



## CONTRIBUTED PAPER

# Conservation beyond protected areas: Using vertebrate species ranges and biodiversity importance scores to inform policy for an east African country in transition

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**Abstract**

Conservation in eastern and southern Africa has historically centered on megafauna and protected areas (PAs), yet, in the face of rapid change, biodiversity outside of PAs is under threat. With policy changes underway in Kenya, we have performed an analysis that (a) quantifies how inclusive the current PA network is of the country's vertebrate diversity, and (b) identifies wildlife policy areas that need reform to achieve conservation targets. We found that species richness of mammals, birds, and amphibians is highest in areas of intermediate human pressures, whereas Kenya's current wildlife conservation policy focuses on land use (LU) types with the least human pressure. Percentage of range overlap for amphibians, mammals, and birds were all highest in rangelands followed by agricultural (cultivated) areas and then national PAs. Out of 1,535 terrestrial vertebrate species, 80 had no range overlap with national PAs. The current wildlife PA network adequately covers only 16% of amphibians, 45% of birds, and 41% of mammals. In addition, we used a biodiversity importance score which demonstrated the importance of rangelands and agricultural areas for biodiversity conservation. Finally, we observed that the distribution of current PAs, and the focus of Kenya's wildlife policy in general, is in areas of lowest human pressure, often with the highest large mammal densities. However, other biodiversity indicators - such as bird and plant species richness - show that areas under human-dominated LU currently support substantial biodiversity. Overall, our analysis demonstrates that formal PAs and wildlife policy presently cover only a small fraction of national biodiversity, which resides mainly in human-dominated landscapes that are undergoing rapid change. These findings echo global calls for a landscape-based approach to conservation policy and practice that promotes the coexistence of people and wildlife within social-ecological systems.

**KEYWORDS**

African wildlife, anthropogenic landscapes, conservation gap analysis, Kenya, landscape-scale conservation, megafauna

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# 1 | INTRODUCTION

Conservation, globally, and particularly in eastern and southern Africa, has historically centered on the protection of landscapes that provide habitat for charismatic megafauna (Adams & McShane, 1992; Watson, Dudley, Segan, & Hockings, 2014). A fortress-based approach to conservation, initiated from the middle of the 20th century, led to the large-scale creation of protected areas (PAs) across the African continent (Brockington, 2002). The policy framework for this national park system perpetuated the misunderstanding that “natural” African savannah ecosystems were wilderness areas lacking what was perceived to be the disturbing influence of people and their livestock (Adams & McShane, 1992). African wildlife policy was based on this wilderness notion, encouraging the separation of wildlife and people.

Despite the establishment of PAs and the exclusion of people, many of these PAs have failed to adequately conserve megafauna (Craigie et al., 2010; Western, Russell, & Cuthill, 2009) and few achieve their broader goals such as conserving regional biodiversity and ecosystem functionality, improving community livelihoods, or contributing toward national economic growth (Geldmann et al., 2013; Lindsey et al., 2014; Watson et al., 2014). These failures are attributable to several reasons, among which financial limitation is paramount, with underfunding and inadequate management of many PAs (Lindsey et al., 2018). Also, although PAs often have higher local species richness and abundance than adjacent unprotected areas (Gray et al., 2016), they are generally not big enough nor in the best places to independently conserve biodiversity and ecosystem services (Larsen, Turner, & Mittermeier, 2018; Venter et al., 2017), and they are seldom designed to protect ecosystem heterogeneity on a scale required by megafauna (Fynn & Bonyongo, 2010; Western & Gichohi, 1993). Finally, the focus on protecting megafauna has often led to a wildlife-versus-people paradigm, negatively influencing the attitudes of communities surrounding PAs and hindering conservation beyond PA borders (Brockington, Igoe, & Schmidt-Soltau, 2006).

Community-based conservation (CBC), is one mechanism that has been used to overcome the limitations with the PA network by incorporating local communities into natural resource management (Hackel, 1999). CBC effectively increases the coverage of the PA network by recognizing the value of ecosystem services, protecting wide-ranging wildlife populations, turning the burden of wildlife into an asset for local communities, and increasing local participation in and support for wildlife conservation (Naidoo et al., 2019; Western, Waithaka, & Kamanga, 2015). CBC establishment

across eastern and southern Africa has largely been reinforced by national policies to create frameworks, including legislation, that support implementation (Muchapondwa & Stage, 2015). However, across the region, many policymakers continue to assume that biodiversity belongs in PAs that encompass wilderness areas, and this should be adequate. This assumption has limited the development of policies encouraging wildlife and biodiversity-friendly LU within human-dominated landscapes outside of PAs and CBC initiatives (Western et al., 2015).

The historical focus of wildlife policy on conserving a narrow segment of biodiversity—megafauna—exists for several reasons. First, charismatic large mammals attract an estimated 69 million visitors per year across Africa, generating much-needed foreign revenue through tourism (Balmford et al., 2015). Second, the charismatic nature of Africa's megafauna also attracts international donor funding and associated political pressure, which strongly influences national policy (Muchapondwa & Stage, 2015). Third, and more recently, megafaunal assemblages are considered to include umbrella and keystone species, so their protection should provide wider benefits for biodiversity and ecosystem services (Lindsey et al., 2018). Finally, with all conservation efforts in Africa being chronically underfunded, choices inevitably have to be made, and so there is little left for conserving the rest of biodiversity, especially outside of PAs (Lindsey et al., 2018).

The importance of Africa's PA network should not be undervalued, but it is evident that conservation practice and wildlife policy also need to incorporate LU options within the human realm (Sayer et al., 2013). Biodiversity within these human-dominated landscapes is under the greatest pressure (Di Marco, Venter, Possingham, & Watson, 2018), threatening ecosystem services and, therefore, human wellbeing (Donaldson, Wilson, & Maclean, 2017; Sayer et al., 2013). Widening the focus of conservation policy beyond PAs is essential for any country to reach global objectives such as the Aichi Biodiversity Targets and the Sustainable Development Goals (Kareiva & Marvier, 2012).

In this paper, we explore the scope for conservation in human-dominated landscapes using a biodiversity-rich country, Kenya, as a case study. Much of Kenya is of high priority for global goals of biodiversity conservation (Jenkins et al., 2013), but like the rest of Africa, is undergoing rapid human population growth, agricultural expansion, and urbanization. Kenya's diverse, charismatic, and abundant large mammal communities attract over 1 million tourists annually, contributing over 9% of the national GDP (Turner, 2017). Kenya is of particular interest among African countries because policy changes

in the 1970s, 1990s and, more recently, legal changes with the new Wildlife Act in 2013, have cemented community conservation into human-dominated landscapes (Western et al., 2015). Terrestrial government-administered PAs cover 11.7% of the country (Ministry of Tourism and Wildlife, 2018), yet 65% of Kenya's megafauna exist outside of those areas (Western et al., 2009). To protect wildlife outside of government-administered PAs 160 conservancies have been established within the last 20 years. An additional 11% of the country (both in private and community land) now has some level of protection of wildlife (KWCA, 2016; Ministry of Tourism and Wildlife, 2018).

Building on the conservancy movement and the associated policy direction, Kenya is developing a new wildlife policy and conservation master plan based on the national wildlife strategy, with the vision that: "Kenya's wildlife is healthy, resilient and valued by Kenyans", which is incorporating both biodiversity and development targets. Under this strategy, wildlife is defined broadly as: "any wild and indigenous animal, plant or microorganism or parts thereof within its constituent habitat or ecosystem on land or in water, as well as species that have been introduced into or established in Kenya" (Ministry of Tourism and Wildlife, 2018).

With these policy changes underway, we have explored the distribution of terrestrial vertebrates at the national scale. We used established global and regional practices (Coad et al., 2019; Riggio, Jacobson, Hijmans, & Caro, 2019) to explore which LU systems cover most species' ranges, how effective PAs are in including species' ranges, and how human impacts vary across LU systems. Finally, we used local data to ground-truth the assumptions made from these broad-scale datasets. This exercise enables us to present a discussion on which policy areas still need reform to achieve broad conservation goals through the inclusion of human-dominated landscapes across eastern and southern Africa, and doubtless more widely.

## 2 | METHODS

LU data were collated for Kenya from two datasets: MODIS MCD12Q1 500 m resolution land cover data from 2013 (accessible at [https://lpdaac.usgs.gov/data\\_access/data\\_pool](https://lpdaac.usgs.gov/data_access/data_pool)); and the World Database of Protected Areas shapefiles (WDPA; accessible at [www.protectedplanet.net](http://www.protectedplanet.net)). The MODIS landcover raster layers were mosaicked and cropped to the Kenyan boundary and aggregated through nearest-neighbor resampling, to retain categorical classification, to a 1 km grid. Land cover categorical data (16 categories)

from the MODIS data were reallocated to one of six LU categories, rangelands (livestock areas); forests, urban areas; agriculture; other; and water. The WDPA was used to categorize PAs into two classes recognized under the Wildlife Act 2013: national PAs (National Parks and National Reserves) and conservancies. Other PAs, primarily forest reserves, but also cultural forests protected through government gazettelement, are covered under the Forest Act, 2016, rather than current wildlife legislation. Internationally designated PAs (UNESCO World Heritage Sites), were removed as they overlapped with other national-level designated areas. The WDPA data were converted into a raster and combined with the MODIS data to create a 1 km resolution grid of LU across Kenya. We removed water and "other" categories before data analysis.

We acquired human footprint index (HFI) data, which represents the level of human pressures on the landscape for the year 2009 (the index is derived from built environments, cropland, pastureland, human population density, night-time lights, railways, road, and navigable waterways), with values ranging from 0 (no impact) to 50 (highest possible impact), with a resolution of 1 km<sup>2</sup> (Venter et al., 2016).

Global gridded species richness data for three vertebrate classes—amphibians, mammals, and birds—were downloaded with a resolution of 10 km<sup>2</sup> from biodiversitymapping.org (Jenkins et al. Jenkins et al., 2013). We aggregated HFI to a 10 km<sup>2</sup> grid using bilinear resampling and plotted richness against HFI for all three classes. Generalized additive models were added to each plot to visualize trends.

Species range data for mammals and amphibians were acquired from the IUCN database (IUCN, 2017), and bird data were acquired from Birdlife International (BirdLife, 2017). These species distribution maps aim to provide the current known distribution of each species. Shapefiles were cropped to the Kenyan boundary and range polygons filtered to include only those polygons that were definitely extant, possibly extant, or possibly extinct, and either native or reintroduced. Percentage of range overlap (%RO) in each LU type was then extracted for each bird, mammal, and amphibian species.

To estimate the proportion of species with ranges that were adequately protected, we used a process (developed by Butchart et al., 2015; see also Coad et al., 2019) that defines individual species' "representation targets" scaled by species range size. A species with a small natural geographic range (<1,000 km<sup>2</sup>) is considered to require 100% of that range protected, with the requirement decreasing to 10% for species with the largest ranges (>250,000 km<sup>2</sup>). The values between these two thresholds are linearly

interpolated using a log-linear scale. We compared these representation targets to the extent of range under protection in areas covered under the current wildlife policy for national PAs and conservancies.

To identify the importance of each LU type in conserving biodiversity, we generated a biodiversity importance (BI) score. This score was based on the Flexibility Score of Macdonald et al. (2017).

$$BI_{LU_n} = \sum_{s=1}^n \%RO_s(EDGE_s)$$

For each LU category the BI score was calculated by summing the percentage of the range overlap (%RO) for each mammal, amphibian, and bird species (s) multiplied by its Evolutionarily Distinct and Globally Endangered (EDGE) score (Isaac, Turvey, Collen, Waterman, & Bailie, 2007, available at [www.edgeofexistence.com](http://www.edgeofexistence.com)), which accounts for both endangerment and phylogenetic diversity as measures of conservation value. Many species within this study did not have an EDGE score due to missing global endangerment (GE) scores, but all species had an evolutionarily distinct (ED) score. We, therefore, recalculated the EDGE metric using the methodology described by Macdonald et al. (2017) and Dickman, Hinks, Macdonald, Burnham, and Macdonald (2015) by assigning GE scores according to each species red-list category: 1, least concern, data deficient, or data absent; 2, near threatened; 4, vulnerable; 8, endangered; 16, critically endangered (following the recommendation of doubling of extinction risk with each increment of red list category). To calculate our modified EDGE score, we summed the GE and ED score of each species. We also divided the BI score by area to adjust for the relative size of the different LU areas.

Two datasets were used as indicators to investigate megafauna bias in wildlife policy. First, the density of large mammals, given in tropical livestock units (TLUs) per square kilometer, on a 5 × 5 km grid, from a 1994 and 1996 aerial wildlife count in the arid and semi-arid rangelands by the Directorate of Remote Sensing and Resource Surveys, was downloaded from <https://www.wri.org/resources/data-sets/kenya-gis-data>. One TLU denotes the feed requirement of a standard animal of a weight of 250 kg. Second, a plant species-richness dataset from the R package *vegetable* was collected across 1946 sites in Kenya. The cumulative density of large mammals against the mean HFI for each cell, and plant species richness was compared to the HFI for the corresponding cell. All measurements of area were based on the Mollweide equal-area projection, and all analyses were conducted in R (R Development Core Team, 2008) using the *raster* package.

## 3 | RESULTS

### 3.1 | Species richness and human impact

All three vertebrate classes in our analysis (mammals, birds, amphibians) have highest species richness along the humid coastal belt, central and western highlands, and along the semi-arid southern border (Figure 1). Species richness is lowest in the very arid north-eastern area of the country. Generalized additive models (inset Figure 1) suggest that all three groups have the highest species richness at intermediate values of human pressures, with richness decreasing past this point. The entire East African region displays a similar trend, except the highest species richness continues to increase with the human footprint (Supporting Information).

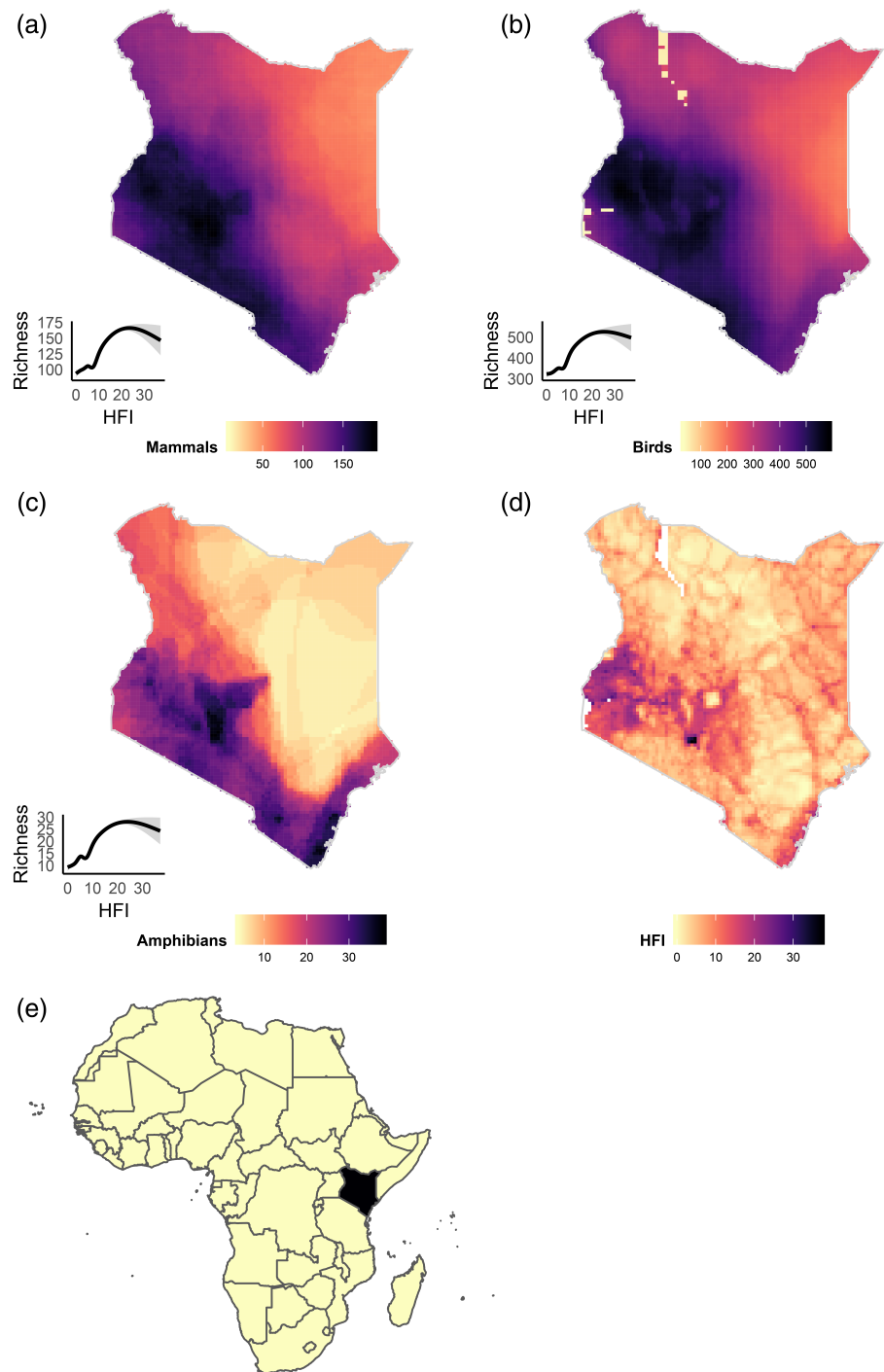
### 3.2 | Land use

Data from WDPA and MODIS land cover (Figure 2b), show Kenya's LU to be overwhelmingly dominated by rangelands primarily used for livestock production, followed by agricultural land, national PAs, conservancies, and other PAs (which are not under the Wildlife Act., 2013), water, and urban areas. National PAs and conservancies are predominately found in areas with the lowest human pressure (Figure 2a), whereas agriculture, urban, forests, and other PAs show a much broader range of human pressures (Figure 2a). Removing the LU categories (built environments, cropland, pastureland) from the HFI (Supporting Information) indicates a similar pattern.

### 3.3 | Range overlap

Range overlap was calculated for all three vertebrate classes (Figure 3a–c, Supporting Information). There is a significantly higher range overlap for all three classes of species with rangelands than any other land-use type. The next highest range overlap for all classes is on agricultural land, with both amphibians and birds having a higher mean range overlap on agricultural land than do mammals. Mean range overlap with LU covered under the current wildlife policy (national PAs and conservancies) was considerably less for all classes. Other PAs had a similar mean percentage range overlap with conservancies for species across all classes, although birds had significantly less range overlap in other PAs than in conservancies. Forest LU covers as much range for amphibians as do conservancies but covers significantly less for the other two classes. Mean percentage of range

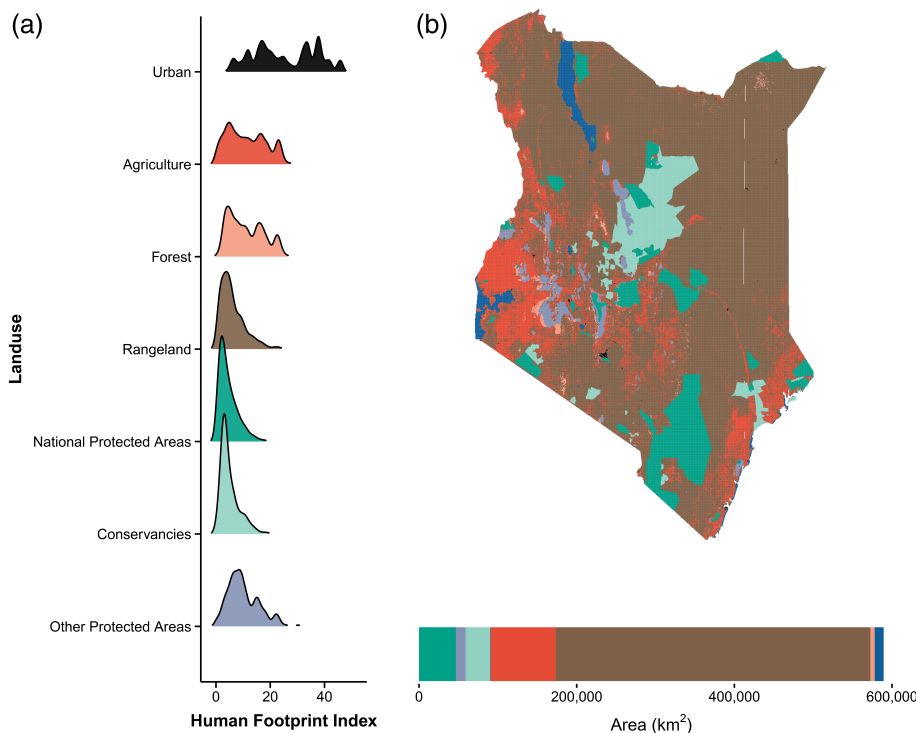
**FIGURE 1** Maps of Kenya depicting variation in (a) mammal species richness; (b) bird species richness; (c) amphibian species richness; (d) human footprint index (HFI). The maps are plotted on a  $10 \times 10$  km grid, with biodiversity data from biodiversitymapping.org (Jenkins et al., 2013) and HFI data from 2009 aggregated to a  $10 \times 10$  km grid from Venter et al. (2016). HFI represents the level of human pressures on the landscape, ranging from 0 (no impact) to 50 (highest possible impact). Generalized additive model smooths (95% confidence intervals are shaded) of HFI and species richness are inset for all three classes. The location of Kenya within Africa is shaded in map E



in urban LU was the lowest for all three classes. These relationships are primarily consistent with the absolute size of each LU category (Figure 4). Of note, however, is that 80 species had no range overlap with national PAs (Supporting Information; 5.2% of all species analyzed), comprising 27 mammals (7.67% of total), 10 amphibians (9.52% of total) and 43 birds (4.0% of total).

### 3.4 | Representation targets

For all three classes, over half the species had inadequate coverage by national PAs and conservancies (Figure 5). Only 16.2% ( $n = 17$ ) of amphibian species met their representation targets. More, but not a majority, of mammal and bird species, had adequate protection under their



**FIGURE 2** Kernel density curves (a) with the shaded area representing the distribution of human footprint index (HFI) values across land use categories in Kenya. A land use map of Kenya (b) was amalgamated from MODIS land cover data and the WDPA. Rangelands cover 399,029 km<sup>2</sup> (67.7%), followed by agricultural land covering 82,429 km<sup>2</sup> (14.0%). All PAs cover 90,694 km<sup>2</sup> (15.4%), broken down into: national PAs 46,751 km<sup>2</sup> (7.9%); conservancies, 31,640 km<sup>2</sup> (5.4%); and other PAs (which are not under the Wildlife Act., 2013), 12,303 km<sup>2</sup> (2.1%). Inland water bodies (dark blue) cover 11,343 km<sup>2</sup> (1.92%), much of which is Lake Victoria and Lake Turkana; urban areas cover 391 km<sup>2</sup> (0.07%)

representation targets, with 40.9% of mammals ( $n = 144$ ) and 44.9% of birds ( $n = 481$ ) having adequate protection.

### 3.5 | Biodiversity importance scores

Rangelands, followed by agricultural areas, have the highest biodiversity importance scores, as measured by range overlap and EDGE score, of all LU types in Kenya (Figure 6a). When scaled relative to LU area (Figure 6b), the relative importance of forest, agriculture, urban, and other PAs also becomes apparent, and the relative importance of rangeland decreases.

### 3.6 | Local data and taxonomic bias

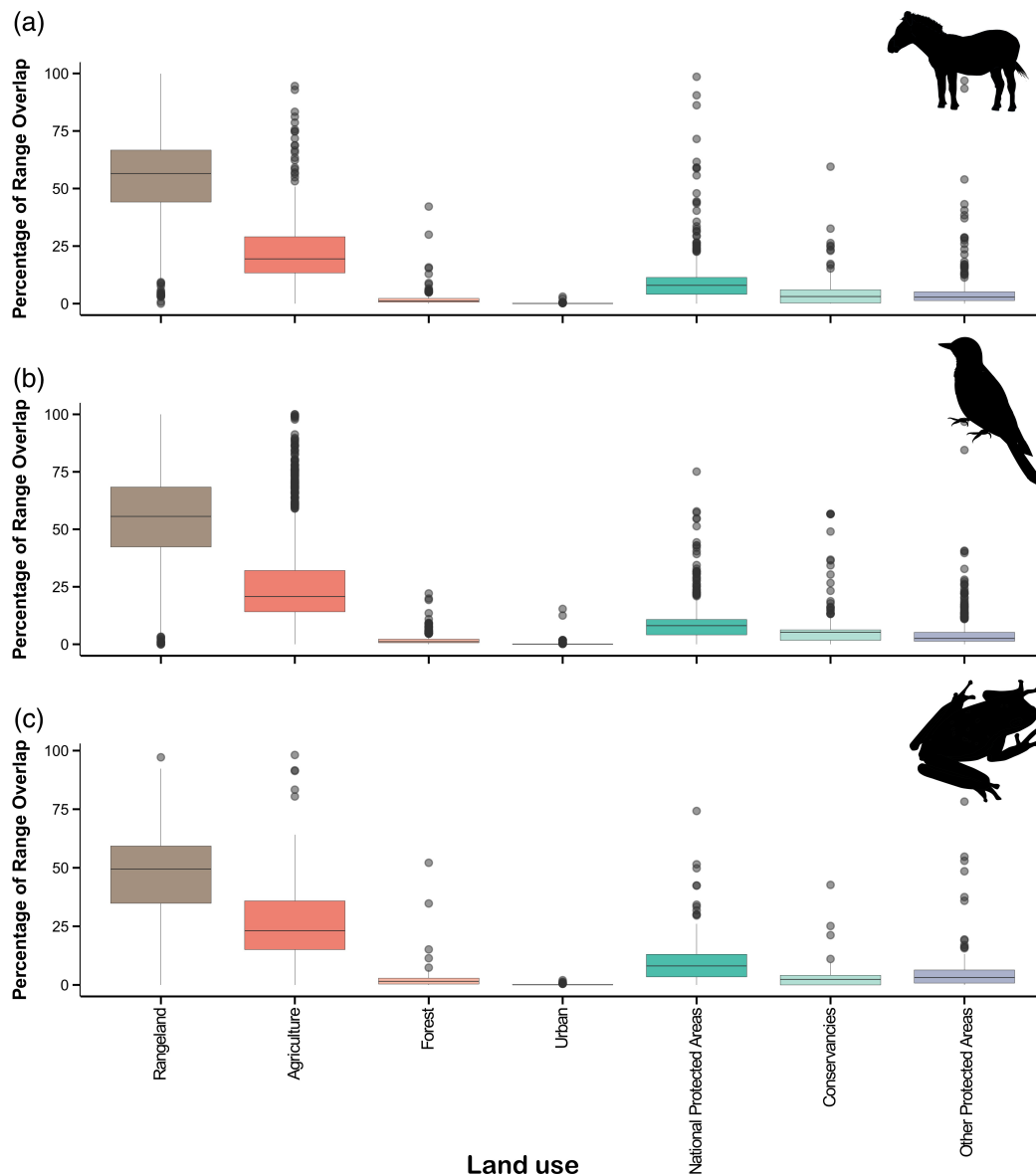
Comparison of two indicators (Figure 7), shows the current bias in wildlife policy in Kenya toward areas of low human footprint and high large mammal density. Cumulative wildlife density (TLUs/km<sup>2</sup>) drops off sharply as human pressures increase, whereas plant species richness increases up to intermediate values of the HFI (Figure 7a).

## 4 | DISCUSSION

Our Kenyan case study demonstrates that effective wildlife conservation at the national scale requires the

development of new wildlife policy for human-dominated landscapes, extending way beyond the scope of the current PA and CBC network. Conservation efforts in human-dominated landscapes should not come at the expense of Africa's national park network, but human pressures are rapidly mounting across all LU categories, many of which are vital for biodiversity (Figure 2, Figure 5). These include urban areas, agricultural landscapes, and rangelands, where the current policy does not explicitly support wildlife conservation. Similar requirements for policy reform and implementation have been identified on other continents (Boakes, Fuller, & McGowan, 2018; Zisenis, 2017). Our analysis of species range data displays a similar result to an analysis of range data within the global PA estate (Coad et al., 2019), and for a regional analysis of endemic species coverage (Riggio et al., 2019).

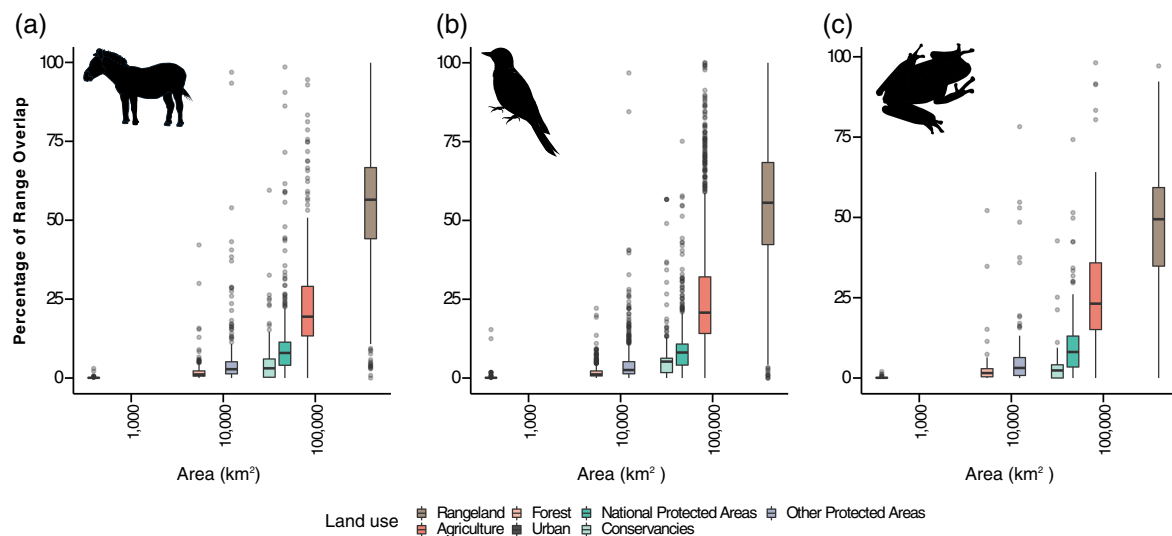
The species range data used in this analysis represents the most up-to-date global distribution maps for species and, for data deficient countries like Kenya, it is the best biodiversity data available. These data are updated regularly to current range whenever possible for each species (<https://www.iucnredlist.org/assessment/updates>). However, these range maps include both past and potential habitat, whether occupied or not at present, including habitat within the matrix of human-dominated landscape. We nevertheless maintain that our findings provide important evidence for policy reform. A comprehensive wildlife conservation policy should protect both presently and previously occupied yet still intact



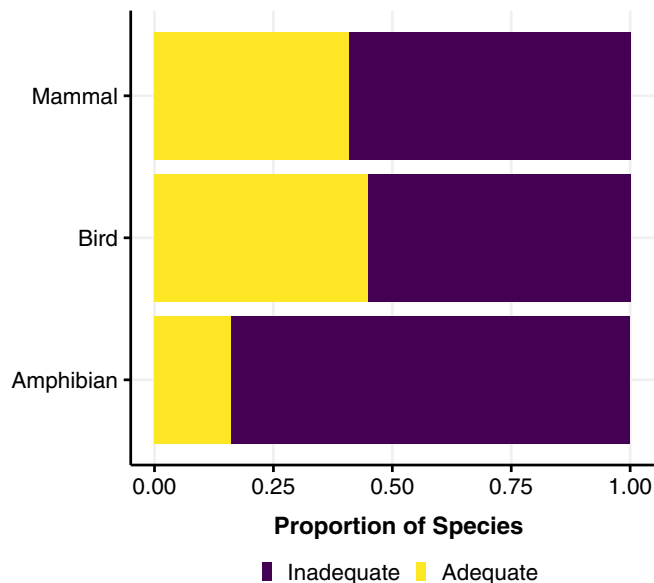
**FIGURE 3** Boxplots of percentage species range overlap with the seven land use categories investigated, for three vertebrate classes: mammals, 352 species (a); birds, 1,078 species (b); amphibians, 105 species (c). Across all classes, 97 species are threatened with extinction. See Supporting Information for descriptive statistics

habitats, with attention to connectivity through the matrix between habitat patches. If only occupied habitat is considered worth protecting, then the total potential area of habitat and the connectivity between habitat patches will ratchet down inexorably as species are locally extirpated. A singular focus on occupied habitat is concerning considering the current inadequate representation of well over half of Kenya's terrestrial vertebrate species within the PA network (Figure 5). Many human-dominated landscapes support both wildlife and people. Rangelands in particular cover the largest area of the country (Figure 2b), have the highest range overlap (Figure 3) and biodiversity scores (Figure 6), and

generally still support considerable biodiversity ranging from large mammals (Ogutu, Kuloba, Piepho, & Kanga, 2017; Tyrrell, Russell, & Western, 2017; Figure 7a) to avian scavengers (González et al., 2019) and invertebrates (Wilkerson, Roche, & Young, 2013). In addition, LU categories under medium-high human pressures, such as urban and agricultural areas classified at 1 km<sup>2</sup> resolution, might contain small patches of critical habitat for some species of plants (Figure 7b), foraging and dispersing primates (Anderson, Rowcliffe, & Cowlishaw, 2007), small-bodied vertebrates (Toth, Lyons, & Behrensmeyer, 2014), and invertebrates (Rogo & Odulaja, 2001). For example, central Nairobi, the area with the highest HFI



**FIGURE 4** Boxplots of the percentage of species range overlap compared with the total size of the land use type across Kenya for the three groups investigated (a) Mammals (b) Birds (c) Amphibians. The total land use size is on a  $\log_{10}$  transformed scale



**FIGURE 5** The proportion of species per vertebrate class that meet their representation targets (Butchart et al., 2015; Coad et al., 2019) in terms of PA coverage in Kenya, with PA in this analysis being national protected areas and conservancies

in Kenya (Figure 1) and classified as urban (Figure 2) at 1 km<sup>2</sup> resolution, has >257 species of bird recorded in the Kenya Bird Map (<http://kenyamap.adu.org.za/>).

#### 4.1 | Species richness and human pressures

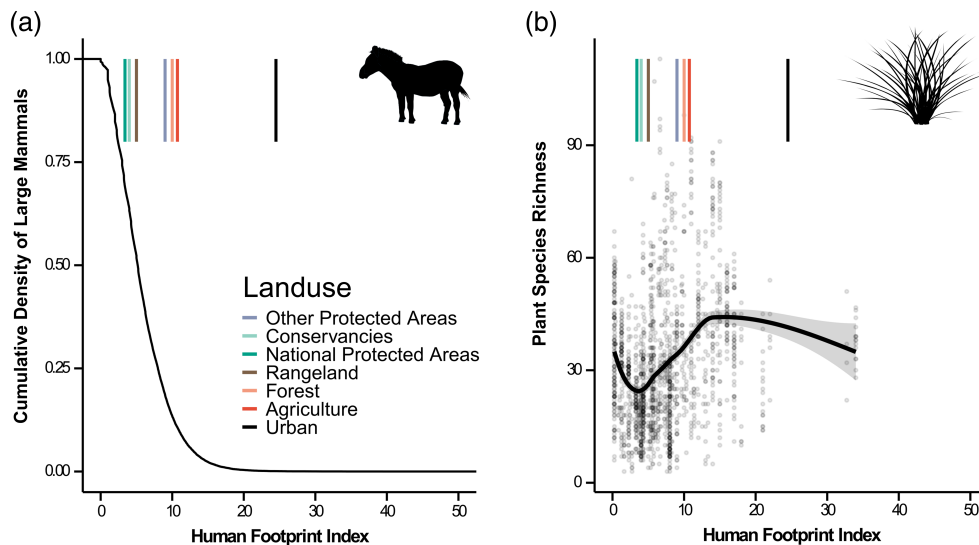
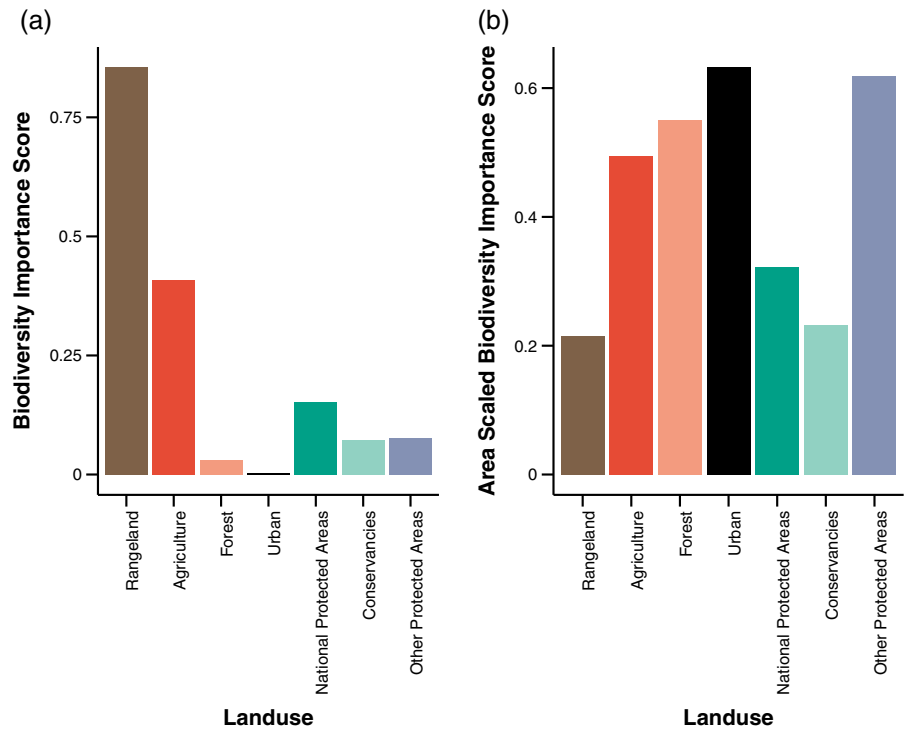
The highest species richness of the three classes investigated was found in areas of intermediate human pressure in Kenya and areas of highest human pressures across

eastern Africa, similar to global patterns observed for vertebrates (Venter et al., 2016). Globally, the steepest biodiversity declines are within these areas (Di Marco et al., 2018), yet due to historical factors the wildlife conservation policy in Kenya (and other African countries) is focused on areas with the lowest human pressures and the highest densities of megafauna (Figures 2 and 7a). Obviously, megafauna needs special protection as keystone and umbrella species (Dickman et al., 2015; Dirzo et al., 2014), and they include the first species to be lost under increasing human pressure (Smith, Smith, Lyons, & Payne, 2018). Nevertheless, wildlife policy focused on megafauna provides diminishingly little protection to the larger segments of biodiversity remaining in areas under higher human pressures (Figure 7b).

#### 4.2 | Beyond PAs

Our analysis demonstrates the importance of developing policies for wildlife conservation in human-dominated landscapes, beyond the scope of the current PA and CBC network, to close the gap in biodiversity conservation across Kenya. Only 16% of amphibian, 45% of bird, and 41% of mammal species meet their representation targets in terms of the percentage of their scale-adjusted range overlapping national PAs and conservancies (Butchart et al., 2015; Coad et al., 2019), being the two LU categories covered by the current wildlife policy (Figure 5). Those percentages are likely over-estimates, given the inadequate resourcing of many PAs and newly established conservancies (Coad et al., 2019). Additionally, PAs fail to protect 80 species that have no range

**FIGURE 6** Biodiversity Importance (BI) scores calculated for each land use type showing (a) total scores, which reflect the importance of rangeland and agricultural areas to biodiversity, and (b) scores scaled by the area of each land use type



**FIGURE 7** Comparison between two indicators used for conservation prioritisations relative to human pressures as indicated by the Human Footprint Index (HFI). The median HFI for each land use category is displayed for reference. The cumulative density of large mammals (A) is highest in areas with the lowest HFI, which is where Kenyan wildlife policy currently applies on the ground. In contrast, plant species richness increases up to intermediate HFI, because humans have settled mesic areas on fertile soils where historically high plant species richness still persists, but many wildlife species have been extirpated. Large mammal density was calculated from 1994 and 1996 aerial wildlife counts in the arid and semi-arid rangelands by the Kenyan Department of Remote Sensing and Resource Surveys, downloaded from <https://www.wri.org/resources/data-sets/kenya-gis-data>. Plant species richness comes from the R package *vegetable* using 1946 sites across Kenya, with data points fitted with a loess smooth and 95% confidence intervals (gray shading)

within PAs and many face immediate threats to their survival: one of these is critically endangered (Taita warty frog, *Callulina dawida*), seven are endangered, two are vulnerable, and five are near threatened (Supporting Information).

There is little scope for the expansion of government-administered PAs across Kenya to protect biodiversity due to limited funding opportunities and pressure for competing LU options, as applies throughout sub-Saharan Africa. However, a feasible path to protecting

more biodiversity is to integrate all PAs under a common policy framework. In doing so, coordinated efforts between currently disparate government agencies and policy sectors can be achieved, potentially increasing the effectiveness of conservation planning and implementation across different PA types. Integrating CBC into Kenyan wildlife policy and legislation was one step along that path and integrating forest reserves (“Other PAs”), which are administered by the Kenya Forest Service under the Forest Act of 2016, could be the next. Presently, clearing of forest for farmland is removing habitat for forest-obligate species such as the endangered Turner’s eremomela (*Eremomela turneri*; BirdLife International, 2018). Despite high human pressure though (Figure 2), forest reserves appear to be as important for biodiversity conservation as conservancies (Figure 6a) and add an extra 2.1% of Kenya’s land surface. Being situated primarily within or near to human-dominated landscapes, they form an important link between biodiversity and the Kenyan people while protecting ecosystem services for burgeoning urban areas. Human populations in urban areas across Africa totalled 395 million in 2010 and are predicted to reach 1.34 billion in 2050 (Güneralp, Lwasa, Masundire, Parnell, & Seto, 2018). Considering the link between the HFI and species richness (Figure 1; Figure 6; Supporting Information), and evidence from North America, conservation efforts in emerging urban centers will be important both for retaining some biodiversity (Ricketts & Imhoff, 2003) and for creating urban landscapes that enable human well-being.

The high biodiversity importance of rangelands is, in part, a function of their overwhelming area (Figure 4). When scaled by area, LU types found in areas of higher productivity, and thus higher human pressure (such as agriculture, urban and forests), gain local importance (Figure 6b; Balmford et al., 2001). Overall, however, rangelands are important as interfaces with PAs and as buffer areas for the megafauna within them (Beale et al., 2013). Yet, continued changes in tenure, management, and use of rangelands threaten biodiversity and human livelihoods across Kenya and much of the region (Reid, Fernández-Giménez, & Galvin, 2014). Additionally, agricultural expansion into rangelands involves habitat loss and widespread land subdivision, with fencing posing a major threat to movements of large mammals including the world-famous migration in the Serengeti-Mara ecosystem (Løvschal et al., 2017). Nevertheless, the coexistence of livestock and wildlife can be sustained in rangelands with production systems that promote functional heterogeneity at the landscape scale (Fynn, Augustine, Peel, & de Garine-Wichatitsky, 2016; Tyrrell et al., 2017). Such systems can provide benefits for biodiversity, ecosystem services, and local livelihoods, without

the need for “top-down” administrative control (Keesing et al., 2018).

Under increasing food demands, agricultural landscapes are likely to both intensify production and increase in size at the costs of forest cover, which will drastically alter habitat availability for forest-dependent species (Laurance, Sayer, & Cassman, 2014). In our Kenyan example, this will have important ramifications (Figures 2 and 3) for many amphibian species, which are reliant on both agricultural and forest landscapes (Figure 3, Figure 5, Figure 6 & Supporting Information) and are poorly represented under the wildlife PA network (Figure 5). Policies to encourage and implement the restoration and preservation of remaining large forest patches within agricultural mosaics is of critical importance. Policies that support a continuum of land-sparing and land-sharing strategies, dependent on the local conditions, can protect biodiversity and ecosystem services in agricultural landscapes (Alvarado, Williams, Arroyo-Rodríguez, & Escobar, 2018; Baudron & Giller, 2014; Laurance et al., 2014). In southern Uganda, for example, land-sparing, through the preservation of remaining forest patches in intensive agricultural land, may benefit some bird species (Hulme et al., 2013). Land-sharing, through modifying agricultural LU and practices, can also have positive consequences for biodiversity conservation and ecosystem services (Haslem & Bennett, 2008; Phalan, 2018). Despite human pressures, well-managed agricultural landscapes can be important areas for biodiversity conservation and ecosystem service provision, which complement sustainable livelihoods (Scherr & McNeely, 2008).

### 4.3 | Policy reforms

Achieving transformative and effective policy reform for natural resources is especially challenging in developing countries such as Kenya, but we urge that our analysis should motivate progress in feasible steps. Prioritizing conservation interventions at the national level, across land-use types, is an important step. The development of National Red Lists, as has been done in Uganda and South Africa, could facilitate targeted regional conservation action for threatened species. Local programs to collect, collate, and periodically summarize temporally and spatially explicit data on biotic and abiotic environmental variables, LU, human demographics, and economic indicators, could contribute importantly toward national conservation goals (e.g., Xu et al., 2017).

Leveraging existing laws, and shaping cross-sector policy, could improve the scope for conservation in human-dominated landscapes. At present in Kenya, the

Agricultural Act of 2013, the Forest Conservation and Management Act of 2016, and the Environmental Management and Coordination Act of 1999 (revised in 2012) all work independently and influence biodiversity in different ways across different land-use sectors. Implementation and enforcement are problematic in each case while other policies, such as national spatial plans, urban development plans, and wide-scale infrastructural development, contradict conservation goals (Lambin & Meyfroidt, 2011; Laurance, 2018). Clearly, integration of biodiversity conservation policy across LU sectors is required, and the relevant agencies and institutions have to operate together at one appropriate scale, which is the landscape scale (Sayer et al., 2013).

Finally, to make conservation in human-dominated landscapes achievable there is a need for the empowerment of appropriate management structures, devolved governance systems, and coordination and consensus among stakeholders at various levels (Arts et al., 2017). The weak incentives for grass-roots conservation present a particular challenge with most landholders unable to convert wildlife and biodiversity from a short-term liability into a long-term asset (Norton-Griffiths & Said 2010). To overcome this problem, the exploration of innovative solutions to generate financial momentum across all LU types is required. Appropriate policy changes are urgently needed to encourage conservation incentives in human-dominated landscapes because prospects of large-scale restoration of biodiversity are difficult or unrealistic (Possingham, Bode, & Klein, 2015), as demonstrated by the rangelands of the USA (Reid et al., 2014) and the agricultural landscapes of Europe (Kleijn & Sutherland, 2003).

## 4.4 | Conclusions

This case study of Kenya, which is world-renowned for its natural capital, demonstrates that only a fraction of national biodiversity, as indicated by species ranges of mammals, birds, and amphibians, occurs within government-administered PAs. However, wildlife policy and conservation attention remain focused on megafauna in these areas, while the bulk of biodiversity outside of PAs receives minimal protection. PAs must be adequately supported, but innovative wildlife policies and practices are also needed to facilitate the transition of biodiversity from a short-term liability to a long-term asset for the burgeoning human populations living in the matrix of rangeland, cropland, and even urban sprawl. This echoes international calls for landscape-based approaches to conservation and policy reforms that integrate biodiversity conservation with all other sectors of LU (Sayer

et al., 2013). Our analysis calls for the focus of national wildlife policy to widen beyond wilderness and megafauna and to include landscape heterogeneity, land-use diversity, key habitat patches (and dispersal among them) within the human-dominated matrix, and ecosystem services upon which people depend (Kremen & Merenlender, 2018). Nowhere else is this more applicable than across the tropical grasslands and savannas of eastern and southern Africa, where, over the next 50 years, the terrestrial vertebrate diversity of these ecosystems is predicted to be impacted the most by the combined global-scale effects of land-use and climate change (Newbold 2018).

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## CONFLICT OF INTEREST

The authors declare no potential conflict of interest.

## AUTHORS' CONTRIBUTIONS

P.T. developed the ideas and methods for this research, conducted the analysis, and wrote the first draft of the manuscript. J.D.T and D.W.M edited and reviewed the subsequent drafts.

## ETHICS STATEMENT

No ethics approval was required for this research.

## DATA AVAILABILITY STATEMENT

All data used in this manuscript is freely accessible at the referenced sources.

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## SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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