. Two such approaches, which have proven effective in addressing these information gaps, include paleoenvironmental perspectives and the incorporation of Indigenous Knowledge – both of which depend on historical information to inform decision makers on the most effective means to address our ever changing and escalating environmental issues.

The long-term trajectories of major environmental problems may not be documented in data loggers or in scientists' notebooks, but fortunately the planet's ecosystems have been monitoring the environment for us, typically in the form of various types of proxy data preserved in paleoenvironmental archives. One of the better-known approaches is the analysis of tree rings (dendroecology) to track long-term changes in climate and forest growth. Another approach is the stratigraphic analyses of ice cores from polar and high-altitude regions, which can provide key environmental data from these climatically sensitive regions. A third method comes from the record preserved in the calcareous components from various invertebrates (sclerochronology). When it comes to the myriad water-related pollution issues we must deal with, the stratigraphic study of lake and river sediment cores (i.e., paleolimnology) has been shown to provide critical environmental data over time scales of decades, centuries and millennia. High-resolution sediment cores can be collected from a wide variety of aquatic habitats, dated using various chronological approaches (e.g., ^{210}Pb dating of the last 150 or so years, ^{14}C dating on longer time scales), and the physical, chemical, and biological proxy data preserved in the dated sediment profile can be used to reconstruct how the environment has changed due to natural and anthropogenic stressors. Such techniques are being effectively used to study the repercussions of, for example, acid precipitation, metal pollution from abandoned and ongoing mining and smelting activities, long-distance transport of pollutants, eutrophication, salinization, erosion, over-harvesting and climate change, as well as many other stressors. Although not foolproof, these "forensic paleoenvironmental studies" can prove critical in determining if a problem exists and who/what is to blame. It should be noted that, if one is going into battle, a blunt battle axe is better than no weapon at all.

A second and still largely untapped resource is the collective information available from community knowledge holders. Although such records are rarely documented in writing, many communities, particularly among Indigenous Peoples, have strong oral traditions of environmental information, passed down from generation to generation. Moreover, many Indigenous people live closely associated with the land and water and have been observing changes in their local environments for decades. Intuitively it should make sense that those living closest to the land likely understand it best and are better informed to predict future conditions: think

of fishermen, farmers, and hunters around the world, where survival has depended on their ability to read, respond to and predict the environment. Nonetheless, it has only been since the late 20th Century that scientists have increasingly recognized that community knowledge can be a powerful companion to western scientific approaches to understanding the environment, and this is particularly true in remote regions. For example, in Arctic Canada, recent outbreaks of avian cholera in Hudson Bay prompted scientists to wonder if this was a new phenomenon, likely linked to global warming, or if there were previous outbreaks in local waterbird populations. Interviews with Indigenous communities around Hudson Bay suggested no similar outbreaks occurred over at least the past century. Over a similar time period, scientists interviewed Inuit hunters from Baffin Island, and found that they could reliably predict temporal changes in habitat use and numbers of caribou (*Rangifer tarandus*). Moreover, Inuit suggested that caribou have a population cycle with a period of ~60-80 years, an important nugget of long-term information that scientists would take years to determine from survey work. In Mexico, interviews with Indigenous communities suggested substantial habitat and biodiversity loss over recent decades, again information that cannot be acquired in the absence of historical baseline survey information. While there are still many challenges to be addressed for acquiring and using community knowledge, its use to provide a historical perspective and to better predict future changes is a fertile area for research and environmental management.

It is believed that scientists have to address the constraints on interdisciplinary research, and embrace contributions from different perspectives – not just between the sciences but across all fields, including the social sciences, humanities, economics and psychology. It is from this more holistic framework that robust approaches can develop, that unexpected drivers of change and barriers to solutions can be identified, and that broad support for education on issues, as well as pressure for conservation and restoration, can be generated.

Environmental crises are surrounding us. Complex problems require complex solutions, and as such we do not have the luxury of excluding any credible information that can be used to address our environmental challenges. Indeed, we should be advocating for, if not expecting or requiring, its collection and use.