

Viewpoint

Climate change and birds in the forgotten tropics: the importance of tropical dry forests

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In a world with limited financial and human resources, scientists are forced to evaluate research priorities and focus on questions of particular concern (ter Steege 2010). Recently, Harris *et al.* (2011) argued that more research is needed on the potential effects of climate change in tropical ecosystems (see also Felton *et al.* 2009). We agree that this topic is poorly researched but are concerned that their article focused exclusively on wet tropical forests, even though dry forests constitute 42% of all tropical forest (Murphy & Lugo 1986). Although large areas of tropical wet forest remain, dry tropical and subtropical forests are endangered everywhere (Olson & Dinerstein 1998, Hoekstra *et al.* 2005), with < 2% of original forest remaining in some regions (Janzen 1988). Moreover, 97% of the dry tropical forest remaining is considered to be at high risk from one or more threats, including anthropogenic activities and climate change (Miles *et al.* 2006). Despite this, research has historically focused on wet tropical forests (Sánchez-Azofeifa & Portillo-Quintero 2011).

In some regions, dry tropical forests have higher bird species diversity than nearby wet forests (Kepler & Kepler 1970); even when dry forest diversity is lower, many species are endemic to, or have their highest densities in, dry forest ecosystems, and the proportion of species endemic to the habitat is higher (Stotz *et al.* 1996). The high rate of endemism in dry tropical forests, and the high rate of regional endemism (Stotz *et al.* 1996) is

cause for concern, as specialists are thought to be more vulnerable to climate change than are generalists (Julliard *et al.* 2004). Nearly 80% of bird species restricted to tropical dry forests are considered to be at risk, a far higher percentage than in other tropical forests (Stotz *et al.* 1996).

The direct effects of climate change vary among tropical regions, with expected temperature increases in all tropical dry forests but region-specific changes in precipitation regimes (Christensen *et al.* 2007, Meir & Pennington 2011). However, tropical dry forests are among the ecoregions expected to experience the earliest and most severe impacts of climate change (Enquist 2002, Beaumont *et al.* 2011). In the Neotropics, increased temperatures and decreased precipitation will interact to reduce net available moisture, particularly during the dry season (Singh 1997, Christensen *et al.* 2007, Meir & Pennington 2011). High temperatures are associated with direct reductions in avian reproductive success and survival, even in wetter or more temperate regions (Williams & Middleton 2008, Santisteban *et al.* 2012; W. Cox, F. Thompson, J. Reidy & J. Faaborg, unpubl. data). In addition, tropical arthropods and reptiles respond negatively to increasing temperatures (Deutsch *et al.* 2008, Huey *et al.* 2009, Bonebrake & Deutsch 2011), altering the food chain and exacerbating the current limitation of food resources during the dry season (Johnson *et al.* 2006, Toms 2011).

Climate change will also interact with other stressors (Brook *et al.* 2008, Mantyka-Pringle *et al.* 2012). Dry tropical forests are already heavily impacted by human activities such as agriculture and urban development (Trejo & Dirzo 2000, Fajardo *et al.* 2005, Portillo-Quintero & Sánchez-Azofeifa 2010, Sánchez-Azofeifa & Portillo-Quintero 2011). Conversion of habitat to urban development or agriculture can restrict the ability of species to adjust their range as their climate envelopes shift (Opdam & Wascher 2004). This problem is likely to be most pronounced in ecosystem types where the remaining habitat is limited to highly isolated patches, such as tropical dry forests (Miles *et al.* 2006, Portillo-Quintero & Sánchez-Azofeifa 2010). Importantly, differences in underlying soil properties mean that reductions in net available moisture in moist tropical forests will lead to tropical savannah rather than dry forests in most areas (Quesada *et al.* 2009). Additionally, climate change can increase the rate of habitat loss by introducing novel stressors such as fire and increasing the prevalence of other stressors such as invasive species, parasites or disease (Vitousek *et al.* 1997, Harvell *et al.* 2002, Sánchez-Azofeifa & Portillo-Quintero 2011). In dry regions, climate change will also interact with human activities to increase the risk of desertification (Mabbutt 1989, Leal *et al.* 2005).

The main recommendation of Harris *et al.* (2011) was to increase biodiversity monitoring throughout wet

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tropical forests. However, long-term monitoring is resource-intensive and should not be undertaken lightly. Capture-recapture studies are particularly difficult in species-rich communities, where the total number of captures for an individual species may be low. Even at our comparatively species-poor study site in Puerto Rico, at least 10 years of data are required to estimate species richness reliably (Faaborg *et al.* 2007); detecting changes in individual species will usually require even longer sampling periods. For this reason, we believe that monitoring should occur at least annually, rather than with longer sampling intervals. Monitoring at sub-annual intervals allows researchers to monitor not only population growth, but also other characteristics of individuals and populations that may be more sensitive to stressors, such as body condition, reproductive status, reproductive success, stress hormones, moult status (including stress-linked feather defects), feather growth rate, residency status and seasonal movements. Finally, while monitoring future changes is important, we caution that the effects of climate change are already widespread, and contemporary data will not provide a reliable baseline. Although historical data, such as those derived from museum collections, may also be biased (e.g. Hijmans *et al.* 2000), they can be useful in assessing changes in species abundance and distribution over time (Elith *et al.* 2006) and should be considered a useful adjunct to contemporary monitoring.

Wet tropical forests are centres of species diversity, but the tropics as a whole include many other ecosystems worthy of study and protection. Given that tropical dry forests have already been heavily impacted by humans, are currently under risk from multiple threats, and may have a limited capacity to adjust to future climate change, we argue that these unique ecosystems should be given high priority for future research and management.

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