Unraveling Ecosystem Responses to Climate Change on the Antarctic Continent through Long-Term Ecological Research

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Although climate change is occurring on a global scale, its ecological impacts are often specific, and they vary from region to region. Climate changes in polar regions are amplified, making these high-latitude areas sentinels not only for monitoring climate variability but also for the determination of how ecosystems respond to this variability. There has been a large focus on temperature warming in the Arctic and its ramifications for geopolitics, human inhabitants, and changes in north polar ecosystems. Despite its importance in regulating our planet's climate, much less is known about Antarctica, the fifth-largest continent and repository of approximately 70 percent of Earth's freshwater. The Antarctic continent and the surrounding ocean represent coupled components that both drive and respond to climate. Remarkable changes have been observed in Antarctica over the past several decades, including the rapid collapse of ice shelves, changes in penguin populations, and extreme flooding within the polar deserts of the McMurdo Dry Valleys. Our understanding of the mechanisms behind these events is improving, but the complex interactions among the atmosphere, ocean, cryosphere, and biosphere are difficult to resolve. Changes are occurring faster than were predicted only a few years ago, and although the future trajectory remains uncertain, these changes have been projected to alter both marine and terrestrial Antarctic ecosystem structure and function.

Climate variability and ecosystem response are best understood by long-term monitoring. The National Science Foundation currently supports Long Term Ecological Research (LTER) sites in Antarctica at Palmer Station (PAL) on the western coast of the Antarctic Peninsula and in the McMurdo Dry Valleys (MCM) of Southern Victoria Land. These projects have been collecting climate and ecosystem data for more than 20 years and have shown clearly that ecosystem structure and function are tightly coupled with changes in climate, in large part because of climate-induced alterations in ice cover. Despite the disparate nature of these ecosystems (i.e., marine vs. polar desert), there are fundamental similarities in the way that they respond to climate.

This issue includes three Overview articles that integrate data from both Antarctic LTER sites to show how these ecosystems respond to climate variability. Fountain and colleagues present information on the role of the southern annular mode on continental-scale climate variability and highlight the sensitivity of the PAL and MCM ecosystems to discrete climate events. Obryk and colleagues show that the extent and thickness of marine (PAL) and lake (MCM) ice covers are inextricably linked to both short- and long-term climate variation and that this variation is a major driver of biological production. Bowman and colleagues show that the differences in the sources of organic carbon between these sites drive differences in microbial community structure and function, as well as different ecosystem responses to climate events. The integration of long-term data presented in these articles provides a starting point for our understanding of the cascade of environmental consequences related to rapid climate change on the Antarctic continent.

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