Saving logged tropical forests: closing roads will bring immediate benefits

Peer-reviewed letter

There is growing recognition that selectively logged tropical forests retain high conservation value (Gibson *et al.* 2011). In their editorial, Laurance and Edwards (*Front Ecol Environ* 2014; **12[3]**: 147) drew attention to the vulnerability of forests after logging and proposed several highly pertinent strategies to minimize subsequent biodiversity loss. One of these – the closure of logging roads – warrants closer scrutiny. To date this has been under-acknowledged in the context of selectively logged forests, but this single action could pay immediate dividends to tropical biodiversity. By way of illustration, we show that from 2000 to 2012 in Kalimantan, Indonesian Borneo, forest loss was nearly twice as high in areas where logging roads (built before the year 2000) were present than in areas where such roads were absent (Figure 1a).

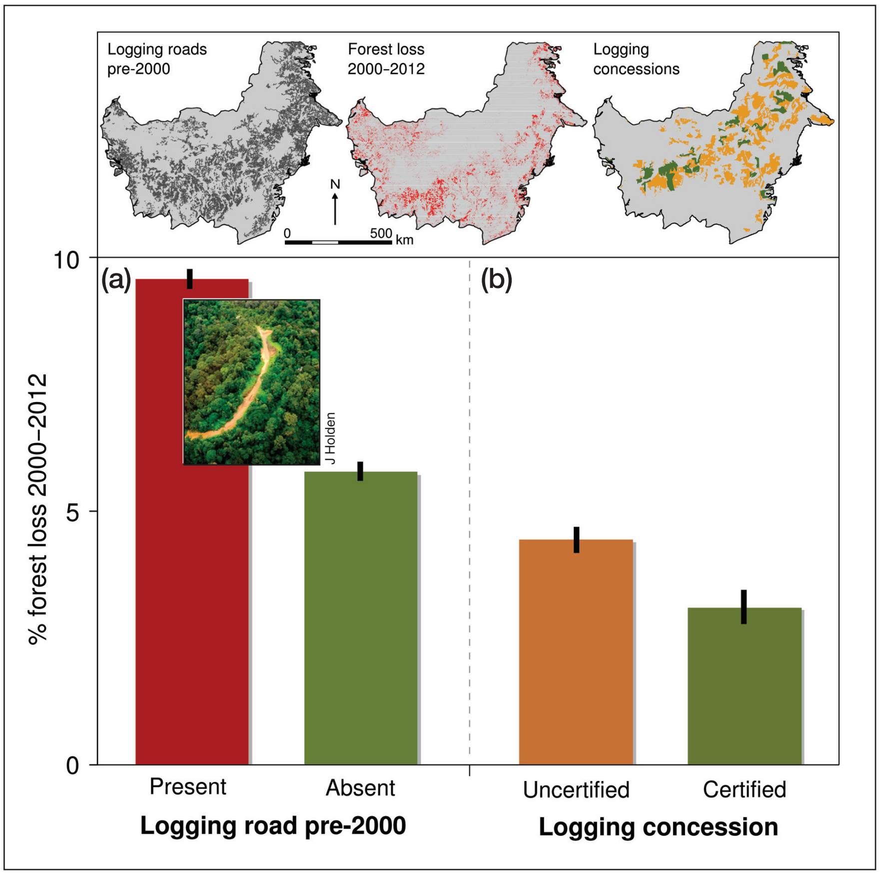

Figure 1. Percent forest loss (mean ± standard error) in 10-km × 10-km grid cells from 2000 to 2012: (a) where primary logging roads pre-2000 were present (red) or absent (green) and (b) in certified (green) and uncertified (orange) logging concessions. Inset photograph in (a) depicts a typical primary logging road through Borneo's timber production forests. Maps show primary logging roads pre-2000, forest loss between 2000 and 2012, and certified and uncertified logging concessions in Kalimantan. Concession data were acquired from the Ministry of Forestry of Indonesia. We measured forest loss using high-resolution global maps of 21st-century forest-cover change (Hansen et al. *2013). Primary logging roads were mapped through the use of LANDSAT images classified in Gaveau* et al. *(2014); we excluded secondary logging roads that infrequently open the canopy. Primary roads are typically unsurfaced and are designed for heavy machinery used to extract and transport timber. To account for image misclassification or possible forest regeneration, we first removed small patches of unforested land from the analysis using the generalization tool in ArcGIS. Strictly protected areas were excluded from the analysis and, to account for access provided by rivers, areas within a 1-km buffer of rivers were also excluded.*

Across tropical forests, authorities grant logging concessions to companies for the harvest of timber via selective logging. During the lease period, corporations are responsible for the management of their concessions, and other land uses (eg agriculture) should typically be prohibited or heavily restricted under the lease agreement. For companies invested in the long-term fate of the timber through their involvement in forest certification schemes, road closure after harvesting is recommended in order to maintain forest cover (FSC 2010). Indeed, we find that forest loss across Kalimantan was higher in uncertified concessions as compared with those that were certified (Figure 1b).

Across Kalimantan, 25% of the land allocated for timber production in 2000 later had its status changed for conversion to industrial plantation (Gaveau *et al.* 2013). This most frequently happens under the "cut and run" scenario emphasized by Laurance and Edwards, whereby logging concessions are abandoned after harvest and, consequently, face exploitation through illegal timber extraction, agriculture, and mining: all of which are facilitated by the logging roads (Wilkie *et al.* 2000; Laurance *et al.* 2001; Meijaard *et al.* 2005). In such instances, logging estates are classified as "degraded", greatly increasing the likelihood of the land being re-allocated for conversion.

Logging concessions therefore follow one of two broad trajectories: timber companies either (1) ensuring high production for the next harvest through responsible management and restricted access or (2) doing little to protect the forest due to lack of incentives, resulting in eventual land-use change. Under these two scenarios, biodiversity follows much the same fate as the forest (Figure 2; Edwards *et al.* 2014).

Spatial determinants of tropical

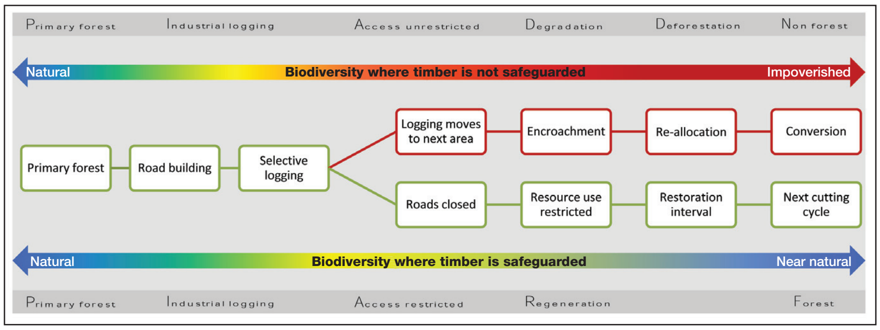

Figure 2. *The consequences for biodiversity of two logging concession scenarios: (top) forests that are unmanaged with unrestricted access and (bottom) forests that are managed, including access restriction.*

deforestation include roads and linear transport routes (eg rivers, train lines), in addition to factors associated with accessibility (eg slope, topography, distance to settlements) and the suitability of the land for conversion to alternative uses (Laurance *et al.* 2002; Gaveau *et al.* 2009). While the relationship between deforestation, logging roads, and certification highlighted here could thus potentially be confounded by several additional variables, roads into tropical forests are a well-known precursor to much more high-impact forms of disturbance. For example, in the Brazilian Amazon, 95% of deforestation occurs within 5 km of roads (Barber *et al.* 2014).

Given that more than 4 million km^2 of the world's tropical forests are officially designated for future timber production, it has never been more critical to consider the fate of logged forests and the biodiversity value they hold. Road closure between harvests is fundamental and can be easily and inexpensively achieved by deconstructing bridges and installing physical barriers (Applegate *et al.* 2004). However, ensuring that roads stay closed requires investment, monitoring, and enforcement to discourage illegal behavior. To provide incentives for the logging industry, forestry authorities should lease concessions over multiple cutting cycles; thus, more responsibility is placed on companies – even those that do not seek certification – to safeguard future timber stocks. The ability of forestry authorities to achieve these moderate changes to management and regulations may be constrained by local contexts, and could even require governments to sanction timber corporations that do not adequately protect forest cover in their concessions. In many forests, closing roads is an important step in protecting timber stocks; consequently, this action could make a vital contribution to the protection of not only the long-term sustainability of forestry but also the biodiversity within managed tropical landscapes.

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Barriers to adding UAVs to the ecologist's toolbox

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The emergence of autonomous unmanned aerial vehicle (UAV) technology has sparked excitement among ecologists. UAVs hold great potential for providing advancements in aerial imagery (Shahbazi *et al.* 2014), species distribution and abundance surveys (Vermeulen *et al.* 2013), and large-scale conservation efforts (Koh and Wich 2012; Mulero-Pázmány *et al.* 2014). UAVs can collect novel data rapidly, inexpensively, and with high frequency. The rate that these possibilities can be realized is directly related to overcoming barriers to implementing UAV-driven research.

Anderson and Gaston (*Front Ecol Environ* 2013; **11[3]**: 138–46) provided a commendable review of the available hardware and many of the potential applications of UAVs in ecological research. As ecologists who are currently using UAVs in our own research, we feel it is imperative to highlight a factor that Anderson and Gaston did not address: the most difficult and time-consuming element of using UAVs for research (in the US, in our case) is earning government approval and navigating stipulations that impose substantial restrictions on UAV use in "official" settings (eg university-affiliated projects).

We believe the arduousness of the UAV approval process for research is largely unknown to ecologists; indeed, only a few reports have mentioned some of the associated requirements and difficulties (Marris 2013; Whitehead and Hugenholtz 2014). Traditionally challenging elements of academic research – such as writing successful grants, or mastering new data collection methods – are just the beginning of a UAV research program. Here, we offer an example from our personal experience of instituting a UAV research project at a public university in the US.

Funding sources embraced our proposal to use UAVs to expand on an established wildlife tracking study. Our study area is characterized by very sparse human habitation and our research primarily occurs on public lands. Thus, we assumed the barriers to begin our research would be minimal. To start, researchers using UAVs risk being fined US$10 000 if they fail to obtain a Certificate of Waiver or Authorization (COA) from the Federal Aviation Administration (FAA). We began the process of obtaining a COA in December 2013, but it was not granted until June 2014. During the intervening months, we spent many hours soliciting and submitting letters from university lawyers to certify our university's "governmental status" and departmental ownership of our "research aircraft". To complete the COA application, we were required to exhaustively detail flight procedures and protocols, as well as answer questions riddled with FAA acronyms and "pilot speak". Without the assistance of experienced UAV researchers (aerospace engineers) at our home institution, it would have been nearly impossible to procure our COA.

What follows is a sample of the requirements one must meet to receive and use a COA: a pilot with a valid and current FAA pilot's license must always be at the UAV controls; two individuals (having successfully passed Class II airmen physical examinations) must act as observers for every flight; a static study area – the boundaries of which must be more than five nautical miles from any airport (in our case, a rarely used grass airstrip) – must be delimited; and an FAA "notice to airmen" (aka NOTAM) must be filed at least 48 hours before any flight and reported to the regional air traffic control hub daily during operations. Once in the field, UAVs are required to be in line of sight of the operator or observers at all times, under 400 feet in altitude, and confined in the previously defined study area – stipulations that severely limited our research on mobile wildlife. Additionally, we were recently notified that our two-pound quadcopters now require uniquely identifying "N" numbers (the same requirement for large aircraft), which are to be cleared with the FAA, under penalty of revocation of our hard-earned COA.

The magnitude of over-regulation of research-related UAV flights in the US cannot be overstated, especially considering that any hobbyist – as long as their "drones" avoid restricted airspace and stay below 400 feet in altitude – may fly UAVs wherever and whenever they please (even above their neighbors' houses if they stay above 83 feet!). Regulation is certainly necessary, and we fully acknowledge the inherent danger of operating UAVs, but current policy toward implementing this technology in a research setting represents an almost impassible barrier for most researchers in the US.

If ecologists hope to realize the potential for advances in aerial imagery, population and community ecology, and large-scale conservation that could result from using UAV technologies, then it is essential that we advocate for lower barriers to entry so UAVs may become part of the ecologist's "toolbox". The status quo of governmental regulation of UAV-driven research requires effort and time beyond what is realistic for practitioners who wish to use UAVs as an additional element of a research program. While we advocate for careful consideration of the prohibitive nature of permitting before attempting to incorporate UAV technology into an ongoing project, nothing but continued persistence and pressure will change UAV regulation. UAV technology will revolutionize ecology, but only if it can be widely and easily implemented.

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