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Introduction—Losing the high ground: rapid transformation of tropical island alpine and subalpine environments

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This special issue focuses on the nature of alpine and subalpine environmental change on tropical island mountains. In August 2012 an international symposium on this theme was organized by the University of Hawai'i at Hilo and its Office of Mauna Kea Management. Tropical mountains, because of their exceptional topoclimatic gradients, typically possess an array of distinctive, vertically compressed biomes or vegetation zones with associated localized biodiversity and endemism (e.g., Kilimanjaro; see Hemp, 2006). A subset of such tropical and subtropical high mountains occurs on oceanic islands in the Atlantic and Indo-Pacific. These insular mountains may include relatively large massifs (e.g., Taiwan and New Guinea) or individual volcanic peaks as found in Hawai'i and La Réunion. We identified island mountains with prominences greater than 2750 m as those that host tropical subalpine and alpine ecosystems. The global distribution of these insular mountains is illustrated in Figure 1. The symposium organizers narrowed their focus to inviting participation by a range of experts on tropical islands with mountains that have important subalpine and alpine environments. The shared "special" character of such mountains often includes volcanic origin, geographic isolation, compressed spatial scales, mountain-mass (*Massenerhebung*) effects (Grubb, 1971), Hadley-Cell synoptic climate control, specialized endemic biota, and frequently magnified direct or indirect human impact in their restricted alpine and subalpine zones.

The impetus for this symposium was driven by the University of Hawai'i's specific statutory responsibility for the management of a scientific reserve on the summit of the Hawaiian volcano Mauna Kea (4205 m), which has, over the past 45 years, become home to the world's greatest concentration of very large research telescopes and consequently a range of associated land-use, cultural, and environmental conflicts resulting from their development (Juvik et al., 1992) (Fig. 2). The organizers wished to gain a global perspective on the current state of atmospheric and terrestrial science relative to tropical island high mountains and various best-management practices for these fragile alpine and subalpine environments.

Both university and public management concerns for Mauna Kea have focused on a range of issues including (1) climate change and the shrinking and possible disappearance of the culturally important shallow alpine lake Wai'au (Delparte et al., 2014); (2) possible impact of continued summit development on unique endangered alpine invertebrates such as the Wēkiu bug (*Nysius wekiuicola*, see Fig. 3) (Eaton and Businger, 2014); (3) continuing threats to the endemic alpine flora from alien feral ungulates; and (4) differing demands by Hawaiian cultural practitioners and other general recreational users relating to public access and use of the subalpine and alpine zone on Mauna Kea. The diversity of mountain users and stakeholders have historically operated under a prevailing "multiple-use" management paradigm (Juvik and Juvik, 1982).

Climate Change and Paleoenvironmental Reconstruction

The rising freezing heights and rapid retreat of tropical alpine glaciers worldwide (e.g., Kilimanjaro, Cullen et al., 2013; and New Guinea, Thompson et al., 2011) have been well documented for several decades and offer stark evidence of the accelerating pace of global environmental change. Tropical environments may be particularly sensitive, because the changes in tropical sea-surface temperature and humidity are predicted to be largest and most systematic at low latitudes (Diaz and Graham, 1996). Tropical subalpine and alpine environments on isolated islands form especially critical headwaters that anchor surface and groundwater resources for local communities and further support unique elements of endemic biodiversity. Accordingly, they have been identified as one of the terrestrial ecosystems most vulnerable to global environmental change (Buytaert et al., 2011). Despite their vulnerability and the importance for biodiversity conservation and socioeconomic development, they are among the least studied ecosystems in the world. In this issue, Diaz et al. (2014) provide an updated review of

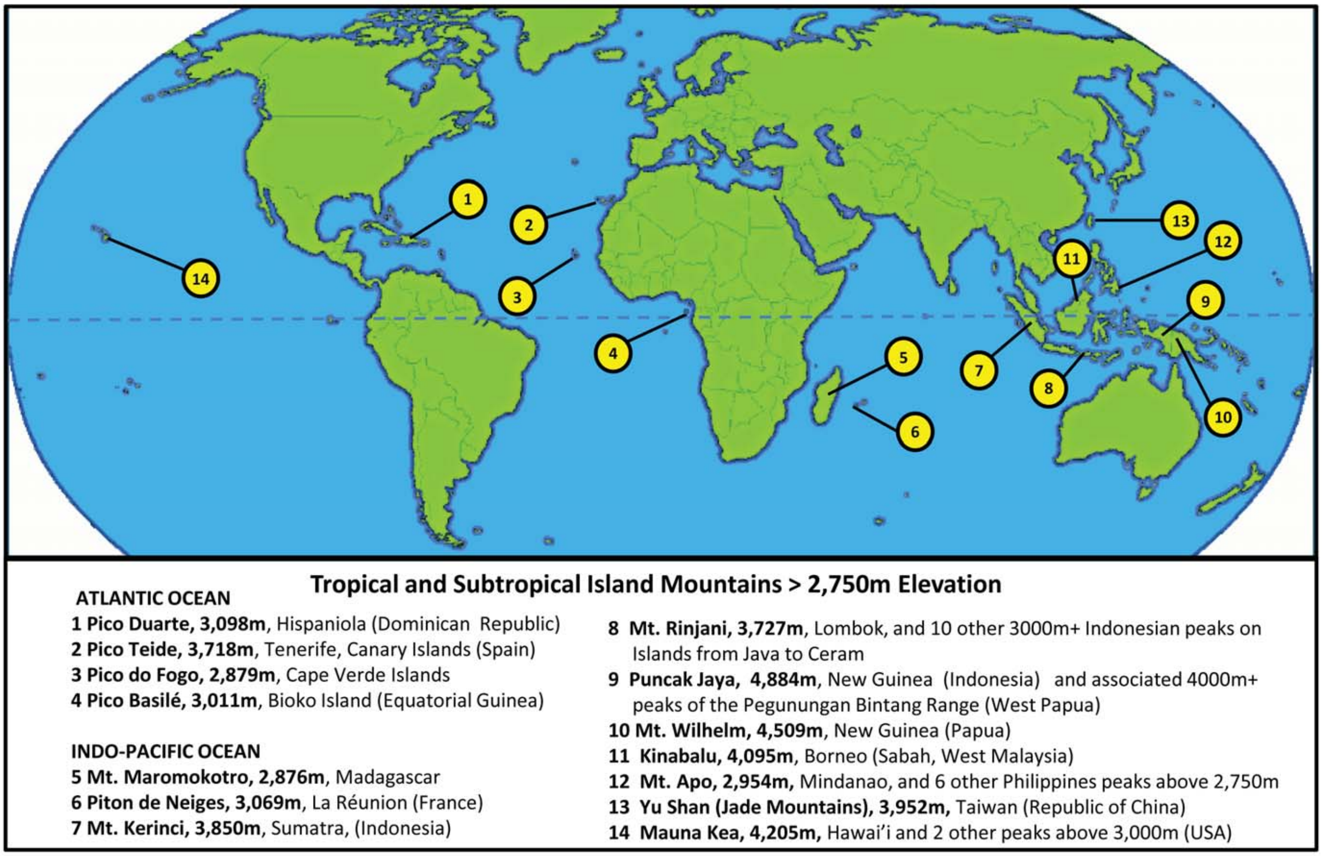

FIGURE 1. Tropical Islands with subalpine and alpine environments.

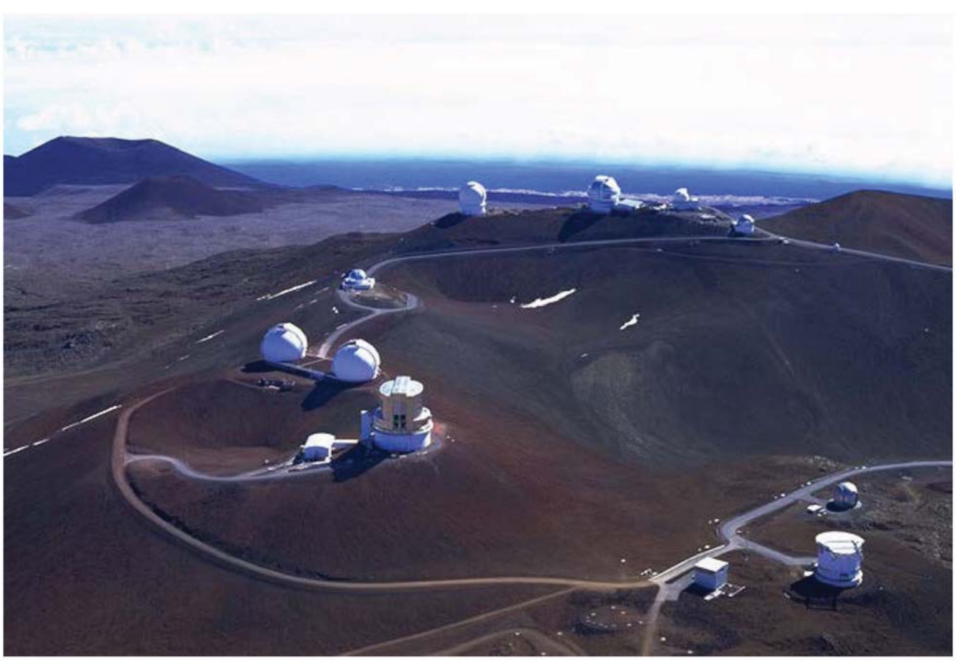

FIGURE 2. A dozen large international telescopes now operate on the summit of Mauna Kea. Photo by Richard Waincoat.

FIGURE 3. The endemic Mauna Kea Wēkiu Bug (*Nysius wekiuicola*) and other alpine biota as well as native Hawaiian sacred site concerns have led to ongoing controversy in the development of the summit area for astronomy. Photo by Jesse Eiben.

anthropogenic global warming projections with a focus on tropical mountains.

Tropical mountains are dominated synoptically by either the ascending (New Guinea) or descending (Hawai'i, La Réunion, and Canary Islands) arms of the Hadley Cell (along with a Walker Cell component in the Pacific Ocean) that creates very different topoclimatic profiles dependent on latitudinal location (Nullet and Juvik, 1994). In their respective assessments of the influence of the trade wind inversion in high mountain ecosystems on Kinabalu, Malaysia, and Pico Duarte (Hispaniola), Kitayama et al. (2014) and Martin and Fahey (2014) demonstrate the importance of persistent large-scale subsidence on high mountain drying trends and ecosystem response and vulnerability. For Hispaniola, Gannon and Martin (2014) further evaluate the impact of hurricane disturbance history on the high mountain forest landscapes of the island, which may see future intensified hurricane impact under various climate-change scenarios (Knutson et al., 2010).

Paleoenvironmental reconstruction for previously understudied tropical mountains is now providing valuable insight into the dynamics of these high elevation "islands within island" ecosystems. In this issue, Hope (2014) shows how the biota of the world's highest, largest, and wettest tropical island mountains in New Guinea are reacting to climate change and other anthropogenic impacts (such as fire, over-hunting, mining, and tourism) within the context of the general post-Holocene historical environmental dynamics of the area. For subtropical Hawai'i, controlled synoptically by descending Hadley Cell air, Crausbay et al. (2014) present a 7300-yr paleo-reconstruction from the slopes of Haleakala, Maui (summit 3055 m). In the lower subalpine cloud forest zone, using lake pollen and charcoal assemblages, they discovered predominately fire- (natural) and drought-driven forest dynamics with resilient post-disturbance forest recovery and persistence.

Mountain Biodiversity

Many tropical island alpine and subalpine ecosystems are characterized by extreme geographic isolation that both limits long-distance plant and animal dispersal and encourages adaptive radiation and endemism in successful colonists (Carlquist, 1974). Fernández-Palacios et al. (2014) provide an overview of the habitat history and constraints on insular biodiversity in the alpine and subalpine zones. For comparison, Anthelme et al. (2014) transfer the analysis of insular high mountain biodiversity to the continental Andes, in relation to high elevation "habitat islands." In a general review of mountain tree-line shifts, Greenwood and Jump (2014) investigate the global impact of climate change on the diversity and function of alpine systems where habitat fragmentation, species displacement, and community disassembly are ongoing. Ah-Peng et al. (2014) contribute an important analysis of the functional diversity of insular alpine bryophyte flora on the Piton des Neiges volcano (3000 m) on La Réunion in the western Indian Ocean.

Contemporary Anthropogenic Disturbance

While the previous papers provide irrefutable evidence of the dynamic nature and vulnerability of tropical island alpine and subalpine environments, the papers by Nogales et al. (2014), Irl et al. (2014), Banko et al. (2014), and Cronin et al. (2014) address the crucial question of how we transcend the disturbance on these mountains to sustain the welfare of local mountain dependent human communities and unique yet spatially restricted ecosystems. These authors advocate rehabilitation of habitats driven by a better understanding of local paleoenvironmental conditions to pinpoint the time frame in which anthropogenic changes have taken place as well as the ecosystem components found in the fossil evidence. The degree of divergence between past and present conditions identifies the extent of the revitalization efforts needed to achieve habitat rehabilitation. Both Irl et al. (2014) and Banko et al. (2014) demonstrate the efficacy of exclosures as an essential management strategy for ecosystem protection. Irl et al. (2014) find that by excluding (i.e., fencing out) alien ungulates they could establish that human impact had severely undermined the natural species richness on La Palma in the Canary Islands. In employing similar strategy, Banko et al. (2014) hope to achieve the protection of habitat that is critical if the population of endemic and endangered palila bird (*Loxioides bailleui*) is to endure in the now-degraded subalpine forests on Mauna Kea.

This compilation of research on high-altitude tropical mountains reveals significant environmental transformational trends. Likewise, it provides important references and baselines for evolving management practices that can be incorporated into necessary rehabilitation efforts in these fragile ecosystems, which are universally valued for their scientific, economic, aesthetic, and spiritual assets.

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