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The Rock and Ice Problem in National Parks: An Opportunity for Monitoring Climate Change Impacts

Andrew G. Bunn
Western Washington University, andy.bunn@wwu.edu

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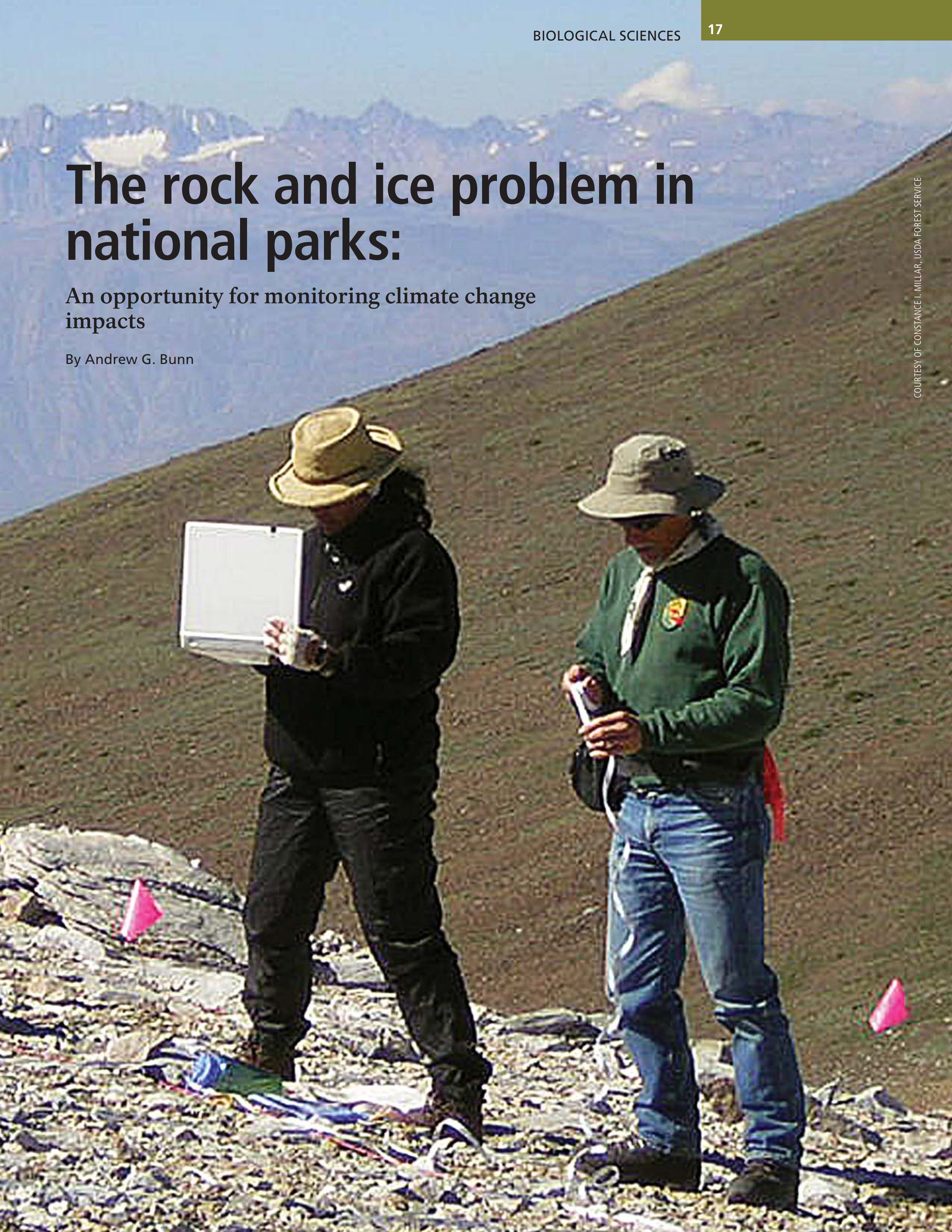

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IN 1979, ALFRED RUNTE ADVANCED THE WORTHLESS-LANDS THESIS (Runte 1979). This loosely posits that the National Park System comprises lands with low economic, and subsequently low ecological, value. The concept is controversial in some respects, but many alpine researchers have acknowledged the "rock and ice problem" in national parks. Certainly, scenic alpine vistas are overrepresented in national park units compared with low-elevation areas with higher primary production, species diversity and richness, and complex ecosystem structure. The National Park Service has a unique chance to use the rock and ice problem as an advantage in understanding climate change, which might be the greatest challenge scientists and society have ever faced (Speth 2005).

The fundamental physics of an enhanced greenhouse effect due to fossil fuel combustion is well understood, and Earth is warming (IPCC 2007). Considerable uncertainty exists regarding the impacts of climate change, but high latitudes and high elevations are thought to be leading indicators of future trends. The suite of high-elevation lands protected by the National Park Service is ideal in terms of documenting and monitoring the physical, floral, and faunal impacts of climate change. Indeed, the network of alpine lands managed by the Park Service in the mountainous western United States spans maritime-to-arid ecosystems over a dozen degrees of latitude (fig. 1). The web grows even farther if we consider alpine park units in Hawaii, Alaska, and the eastern United States. It is a network that has no other analog and offers unparalleled opportunities for global change monitoring.

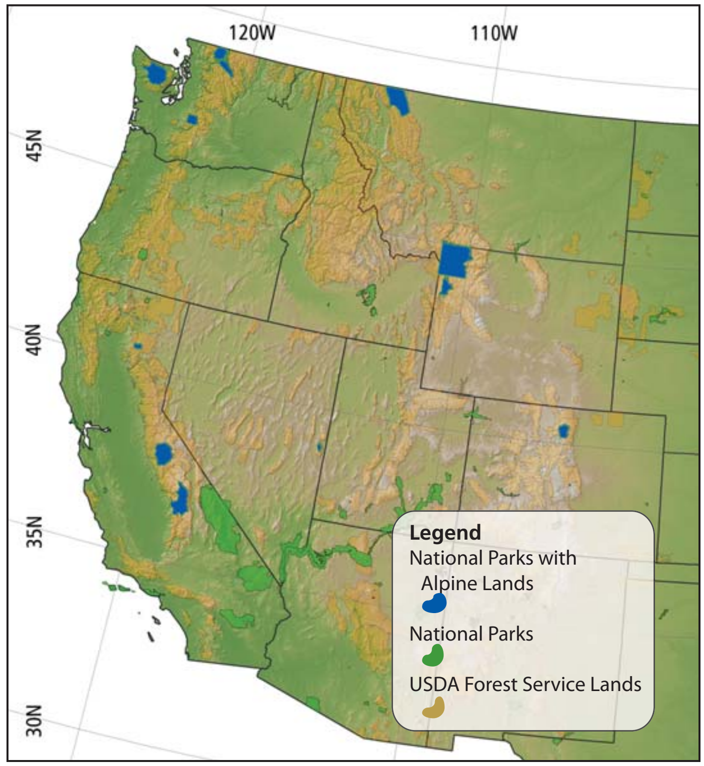

Figure 1. National Park System units in the western conterminous United States contain extensive alpine areas and span maritime-to-arid ecosystems over a dozen degrees of latitude. As part of a suite of high-elevation, protected areas, extensive alpine sites adjacent to park boundaries are managed by the USDA Forest Service and other agencies.

PROJECTION: ALBERS EQUAL AREA CONIC, NAD 83. *DATA SOURCES:* USDA FOREST SERVICE, NATIONAL PARK SERVICE, ESRI, U.S. NATIONAL ATLAS. *CARTOGRAPHER:* JACOB TULLY, WESTERN WASHINGTON UNIVERSITY, GEOGRAPHY DEPARTMENT.

Physical attributes

Glaciers present ideal opportunities to directly measure climate change impacts on alpine areas. Many of the relatively small glaciers in national parks have experienced widespread changes. Some have been measured and photographed over time, yielding aerial estimates of retreat, and some have had more formal studies of mass balance. The retreat of glaciers has been documented with repeat photography most famously in Glacier National Park (Montana) (Key et al. 2002) and also through aerial estimates of glacial ice changes in other national parks, including Kings Canyon (California), Rocky Mountain (Colorado), North Cascades (Washington), and Mount Rainier (Washington) (Fountain 2007; Hoffman et al. 2007).

Although rarer than ice glaciers, rock glaciers provide an intriguing and often overlooked opportunity for climate monitoring. Although their geologic origins are a matter of debate (Whalley and Martin 1992), rock glaciers are essentially fields of underground ice that are covered by rock. The extent of rock glaciers in national park units is poorly known, but they are thought to be retreating like ice glaciers and are critical water supplies for high-elevation ecosystems in summer (Millar and Westfall 2008).

Other physical attributes of national parks can be monitored for climate change (see Lundquist and Roche, page 31 this issue), but glacier retreat is a charismatic phenomenon that has captured the imagination of the public. Nevertheless, the National Park Service does not have a systematic glacial monitoring program in place that integrates observations across the National Park System. Although mass balance of glaciers would be of great scientific value, a monitoring program for aerial extent of glaciers in the alpine areas of national parks would be a logical start; protocols exist for incorporating glacier monitoring into management (Fountain et al. 1997).

One particularly appealing method of monitoring faunal changes is to make better use of historical zoological surveys that exist in many park units.

Flora

Several avenues exist for monitoring climate change using alpine flora in national parks, where growth is typically limited by climate. The two most promising lines of monitoring the response of alpine vegetation to climate change are expansion in woody vegetation at alpine tree line and community composition of herbaceous growth.

Alpine tree-line expansion and contraction can be monitored at temporal scales ranging from centuries to decades (Bunn et al. 2005; Graumlich et al. 2005). The spatial patterns of tree line can be complex (see, for example, Alftine and Malanson 2004). Further, changes in tree line have the potential to greatly transform the alpine land surface, as can be observed from historical repeat photography (Klasner and Fagre 2002) and future predicted changes of conifer distribution under climate change (Schrag et al. 2008). The ways that tree lines are likely to change across national parks in the West involve complex series of feedbacks, including seed dispersal, snow dynamics, and spatial patterns brought about by modifications of microclimate in and along the boundaries of low-growing prostrate growth forms (e.g., krumholtz) (Malanson et al. 2007).

The longevity and slow growth of subalpine conifers lead to lags in climate-driven, tree-line changes; monitoring of herbaceous plants in alpine areas might yield better measures of how alpine changes are occurring in time scales more relevant to land managers (years to decades). One mechanism is to work within the international Global Observation Research Initiative in Alpine Environments (GLORIA) project (Grabherr et al. 2000; see http://www.gloria.ac.at). GLORIA is a network of long-term alpine observatories where scientists collect vegetation and temperature data specifically to discern climate-related pressures on high-elevation ecosystems (fig. 2). More than 40 GLORIA sites are operating on conical mountaintops worldwide, with another 50 in various stages of planning. The sites use simple survey methods and have low maintenance costs; vegetation response is monitored every 5 to 10 years. Several installations are planned in park units and national forests throughout the western United States.

Fauna

Animals that live in alpine areas of national parks are of intense interest to park managers and visitors. They also have the potential to be seriously impacted by predicted climate changes. For instance, American pikas (*Ochotona princeps*) are under threat from climate change; the Center for Biological Diversity (San Francisco, California) has filed petitions to list the species as endangered under the Federal Endangered Species Act and the California Endangered Species Act. Monitoring of alpine fauna has tremendous promise for documenting and understanding climate-induced changes to parks. One particularly appealing method of monitoring faunal changes is to make better use of historical zoological surveys that exist in many park units.

The most comprehensive historical zoological survey in the alpine areas of national parks was the work of Joseph Grinnell in the early 20th century (Grinnell and Storer 1924). Grinnell systematically surveyed the alpine areas that are now Yosemite and Lassen Volcanic national parks (California) as well as several other alpine

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Figure 2. More than 40 long-term, alpine observatories—part of the international Global Observation Research Initiative in Alpine Environments (GLORIA) project—record vegetation and temperature data in high-elevation ecosystems. The GLORIA installation pictured here and on page 17 is in the White Mountains of California in the Inyo National Forest.

The suite of high-elevation lands protected by the National Park Service is ideal in terms of documenting and monitoring the physical, floral, and faunal impacts of climate change.

areas in California. His famous attention to detail has made a resurvey of those areas possible (Moritz 2007; see http://mvz.berkeley.edu/Grinnell). The Grinnell Resurvey Project has noted extensive habitat and community changes of alpine mammals coincident with warming temperatures. Similar work is possible in other units of the National Park System. The study of historical changes to fauna can take advantage of a wealth of physiological studies. For instance, hibernating small mammals are directly affected by climate change because body temperatures during torpor are strongly influenced by exterior temperature. A prime example of this is the golden-mantled ground squirrels (*Spermophilus lateralis*) in the White Mountains of California, which show delayed entrance into hibernation with increasing temperatures (Frank 2007).

Conclusion

Climate change in the coming decades will impact national parks, and managers must be prepared to anticipate and adapt to those changes (Stephenson et al. 2006). In addition to GLORIA (described above), other routes for institutional assistance are available to the National Park Service for alpine monitoring, such as the Western Mountain Initiative (Stephenson et al. 2006; see http://www.cfr.washington.edu/research.fme/wmi) and the National Phenology Network (Betancourt et al. 2007; see http://www.usanpn.org). The National Park Service has an opportunity to better document and understand climate change–related impacts on national parks through its Inventory and Monitoring (I&M) Program. Park-specific management issues make Service-wide integration of standardized I&M Program priorities difficult, but the relatively low diversity, structural complexity, and human uses of alpine areas offer the potential for these places to help implement standardized inventorying and monitoring throughout parks in the western United States. Efforts under way to implement systematic monitoring such as those described by Manier et al. (2006) should be strongly encouraged.

The National Park Service controls a globally unique network of alpine lands that span an impressive array of latitudes and longitudes. Approaching alpine monitoring in terms of physical, floral, and faunal components makes logical and logistical sense for setting up low-cost, simple, and flexible schemes. The Service has a chance to foster better understanding of the impacts of climate on alpine systems. Indeed, the time is ripe to turn the "rock and ice problem" into the "rock and ice opportunity."

Acknowledgments

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About the author

Andrew G. Bunn *was a 2001 Canon Scholar from Montana State University, Bozeman. He completed his dissertation, "Temporal and spatial patterns at alpine treeline in the Sierra Nevada USA: Implications for global change," in 2004. Dr. Bunn is an assistant professor in the Department of Environmental Sciences, Huxley College, Western Washington University, and can be reached at andrew.bunn@wwu.edu.*