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Conservation priorities to protect vertebrate endemics from global urban expansion

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ABSTRACT

Earth is undergoing unprecedented urban growth, with urban areas forecasted to increase by 120 million ha from 2000 to 2030, impacting natural habitat. However, to date it is unclear where conservation investments can best mitigate biodiversity loss due to urban expansion into natural habitat. Here we combine spatially-explicit global forecasts of urban expansion, information on terrestrial vertebrate endemism, and data on current land cover and protected areas to define conservation priorities. Globally, 13% of endemics are in ecoregions under high threat from urban expansion. Biodiversity losses are highly spatially concentrated, with 78% of endemics threatened by urban growth occurring in just 30 priority ecoregions (4% of all ecoregions). Natural habitat protection of 4.1–8.0 million ha, < 7% of total forecasted urban expansion, would be needed in these priority ecoregions. As an added benefit, such protection would also reduce GHG emissions by an amount worth up to 87.6 billion USD.

1. Introduction

We are living in the fastest period of urban growth in human history. More than 2 billion additional urban residents are expected in urban areas by 2030, with the largest increases forecast to occur in Asia and Africa (UNPD, 2014). Given projected increases in urban populations and economic development, it is likely that between 2000 and 2030 around 120 million ha will be converted to urban land-use, an area that is roughly the size of the country of South Africa (Seto et al., 2012). This dramatic urban growth is expected to impact the global environment significantly (Elmqvist et al., 2013), both directly through the expansion of urban area (McDonald et al., 2008; Güneralp and Seto, 2013) and indirectly through the resource use footprint of urban areas (Luck et al., 2001).

The focus of this paper is on the direct effects of urban areas on biodiversity. The direct effects of urban expansion on biodiversity are complex, including loss of habitat area and connectedness, and changes in disturbance regimes and invasive exotic spread (McDonald et al., 2009). The greatest impact of urban expansion on global biodiversity is likely the reduction of habitat area for species with small ranges that have the misfortune of being located near expanding urban areas (Elmqvist et al., 2013; McDonald et al., 2015). Moreover, because urban areas are preferentially located in areas of high productivity (Luck, 2007a, 2007b), as well as near coastlines and on islands (McDonald, 2008), the global impact of urban areas on biodiversity is disproportionately high.

Despite several studies that have examined the impact of urbanization on biodiversity (Elmqvist et al., 2013; Güneralp and Seto, 2013; Conde et al., 2015; Güneralp et al., 2017a), there are few studies that have designated global conservation priorities for preventing biodiversity loss from urban area expansion. To our knowledge, no studies have estimated the amount of natural habitat that may be lost in those high biodiversity areas. Consequently, non-governmental organizations and international policymakers struggle to know where to focus attention or resources. For instance, national obligations under the Convention on Biological Diversity relate to the amount of natural habitat protected or converted, and so policymakers need estimates of the impacts of urban areas in those terms.

International policymakers are also devoting considerable attention to studying the potential of natural habitat protection and restoration to contribute meaningfully to mitigating climate change, by reducing emissions from deforestation and degradation (REDD) (Venter et al., 2009). While there have been studies on the overlap of carbon storage with other ecosystem services (Onaindia et al., 2013; Locatelli et al.,

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2014), it remains unclear how the geography of the potential carbon financing for natural habitat conservation overlaps with the geography of direct impacts from urban expansion on biodiversity.

The goal of this analysis is to rectify this situation by using global datasets of forecasted urban expansion, biodiversity importance, current land cover, and current land protection status to define a clear set of conservation priorities. Specifically, we will answer three questions. First, where are priority ecoregions in which urban expansion will occur on natural habitat with large numbers of endemic species? Second, how much natural habitat in priority ecoregions is likely to be lost by urban growth, and where are impacted patches of natural habitat located? Third, how much carbon emissions can be avoided, as an added benefit, from protection of critical habitats at risk from urban expansion?

2. Methods

In this section, we present our data sources and methodology for selecting priority ecoregions, as well as the methodology of analyses used to quantify the uncertainty in our results or to assess the sensitivity of our selection of priority ecoregions to our methodology. There were five main steps in our analysis. First, we chose an urban-expansion forecast and statistically analyzed its uncertainty. Second, we quantified the impact of urban growth on natural habitat, quantifying the sensitivity of our results to our choice of global land-cover datasets. Third, we overlaid areas of natural habitat loss with data on terrestrial vertebrate endemism, our metric of biodiversity importance, and then conducted a sensitivity analysis by comparing our results to those calculated using other possible biodiversity metrics. Fourth, we selected priority ecoregions, quantifying with a sensitivity analysis how different thresholds of threat (loss of natural habitat) and biodiversity value (endemism) would have altered our results. Fifth, we calculated the amount of carbon that would be released due to urban-caused habitat loss, and its economic value.

2.1. Urban expansion

We use the global urban-expansion forecasts out to 2030 from Güneralp and Seto (2013). These forecasts of the land area to become urban are based on the projections of regional populations, corresponding regional estimates of urban proportion from the UN Population Programme (UN, 2009, 2010) and the projections of regional economic growth from the 4th Assessment Report of the IPCC (IPCC, 2000). The forecasts are probabilistic and reflect the uncertainty in both population growth projections and economic growth scenarios (Güneralp and Seto, 2013). A spatial simulation model is then used to estimate the location of urban expansion at 5 km resolution, by allocating the forecasted land area to become urban, using as covariates slope, weighted distance to roads, population density, and land cover (Güneralp and Seto, 2013). This resulted in 1000 discrete permutations of urban expansion, each a spatially explicit global map of where urban expansion will occur.

For each ecoregion, we assessed natural habitat loss for each of the 1000 urban-expansion permutations. Note that our calculations of potential natural habitat loss due to urban expansion are done at the pixel level, explicitly accounting for the current land cover. This is important since in some ecoregions urban growth is predominately forecast to occur on areas of currently natural habitat, while in other ecoregions it is forecast to occur on areas that are already converted for agriculture or other purposes. Only urban expansion that is forecast to occur on pixels of natural, unprotected habitat will affect our calculation of natural area lost.

We report the median, as well as the 10th and 90th percentiles (i.e., the highest and lowest decile) for natural habitat loss (Table S1). These quantiles are also used during derived calculations, such as the amount of carbon lost and its economic value. Within each ecoregion, we also mapped the spatial pattern of potential natural habitat loss due to urban expansion. This pixel-level data let us define priority locations for potential future conservation efforts in the region.

2.2. Land cover

Our map of contemporary land-cover data for this project was taken from GlobCover classified land cover (GlobCover 2.2, 2009), a global land-cover classification based upon ENVISAT MERIS data at 300 m resolution. This is the same land-cover layer used in the recent reanalysis of the Human Footprint (Venter et al., 2016), and it remains one of the best available global land-cover datasets, although we acknowledge that it is now somewhat dated. We defined as natural habitat any land cover (excluding water features, GlobCover category 210) that was not anthropogenic. Anthropogenic categories include cropland (GlobCover categories 11, 14, 20, and 30) and developed areas (GlobCover category 190). We then incorporated into the GlobCover data information on what was urban in 2000 according to the Seto et al. (2012) dataset. Furthermore, we integrated information from the World Database on Protected Areas (WDPA) into the analysis (WDPA Consortium, 2016), defining natural habitat as protected if it was within a protected-area polygon. To account for point features in the WDPA (protected areas with known area and centroid, but unknown boundaries), we buffered them to create polygon features that were the same size as the reported area of the protected area. In our analysis, we examined land protection for all IUCN categories (I–VI). All GIS raster operations described in Sections 2.3, 2.4, and 2.5 were conducted at the 300 m resolution of the GlobCover dataset unless otherwise noted.

To assess the sensitivity of our results to this choice of land cover, we reran our entire analysis using an alternative global land-cover map derived from MODIS imagery. This is the MODIS IGBP map, the MOD12Q1 product, collection 5.1. This land-cover map is circa 2000, and is at 500 m resolution. More detail on the methodology used to create this dataset can be found in Friedl et al. (2014), and the dataset can be downloaded online from http://glcf.umd.edu/data/lc/.

2.3. Biodiversity

Our metric of biodiversity importance was terrestrial vertebrate endemism, obtained from the Wildfinder database, which provides presence and absence data for major taxonomic groups in the terrestrial ecoregions of the world, as defined by the World Wildlife Fund (WWF, 2006). Ecoregional boundaries follow those defined by Olson et al. (2001). Taxonomic groups featured in the database are mammals, amphibians, reptiles, and birds.

We chose to focus our analyses on ecoregional endemics, species that occur in only one ecoregion. These ecoregional endemics are very important for global biodiversity and are disproportionately threatened by land-use changes, including urban expansion, within the ecoregion (Lamoreux et al., 2006). They have by definition relatively small ranges, as they are entirely confined within an ecoregion, and numerous studies have shown that small range species (Purvis et al., 2000; Ripple et al., 2017), or species that have lost a significant fraction of their natural habitat, are more likely to go extinct (Peters et al., 2015).

To understand the sensitivity of our results to our chosen metric of biodiversity importance (terrestrial vertebrate ecoregional endemics), we compared this metric to two other common metrics of biodiversity importance. First, we compared the distribution of endemism with the location of extremely rare species featured in the Alliance for Zero Extinction (AZE) database (Alliance for Zero Extinction, 2010; Conde et al., 2015). Second, we examined the distribution of IUCN Red-Listed vertebrate species.