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Disappearing climates will limit the efficacy of Amazonian protected areas

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ABSTRACT

Amazonian forests support high biodiversity and provide valuable ecosystem services. Unfortunately, these forests are under extreme pressure from land use change and other anthropogenic disturbances. A recent study combined data from an Amazon-wide network of forest inventory plots with spatially explicit deforestation models to predict that by 2050, 36% or 57% of species will be 'globally threatened', as defined by IUCN Red List criteria, due to deforestation under Increased-Governance or Business-As-Usual scenarios, respectively. It was also predicted that the number of threatened species will drop by 29–44% if no deforestation occurs within protected areas. However, even the best-protected areas of the Amazon may still be susceptible to the effects of climate change and rising temperatures. To illustrate the potential dangers of climate change for Amazonian parks, we calculated the percentage of land area within all officially designated protected areas of tropical South America that will or will not have future temperature analogs under various scenarios of temperature change and park connectivity. We show that depending on the rate of warming and degree of connectivity, about 19–67% of protected areas will not have any temperature analogs in the near future (2050s). These results help to emphasize that protected areas are not immune to the effects of climate change and that large portions of Amazonian protected areas include 'disappearing climates'. In the face of these disappearing climates, the biggest determinant of many species' extinction risks may be their ability to migrate through non-protected habitats.

Keywords

Amazon, climate change, extinction, global warming, Red List, species migration, landscape connectivity.

Amazonian forests support the highest diversity of plants on Earth and play a vital role in the regulation of the global climate system. Amazonian forests are also under extreme pressure from land use change and other anthropogenic disturbances. A recent study by ter Steege *et al.* (2015) combined data from an Amazon-wide network of forest inventory plots and spatially explicit deforestation models to estimate the number of Amazonian tree species that are threatened by current and future habitat loss. They predicted that by 2050, 36% or 57% of species will be 'globally threatened', as defined by IUCN Red List criteria, due to deforestation under Increased-Governance or Business-As-Usual scenarios, respectively (ter Steege *et al.*, 2015). One notable finding of the study was that effective parks and protected areas have the potential to greatly reduce rates of deforestation and hence the percentage of threatened species. Specifically, ter Steege *et al.* predicted that if no deforestation occurs within protected areas, then the number of threatened species will drop by 29–44%. This finding reinforces the important message that parks are one of our most powerful tools against deforestation. But fences cannot keep out rising temperatures, and even the best-protected areas of the Amazon may be susceptible to the effects of climate change (Hannah *et al.*, 2007; Scriven *et al.*, 2015; Thomas & Gillingham, 2015).

To illustrate the potential impacts of climate change on Amazonian parks, we identified all land areas within the officially designated parks and protected areas of tropical South America that will or will not have future temperature analogs under various future climate change scenarios. To do this, we created a raster map of all designated protected areas in tropical South America (Jantz *et al.*, 2014) at 2.5

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arc minute resolution (approximately 5 × 5 km pixel size at the equator). For each pixel in the protected areas, we located and tallied all areas within tropical South America that are predicted to have similar mean annual temperatures (i.e. same ± 0.5 °C) in the 2050s based on downscaled output of the National Center for Atmospheric Research's Community Climate System Model 4 (http://ccafs-climate.org/; NCAR CCSM4; Gent *et al.*, 2011). Climate predictions were created under Representative Concentration Pathways (RCPs) 2.6 and 8.5, which represent approximate best-case/Increased-Governance and worst-case/Business-As-Usual scenarios, respectively (RCP 2.6 assumes that Greenhouse Gas emissions peak between 2010 and 2020 resulting in a mean warming of 1.5 °C by the 2050s in tropical South America and RCP 8.5 assumes that emissions will continue to increase throughout this century resulting in a mean warming of 2.7 °C by the 2050s in tropical South America). For each of the protected pixels, we then identified and counted the number of future temperature analogs located (1) within any of tropical South America's protected areas, (2) within the same or other connected/immediately adjacent protected areas or (3) within just the same protected area.

We found that under either emissions scenario (RCP 2.6 or RCP 8.5), nearly all parts of the protected areas (> 95%) will have future temperature analogs somewhere within the current system of reserves and protected areas of tropical South America. However, for the most part these future analogs will not be in the same or even connected parks. As such, future analogs may not be available to any populations/species that are temperature-limited and hence forced to migrate in order to remain within suitable climatic conditions. This is especially true given the potential barriers to species movements that will be created by the high rates of deforestation and land use change that are predicted to occur throughout the region over the near future (Soares-Filho *et al.*, 2006; Feeley & Rehm, 2012). More specifically, if we assume that land use and land cover change restrict the potential movement of species to just the connected or adjacent protected areas, we find that 19.0% or 33.5% of the land area currently under protection does not have available future temperature analogs under the Increased-Governance (RCP 2.6) or Business-As-Usual (RCP 8.5) scenarios, respectively. If we further restrict the searches to just within the same protected areas, then 44.6% or 66.4% of areas under protection will not have available future analogs under the two scenarios. In other words, depending on the rate of warming and degree of connectivity between protected areas, only about 1/3 to 4/5 of protected habitats will have any available temperature analogs in the near future (Fig. 1). These results indicate that the climatic conditions found in any one park today will very soon be found in a different

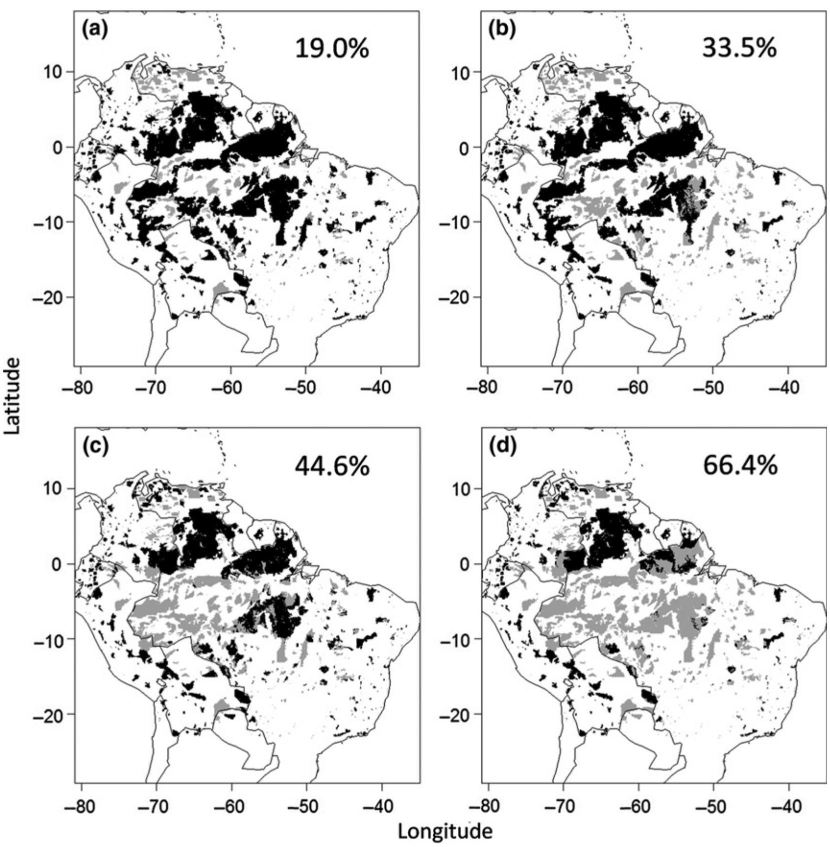

Figure 1 Portions of officially designated protected areas of tropical South America that will (black) or will not (grey) have climate analogs under mean annual temperatures predicted for the 2050s according to the National Center for Atmospheric Research's Community Climate System Model 4 (NCAR CCSM4) under Representative Concentration Pathways (RCPs) 2.6 (left hand panels, a and c) and 8.5 (right hand panels, b and d). Climate analogs are defined as having the same mean annual temperature ± 0.5 °C. In the top row (panels a and b), the search for climate analogs was extended to all connected or immediately adjacent (at ~5 km resolution) protected areas. In the bottom row (panels c and d), the search for climate analogs was restricted to within the same protected area. The percentage of protected area without future climate analogs under each scenario is indicated within each panel.

park(s), making long-range migrations through unprotected habitats essential for the persistence of any Amazonian species that cannot tolerate or adapt to rising temperatures (Scriven *et al.*, 2015). Parks are critical, but the pathways between them may be equally so.

In reality, the percentage of protected areas with available future climate analogs is likely to be even lower than indicated by these estimates. One factor that can decrease the number of available future analogs is the encroachment of deforestation and other human disturbances (e.g. hunting and/or fire) into protected areas (Curran *et al.*, 2004; Peres *et al.*, 2010). Any deforestation or habitat degradation can reduce the number of analogs and increase the actual or effective distance between analogs (Feeley & Rehm, 2012). Also, the analogs that we identified were based just on similarities in current and future mean annual temperatures (Scriven *et al.*, 2015). Climate involves many factors other than average temperatures. For example, maximum and minimum temperatures as well as the timing, duration and magnitude of precipitation are all important factors in defining the distributions of species and ecosystems (Zelazowski *et al.*, 2011). As additional climate variables are incorporated, the number and proximity of analogs will invariably decrease (McCain & Colwell, 2011; Feeley & Rehm, 2012). Other, non-climatic factors such as soils, topography and species interactions can also make some climate analogs ecological non-equivalents (Ibañez *et al.*, 2006). Finally, we did not calculate the actual distances between analogs but rather only considered if the climate analogs occur in the same or other protected areas. If populations or species need to migrate in order to remain within a small range of suitable temperatures through times, then the distances between analogs will be of central importance and may be a limiting factor for the persistence of many species – especially those with limited migration ability, such as many plants (Corlett & Westcott, 2013).

Protected areas are not immune to the effects of rising temperatures and it is clear that large portions of protected areas include 'disappearing climates' (*sensu* Williams *et al.*, 2007). Many of the species occurring in parks today will be at disequilibrium with temperature and other climatic factors by mid-century, not to mention by the end of the century. There is much good news about the efficacy of protected areas in the face of deforestation and other land use pressures (ter Steege *et al.*, 2015; Thomas & Gillingham, 2015). That said, it must be kept in mind, that protected areas are not a panacea and that the current reserve system alone may be insufficient to conserve biodiversity in the face of rapidly rising temperatures. Migration, whether through explicit corridors or through landscapes of working forests managed to facilitate species movement, will be paramount in determining the future of Amazonia (Malhi *et al.*, 2008). In the absence of species migrations, disappearing climates will translate into many more disappearing species than would occur from deforestation alone.

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BIOSKETCHES

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