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Letters

Planning forwards: biodiversity research and monitoring systems for better management

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The world is currently facing a suite of complex and dynamic issues that threaten the diversity and processes sustaining humanity. Ecologists have long debated how to best study these issues, resulting in 'friendly fire' between different camps of thought. The most recent casualties, the Alberta Biodiversity Monitoring Institute (http://www.abmi.ca), and the PPBio Program in Brazil (http://ppbio.inpa.gov.br/Eng/public/) and Australia (http://www.griffith.edu.au/ppbio), results from Lindenmayer and Likens' [1] supposition that these programs lack rigorous questions, a factor that has 'undermined the credibility of long-term research and monitoring'. We believe that Lindenmayer and Likens' [1] misinterpretation of the goals of these programs is perpetuating a false dichotomy between traditional research and innovative programs such as the ABMI and PPBio. This division undermines collaborative research between the two approaches and could impede understanding of long-term ecological patterns and processes. It is now time to resolve this issue because the number of countries initiating similar programs is increasing, and now includes Australia, Canada, New Zealand, Sweden, Switzerland and the USA. Here, we explain the two main reasons for our concern.

First, traditional stand-alone studies (even exceptional examples such as the Hubbard Brook Experimental Forest [1] or the North American Waterfowl Management Program [2]) cannot address all biodiversity needs. Many of the questions that need answering focus on how the cumulative effects of multiple human stressors lead to biodiversity change [3]. The common response to this complex question is to amalgamate data from existing research and small-scale short-term monitoring in meta-analyses, or to monitor habitat change through remote sensing as a coarse-filter proxy. Both of these solutions have well-described limitations [4]. An innovative approach is needed that fosters cooperation to answer multi-scale management-relevant questions [4,5]. Recognizing this, countries increasingly are investing in long-term ecological research and monitoring (LTER) systems, such as the ABMI and PPBio. These systems facilitate multidisciplinary multi-scale research and monitoring over extended periods and are designed to address current and future biodiversity questions [6].

What characterizes a good LTER system? Although space prohibits a detailed explanation of these systems, here we highlight some important commonalities and related advantages (e.g. Refs [4,5,7]). LTER systems are designed to track ecosystem change at scales that are appropriate to management (hundreds to thousands of kilometers) over many decades to reveal how biodiversity responds to landscape and global changes. These systems use modular, systematic designs and standardized methods, emphasize rigorous unbiased sampling designs, and invest in human resources, field sites, data storage and data dissemination. They integrate data from many taxa and ecological processes (e.g. Refs [7,8]). The information collected at each location aids local management and can be synthesized at regional, national and global levels. LTER systems are designed to operate across generations of scientists rather than relying on the commitment of a few individuals. Monitoring systems take advantage of existing gradients, both environmental and stressor related, to address questions nested within their overarching goal. The systems retain statistical power even as these gradients change over time, and also generate original, high-quality research (e.g. http://ppbio.inpa.gov.br/Eng/public/ and http://www.abmi.ca/abmi/reports/reports.jsp?categoryId=63).

This leads to our second concern: despite their obvious advantages for studying and monitoring broad-scale biodiversity change, LTER systems are being misinterpreted [1,2,9]. For example, Lindenmayer and Likens suggest that the ABMI and PPBio have been 'planned backwards, in a collect data now, ask questions later' manner [1]. In reality, these programs strive to plan forwards, and are driven by broad but important questions, such as how biodiversity changes in time and space in response to changing human activities. As new issues and questions arise, scientists can use monitoring system data to answer these questions, similar to the adaptive monitoring approach proposed by Lindenmayer and Likens [1]. Systems such as ABMI and PPBio successfully meet the seven features of successful LTER systems as presented by Lindenmayer and Likens [1], providing comparable data and metadata for cost-effective biodiversity management.

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In summary, LTER systems can provide a standardized infrastructure to collect comparable data to answer the questions of today, and a rigorous scientific basis to address future challenges. We invite scientists to integrate stand-alone studies within innovative LTER approaches to provide future generations with the management tools to move beyond the confines of our current limited biodiversity knowledge.

References

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Letters Response

Improving ecological monitoring

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We welcome the comments of Haughland *et al.* [1] regarding our paper on Adaptive Monitoring [2]. As monitoring programs have had such a poor record of success over the last 3–4 decades, there is a clear need to improve their ability to provide important, if not unique, ecological insights. Therefore, debates about how to make much needed improvements are both healthy and essential. This was the underlying motivation for us to develop our Adaptive Monitoring paradigm [2].

We have major concerns about the underlying design of both ABMI and PPBio and remain unconvinced that these approaches provide 'real solutions for biodiversity monitoring' [1].

Both PPBio and ABMI are what we term 'passive' monitoring programs [3] because they lack management interventions or treatments in their experimental or survey design. For example, the stratification entity for ABMI is space. However, the distribution of the many organisms of interest could be strongly influenced by other factors, such as vegetation type, logging, fire, and insect attack. While such kinds of 'passive monitoring' can sometimes help identify broad trends (e.g. whether environmental conditions are getting 'better' or 'worse'), such an approach makes it extremely difficult to identify or understand the mechanism influencing a change in an ecosystem or an entity. This deficiency is especially problematic when there are multiple stressors with cumulative effects because it confounds assigning causality to observed trends. Thus, while Haughland *et al.* [1] argued that both PPBio and ABMI aim to address questions about how multiple human stressors effect biodiversity, their design makes it difficult to tease apart cumulative effects or help understand why such effects have occurred. By contrast, we strongly co-concur with Nichols and Williams [4] and re-iterate that the most effective monitoring programs will be those that are statistically well-designed with relevant management interventions to help the robust identification of the mechanism(s) that give rise to a pattern or trend [2,3]. Understanding mechanisms in ecology is essential because it is fundamental to identify effective solutions to reverse negative environmental trends such as recovering declining populations of threatened species [5]. In addition, it is critical for generalizing to other landscapes and regions and hence ensuring that ecology, environmental management and conservation science are more than disciplines based on case-studies [6].

Haughland *et al.* [1] noted that good long-term ecological research (LTER) systems aim to 'track changes at scales appropriate to management (hundreds to thousands of kilometers)'. We are acutely aware of this goal as the leaders or past leaders of LTER sites ourselves. Yet, programs like PPBio in Australia are based on ~30 plots with a 1-km × 1-km grid spacing [7]. This scale may be appropriate for some things but totally inappropriate for others. Rather than develop a generic single-scale framework with a 'one-size-fits-all' approach to monitoring programs, we believe it is more likely that a robust design at an appropriate scale can be developed if a monitoring program is underpinned by specific questions.

Haughland *et al.* [1] accused us of 'perpetuating a false dichotomy between traditional research and innovative programs like ABMI and PPBio'. We have no intention of creating false dichotomies – far from it as we are deeply motivated to help promote increasing numbers of more effective monitoring programs worldwide [3]. However, we

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