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Conservation Biology — Update 2014

Nathaniel T. Wheelwright

In the 14 years since *Monteverde: Ecology and Conservation of a Tropical Cloud Forest* was published (Nadkarni and Wheelwright 2000), vast tracts of land have been newly protected in the Monteverde-Arenal Bioregion, thanks to the work of the Monteverde Conservation League, Costa Rican and international conservation groups, and numerous generous donors. The Children's Eternal Rainforest is now the largest private reserve in Costa Rica, with an area of 22,500 ha, more than twice the size of the Monteverde Cloud Forest Reserve (see Chapter 10 Update by Burlingame). A new generation of young scientists and policy makers, many of them students on courses offered by the Organization for Tropical Studies, the Council on International Educational Exchange, and the University of California Education Abroad Program, has visited Monteverde's forests. Building upon what was known about the region's flora and fauna a decade and a half ago, they and others have worked with local organizations to connect knowledge to conservation action.

The first step in protecting biodiversity is conducting thorough inventories of species. In this regard, Monteverde has been a leader among neotropical sites. Documentation of the region's stunning biological diversity continues to be expanded by the observations of visiting biologists and ecotourists, as well as local farmers and citizen scientists (e.g., Rowe and Pringle 2005, Yanoviak et al. 2003a). A team from the Monteverde Cloud Forest Reserve, led by Yoryineth Méndez, has been conducting regular censuses of frogs and toads from the Peñas Blancas Valley to the Reserve to the San Luis Valley. Preliminary results indicate recovery of species that had been missing for more than a decade. Another team, led by Mark Wainwright, documented the recovery of the Green-eyed Frog (*Lithobates vibicaria*). However, there remains much to do in Monteverde with regard to several key areas of conservation biology highlighted by Wheelwright (2000). As of 2014, no one has yet published a study of the impact on cloud forest plant or animal communities of invasive species or native lowland species that have expanded their range upslope (e.g., Keel-billed Toucan,

Ramphastos sulfuratus; Bronzed Cowbird, *Molothrus aeneus*). We still can only guess which plants or animals in Monteverde are keystone species (species whose loss would have disproportionate negative effects on biodiversity; *Ficus tuerkheimii* and *Acnistus arborescens*, trees whose fruits are eaten by numerous bird species, are good candidates), and the population genetic structure and demographics are known for virtually no Monteverde species (although see Soare et al. 2014). Gathering such information is critical because it will help us prioritize conservation efforts and effect management plans that target particularly vulnerable or ecologically important populations.

Monteverde's arthropods have been well-catalogued (Yanoviak et al. 2003b, 2007; Schonberg et al. 2004, Hanson 2014) but knowledge of most herbivorous insect species' host plants is lacking (see Hanson 2014). Soil fauna—bacteria, protists, fungi—remain a mystery, although Nadkarni and colleagues (Nadkarni et al. 2002, Rains et al. 2003) continue to make progress understanding the biology of soils in cloud forest canopies. Monitoring species that are easy to count and are ecologically (or economically) important or that indicate the health of Monteverde's communities and ecosystems ("indicator species") is essential. Populations of vocal animals such as frogs, insects, mammals and birds can be monitored using new technologies such as real-time bioacoustics monitoring (Aide et al. 2013). Three-wattled Bellbirds (*Procnias tricarunculata*) and Resplendent Quetzals (*Pharomachrus moccino*) are two obvious species to begin with. For monitoring plant responses to environmental changes, much could be learned by recording the annual timing and magnitude of flowering and fruiting of a taxonomically diverse set of common, easily recognized tree species (Wheelwright 1986); transects could be set up along readily accessible roads in Monteverde with observations made by "citizen scientists" and entered into on-going phenological databases (c.f. U.S. National Phenology Network). These studies need to be designed and implemented quickly, with the goal of pursuing them over the long-term.

Understanding the causes and consequences of rarity is also crucial for protecting biodiversity. Jankowski and Rabenold (2007) found that endemic species in neotropical montane rainforests such as Monteverde tend to be locally rare: there is a positive correlation between distribution and abundance at several spatial scales. There is also a correlation between regions of high species richness and high endemism, at least for taxa such as bromeliads, palms, aroids and scarab beetles, according to Kohlmann et al. (2010), who single out premontane wet forests in the Cordillera de Tilarán as among the most important conservation priority areas in Costa Rica because of their biological diversity and uniqueness.

The main focus of conservation biology at Monteverde since 2000 has been on the role of landscape features in preserving biodiversity, particularly connectedness between habitats at different spatial scales. Since the late 1970's, not only has the size of protected areas in the Monteverde-Arenal Bioregion (MAB) been greatly expanded, but forest regeneration has also occurred throughout the region, thanks in large part to ecotourism, changes in local attitudes, and abandonment of pastures and coffee parcels (see Chapter 11 Update by Stuckey et al.). As a direct result, population declines in numerous species have been reversed. For example, there was little or no change in the number of bats (individuals and species) captured per unit time per net length over a 27-year period (LaVal 2004). Twenty-four new bat species, most of them from the lowlands, colonized the area over the same time, presumably in response to warming climates and a 19% increase in forest area between 1973 and 1998 (based on aerial photographs; LaVal 2004). Agricultural windbreaks, increasingly planted in open pastures throughout the zone, have had numerous beneficial effects for biodiversity. For one thing, they provide habitat for forest tree species and facilitate forest regeneration within agricultural areas: 91 tree species representing primary and secondary forests occur in Monteverde windbreaks, with tree seedling densities highest in windbreaks connected to forest patches (Harvey 2000a). Dispersal of the seeds of trees and shrubs was greater in

windbreaks planted on dairy farms than in nearby pastures, with 199 species recorded in seed traps during a single year; the presence of remnant forest trees in pastures increased the number of tree species (Harvey 2000b). One encouraging discovery is that, in addition to attracting seed dispersers, relict pasture trees can serve as "regeneration foci"—increasing ecological connectedness on a temporal scale—by ameliorating soil microclimates and supporting diverse canopy seed banks in their decomposing epiphyte masses (Nadkarni and Haber 2009).

O'Donnell and colleagues have studied the effect of forest fragmentation in Monteverde on army ants (Formicidae: Ecitoninae) and the birds that facultatively take advantage of them to flush insect prey. In one study, they found that, compared to forest fragments, continuous forest supported greater bird species richness, larger flocks and great total body mass of birds attending army ant swarms (Kumar and O'Donnell 2007). In another study, microsatellites were used to reconstruct genotypes and determine population genetic structure and found "isolation by landscape resistance": forest clearing impedes dispersal and gene flow between colonies of the keystone ant species *Eciton burchellii* (Soare et al. 2014). The increase in road-building and traffic in Monteverde over the last several decades is likely to have created new barriers to gene flow for numerous species (including, surprisingly, certain understory bird species: Devey and Stouffer 2001). Dust from traffic, as well as noise and light pollution, are other unstudied factors that could negatively affect species near developed areas in Monteverde.

For more mobile species, such as birds that migrate altitudinally, the importance of habitat connectedness is evident at much larger scales. In the last 14 years, radio transmitters and other tracking devices have revealed details of the altitudinal migrations of species such as Bare-necked Umbrellabirds (*Cephalopterus glabricollis*) and Three-wattled Bellbirds (Chaves-Campos et al. 2003, Powell and Bjork 2004, Papeş et al. 2012). These studies confirm the importance of safeguarding natural habitats within parks, reserves, and protected private lands across a broad altitudinal range—

essentially, from the Continental Divide to sea level—and across international boundaries.

Climate change has surged to the fore as the central concern in conservation biology. Making headlines in the popular press in ways that tropical deforestation and the extinction crisis never succeeded in doing, fears about climate change have awoken the public to take action to mitigate the worst effects of global warming on crop production, rising sea levels, disease outbreaks, etc. It was apparent in 2000 that Monteverde had already begun to feel the effects of climate change. In future decades, the flora and fauna of cloud forests throughout Latin America will suffer from climate changes more than those of lowland habitats. Montane landscapes support distinctly high beta diversity (the accumulation of increasing diversity as one moves between sites; Jankowski et al. 2009). Moreover, refuges to escape the rises in temperature and alterations in rainfall and seasonality that are already upon us are limited on mountaintops, and they diminish even further as species are forced upslope. At least half of the 77 cloud forest bird species included in the modeling study of Gasner et al. (2010) are predicted to decline in the next century, with eight species restricted to Central America projected to become locally extinct. Species that are particularly threatened include the Mountain Robin (*Turdus plebejus*)—one of the commonest and most important seed dispersers in the 1980s— and Collared Redstart (*Myioborus torquatus*), a familiar and unwary denizen of the cloud forest known as "amigo del hombre." Gasner et al. (2010) recommend improving protection of cloud forests in larger mountain ranges, such as the Cordillera Central and Talamanca, as a way of safeguarding threatened species from the Cordillera de Tilarán. Epiphytes will be negatively affected as well by shifts in microclimate, as demonstrated by greenhouse studies and experiments by Nadkarni and Solano (2002). Epiphytes that were transplanted along with their arboreal soil from upper cloud forests to lower elevation trees exposed to less cloud water had higher leaf mortality, lower leaf production, and shorter lives. The death of epiphytes resulted in radical changes in the composition of canopy communities (Nadkarni and Solano 2002).

Still, some biologists, myself included, wonder whether today's focus on climate change has diverted attention from urgent and long-standing—but still unsolved—threats to biodiversity (Tingley et al. 2013). It is critical for Costa Rican decision-makers—in fact, people interested in protecting cloud forests worldwide—to understand that species are declining right now in Monteverde and elsewhere primarily not so much because of climate change but because of familiar factors such as habitat fragmentation, environmental contaminants, and introduced species. Armed with a better understanding of the present causes of rarity and extinction, conservationists, teachers, taxpayers, and voters can make more informed decisions about where to invest scarce resources for protecting biodiversity. For example, *Ocotea monteverdensis*, a tree species in the Lauraceae restricted to premontane wet forest on the Pacific slope of the Cordillera de Tilarán between 1200 and 1450 m, has recently been red-listed by the International Union for the Conservation of Nature as "critically endangered." Why? Because of "habitat loss and degradation as forest areas have been cleared for agriculture and housing, business and tourist developments" (Joslin et al. 2013). (Note that this formerly common species was called *Nectandra hypoglauca* in earlier publications [e.g., Wheelwright et al. 1984, Mazer and Wheelwright 1993].) Although there is almost certainly more forest cover today in Monteverde than 35 years ago (LaVal 2004; F. Joyce, pers. comm.), the main point is that many species are in decline quite independent of climate change.

Debate continues about whether altered climate caused the demise of the Golden Toad

(*Incilius [Bufo] periglenes*) in Monteverde. Using stable isotope measurements of tree cores to reconstruct a century of hydroclimatology in Monteverde, Anchukaitis and Evans (2010) found annual variation in dry season moisture associated with El Niño Southern Oscillation (ENSO) events and argue that the extinction was likely due to a severe drought caused by the 1986-1987 El Niño, rather than a long-term trend in global warming. Research by Cheng et al. (2011) implicates an "epidemic wave" of the chytrid fungal pathogen *Batrachochytrium dendrobatidis* (Bd), which moved south through Central America and apparently reached Monteverde by 1987, with disastrous consequences for the Golden Toad. It is worth noting, however, that Richards-Hrdlicka (2013) failed to find Bd in preserved Golden Toad specimens. Pounds et al. (2006) envision an interaction between global warming and Bd, with warming climates creating the conditions for Bd outbreaks in the highlands of Costa Rica.

There is much to be optimistic about in terms of conservation in Monteverde (Wheelwright 2007). Forest regeneration, habitat connectedness, population rebounds of certain high profile species (e.g., danta, *Tapirus bairdii*), increasing awareness of other environmental issues, engagement of concerned citizens—all of these are promising signs. We hope that the next generation of Latin American researchers will find in this book specific ideas for their own research projects, and inspiration to advance and apply what we know about conservation biology to protect biodiversity in the cloud forests of Monteverde and throughout Latin America.

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