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LETTER

The fear factor—Snakes in Africa might be at an alarming extinction risk

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Abstract

Snakes in Africa are responsible for over 20,000 deaths annually, their indiscriminate killing. As a result, snakes are vulnerable to human population increases even at low intensities. Thus, the predicted doubling of Africa's population by 2050 is likely to pose a disproportionate threat to snakes compared to other taxa. Here we quantify the current and future overlap of snake distributions and human population density under three scenarios of population growth. We find that by 2050, on average, 71% of snake ranges of conservation concern will overlap with areas occupied by ten or more people per km^2, a 22% increase from 2020. In addition, the number of Least Concern species with most of their range within areas with high human population density will more than double, likely increasing the number of threatened species over the next decades. Our results call for immediate policy action targeting people's perceptions and fears of snakes, and incorporating snakes directly into development and conservation plans to reduce the impact of future urban expansions across Africa.

KEYWORDS

biodiversity threats, conservation, human population increase, human–snake conflict, human–wildlife conflict, reptiles, snake phobia, socioeconomic pathways, wildlife conflict

1 | INTRODUCTION

Humans are a major driver of the current biodiversity crisis and a primary cause of declines in species and ecosystems (Jaureguiberry et al., 2022), which has led to at least 25% of all described species now threatened with extinction (IPBES, 2019). With the global human population set to increase from less than 7.8 billion in 2020 to ca. 9.7 billion in 2050, human pressure on nature is, thus, expected to only intensify (UN DESA, 2022). However, this increase is not occurring uniformly across the world. While Europe, North America, and parts of Asia are experiencing stagnating or even negative growth rates, the continent of Africa is experiencing the world's highest rates of growth; of over 3% annually. As a result, Africa's population is expected to nearly double before 2050, going from ca. 1.3 billion people in 2020 to over 2.4 billion in 2050 (Bongaarts, 2009). This increase will not only lead to people moving to places already heavily modified but also to the expansion of populated parts of Africa into previously uninhabited areas (Mukeka et al., 2019). Such expansions are likely to exacerbate pressure on nature (Bradshaw & Di Minin, 2019).

However, population change by itself is a very poor proxy for environmental impact and the effects of human population growth on biodiversity relates primarily to historic use and socioeconomic factors. For example, over 640 million Africans (ca. 40 %) have no access to electricity, corresponding to the lowest electricity access rate in the world. Per capita consumption of energy in sub-Saharan Africa (excluding South Africa) is 180 kWh, equivalent to only 3% and 1% of the consumption per capita in Europe and the United States respectively (EIA, 2023; EMBER, 2023; IEA, 2022). The same applies for CO_2 emissions (fossil fuel and industry emissions) (Ritchie et al., 2020). Likewise, the annual ecological footprint of Africa 1.3 billion people is estimated to be 0.8 Earths, compared to the 7.8 Earths needed to sustain the same population size and consumption rate of Europe and North America (Global Footprint Network, 2019).

In addition to socioeconomic factors, species- and taxa-specific traits also play an important role in determining the impact of an increasing human population on biodiversity, with some species more vulnerable to human–wildlife conflict (Richards et al., 2021; Tingley et al., 2013) and others more likely to be exploited or persecuted (Hall et al., 2008). One group where this is the case is snakes. Snakes in Africa account for 20,000 to 32,000 human deaths yearly (Gutiérrez et al., 2017), a figure that is likely to be considerably underestimated due to snakebite underreporting in many rural areas (Farooq et al., 2022). This has led to indiscriminate killing of snakes in many areas where people are experiencing frequent snake-related deaths regardless of whether the specific species poses any real danger (Farooq et al., 2021). Thus, it is very likely that snakes, more than most other species groups, will be at an increased risk following human population expansions, even at low density of people (Fischer et al., 2012). This expansion of human populations, regardless of consumptions patterns, will pose a disproportionate threat to snakes simply by increasing the likelihood of encounter. This is exacerbated by the fact that this group is less studied and often overlooked in conservation priorities and actions (Bonnet et al., 2002).

To explore potential risks to snakes from changing human population patterns, we therefore examine how the expected human population expansion in Africa over 40 years will intersect with the ranges of all African Snakes using data from 754 species of snakes extracted from the IUCN Red List. For all snake species, we calculate both the average overlap with areas of high human population density (> 10 humans per km^2), and how many species have at least half of their range within areas with high human population density. We do this for three socioeconomic pathways that represent different distinct human population trajectories that are each based on multiple socioeconomic predictions (Olén & Lehsten, 2022). Our results provide a first assessment of the potentially threats of human expansion to one of the most persecuted taxa globally (Ceríaco, 2012; Langley et al., 1989; Liordos et al., 2018; Mesquita et al., 2015; Vaughn et al., 2022; Whitaker & Shine, 2000), especially in Africa (Farooq et al., 2021; Onyishi et al., 2021).

2 | METHODS

We obtained all extant terrestrial snake distribution ranges (n = 754, CR = 6; EN = 21; VU = 23; NT = 34; LC = 566; DD = 104) from the IUCN Red List spatial database (IUCN, 2022). Using R *version 4.2. 2* (R Core Team, 2021) and the package sf *version 1. 09* (Pebesma, 2018), we intersected each range with a 50 by 50 km grid in a cylindrical equal area projection (Berhmann). Cells were considered to overlap with snake ranges if any part of their range intersected with the cell. While this increases the likelihood of errors of commission, it was a necessary step to ensure that very small range species were not removed from the dataset. We then grouped snakes into two groups: Least Concern (LC) and Non-Least Concern (Non-LC) based on their IUCN Red List status.

For human population density projections, we imported the spatial layers of population density for 2010, 2030, and 2050 developed by Olén and Lehsten (2022) to R using the package *raster version 3. 6-3* (Hijmans et al., 2015). These projections are originally 1 by 1 km so we aggregated them into 50 by 50 km grids to both minimize the errors at very high resolution and to match the resolution of species layers. For each 2500 km^2 (50 by 50 km) grid cell, we calculated the average human population density. Olén and Lehsten (2022) have developed a series of scenarios for how, and how much the human population of Africa will change. We used three scenarios (SSP1-3) in our modeling which represent very distinct policies and trajectories for the continent: SSP1 (Sustainable development), where the world shifts toward a more sustainable path investing in education and health with emphasis on human wellbeing; SSP2 (Middle of the road) is a scenario where social, economic, and technological trends do not shift markedly from historical patterns. In this scenario, there is an anticipated slow progress toward sustainability objectives, coupled with environmental degradation. Resource and energy usage will see a general reduction, and income disparities will either remain or show minimal improvement; SSP3 (Regional rivalry) describes a setting where investments in education and technological advancements will decrease. This will result in slow economic growth with a focus on material-intensive consumption. Disparities will remain consistent or intensify. Industrialized nations will experience low population growth, whereas developing countries will witness a surge. Moreover, addressing environmental issues will not be a global priority, leading to pronounced environmental damage in certain areas. While all three scenarios represent possible futures and can help illustrate the impact of large-scale policies, current empirical observations of population growth since 2010 (Dorling, 2021) align and even exceed the Regional rivalry scenario.

Using these scenarios, we then calculated the overlap of species ranges and grid cells with at least 10 people per km^2 for the years 2010, 2030, and 2050. We did this to identify frontier areas where the human population increased from negligible to densities high enough to pose a danger to snakes via direct persecution and/or habitat degradation/clearing. We use a threshold of 10 people per km^2 as high human population density (HHPD) based on Cardillo et al. (2004), which showed that the overlap of mammal ranges with areas with 10 or more people per km^2 predicted extinction risk. This threshold is well established to represent the transition from remote to human occupied areas and has been shown to cause a decline in lions in both West and Eastern Africa (Riggio et al., 2013) as well as used to describe high human population density in Madagascar (G. M. Green & Sussman, 1990). This threshold of 10 people per km^2 was considered reasonable and even conservative for snakes (Jacobson et al., 2019). However, to test this assumption, we repeated the analysis using 1–20 people per km^2 (Figure S1).

We also quantified the overlap of snake ranges with cells with high human population density and low human population density for 2010, 2030, and 2050, calculating for each year the average overlap of 20 randomly selected species 1000 times. We used this repeated sampling approach to diminish the effects of extreme cases on the overall pattern. We also calculated at different time scales (2010, 2030, and 2050), the number of species that will have a range overlap of more than half of their range with high human population density cells.

Finally, to test our threshold of 10 people per km^2, we conducted an additional analysis where we calculated the likelihood of finding a species with a Red List category other than LC in Africa, using a binomial regression and weighting the species by the inverse of the cubic root of the snake's ranges as in Harfoot et al. (2021). We then used the layer of likelihood of finding a species with category other than LC in Africa as a response variable in linear models with binary layers of population density at different thresholds using the following formula in base R:

lm(L.NLC ~ Pop, family = 'gaussian')

Where L.NLC is the likelihood of finding a species with category other than LC and Pop is a binary variable of various population density thresholds. We ran models for the following population densities of people per km^2: 0.005, 0.01, 0.25, 0.5, 1, 2, 3, 4, 5, 6, 7, 8, 9. 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, and 20 (Figure S2).

All analyses were conducted in R *version 4.2. 2* (R Core Team, 2021) and the visualizations were produced using the package *ggplot2 version 3.4.2* (Wickham, 2016).

3 | RESULTS

Areas of Africa where snake ranges overlapped with HHPD varied greatly depending on the development scenario used (Figure 1). In 2010, 22.5% of all the 50 × 50 km grids in Africa had more than 10 people per km^2. By 2050, this proportion had increased by 13.5% to 36% under the regional rivalry scenario (SPP3) and by 5% to 28.5% under the Middle of the road scenario (SPP2). Only for the sustainable development scenario (SPP1) did we observe a human population contraction of 1.9% to 20.6% by 2050. For all scenarios, the largest increases were observed in West and East Africa (Figure 1), intersecting with some of the most important areas for conservation such as in the Eastern Arc Mountains or the West African Forests (Burgess et al., 2007; Luiselli et al., 2019; Myers et al., 2000).

Changes in human population density resulted in increased overlap with snakes in two of the tested scenarios (i.e., Middle of the road and Regional rivalry), while overlaps decreased under the sustainable development scenario. Under the Middle of the road scenario (SSP2), the number of non-least concern species overlapping with HHPD areas increased almost 10% from ca. 49% of all species to 57% in 2050. Alarmingly, in the more realistic regional rivalry scenario (SSP3), we observed an increase of over 20%, indicating that 71% of all species of conservation importance would be overlapping with areas where they were at elevated risk of being killed by 2050 (Figure 2). In contrast, in the Sustainable development scenario (SSP1), we observed a small decrease of 49% to 47% (Figure 2). Similar patterns were observed for the non-threatened species, though the numbers in absolute terms were smaller (Figure 2).

For all the years, there was a strong association between the IUCN Red List threatened status of snake species and range overlap with high human population density, so that, threatened species had a higher average overlap with areas of high human population density. This association was observed regardless of the threshold and scenario used (Figure S1). Our analysis of the relationship between the likelihood of finding a snake with a category other than LC and population density also produced significant and positive associations regardless of the used threshold. The strongest relationship occurred at a population density of 0.25 people or more per km^2, which reinforced our choice of threshold of 10 people per km^2 as a very conservative assumption (Figure S2, Table S2).

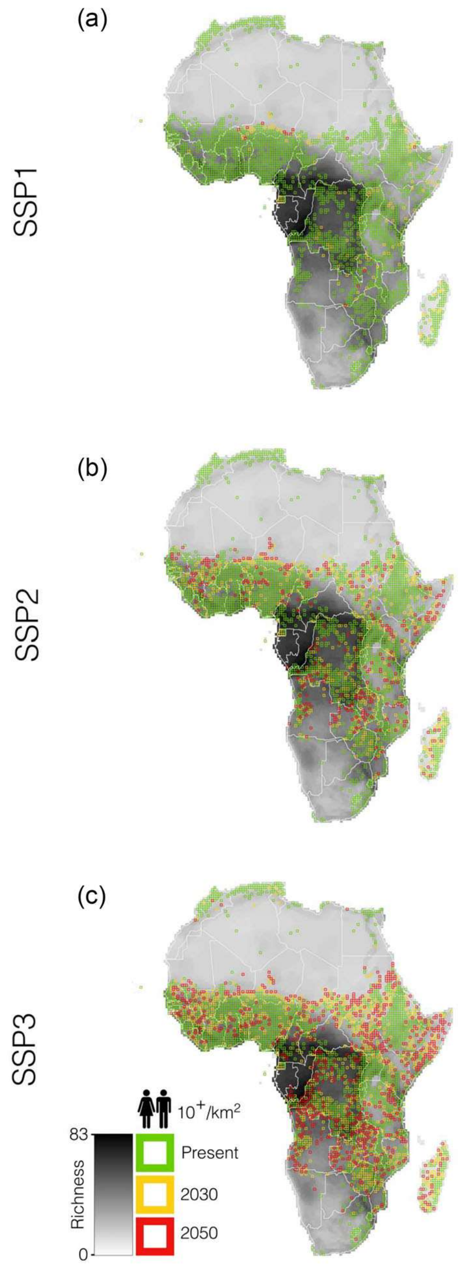

FIGURE 1 Overlap of areas with 10 or more people per km^2 (colors) for the years 2030, 2040, and 2050 and snake richness (grayscale): (a) shows the present and future increase in SSP1, (b) shows the present and future increase in SSP2, and (c) shows the present and future increase in SSP3. Red areas indicate places with 10 or more people in 2010, yellow areas where that threshold has been reached by 2030, and green areas where that threshold has been reached in 2050.

Both the percentage of species' ranges overlapping with areas of high human population density and the number of species with over half of their range overlapping with these areas have increased. For Least Concern species the number of species with half or more of their range overlapping with areas of high human population density increased from 125 (21%) to 296 (52%) species, while the number of non-LC species may increase from 77 (41%) to 122 (65%) (Figure 3; and Table S1 for a list of all species and their current and future overlap with population densities of up to 1 to up to 20 people per km^2).

4 | DISCUSSION

Our results show that under the most realistic trajectories for human population growth in Africa (Regional rivalry; SSP3), snakes will come under increasing pressure in many parts of their ranges currently not overlapping with areas with high population densities. We find that species of snakes assessed with a category other than LC in the IUCN Red List have higher percentage of their range overlapping with areas with high human population density when compared to species assessed as LC, a result robust to all tested thresholds (Figure S1). More importantly, under the worst, but most realistic scenario (SSP3), the average overlap of LC species by 2050 will surpass the current overlap for non-LC species suggesting that we can expect a considerable increase on the number of threatened snakes by 2050. The number of snake species with over half of their range within areas with high human population density will also more than double by 2050, including an increase in species with a category other than LC from 41% to 65%. This increase will likely result in a steep increase on the number of snakes under the risk of extinction in the continent.

Snakes play an important ecological and cultural role in many parts of the world. Depending on their size (Fearn et al., 2001), they can control the populations of vertebrate groups, including pests—in particular rodents (Madsen et al., 2006) and may facilitate seed dispersal (Reiserer et al., 2018). Thus, the lack of snakes could cause an increase of rodents which can negatively impact people's crops and increase the risk of diseases with rodent vectors (Fiedler, 2018). Culturally, snakes are both feared and worshiped (E. C. Green, 1996), sometimes even associated with the belief of reincarnation or fertility (Smith, 2006). Thus, their loss will not only have ecological consequences but also result in the loss of cultural heritage.

4.1 | Future overlap of snakes and high human population density

As human population density expands and intensifies, most species will eventually be affected, either by direct persecution, habitat loss and degradation, or invasive species (Farooq et al., 2023; Gibbons et al., 2000; Shochat

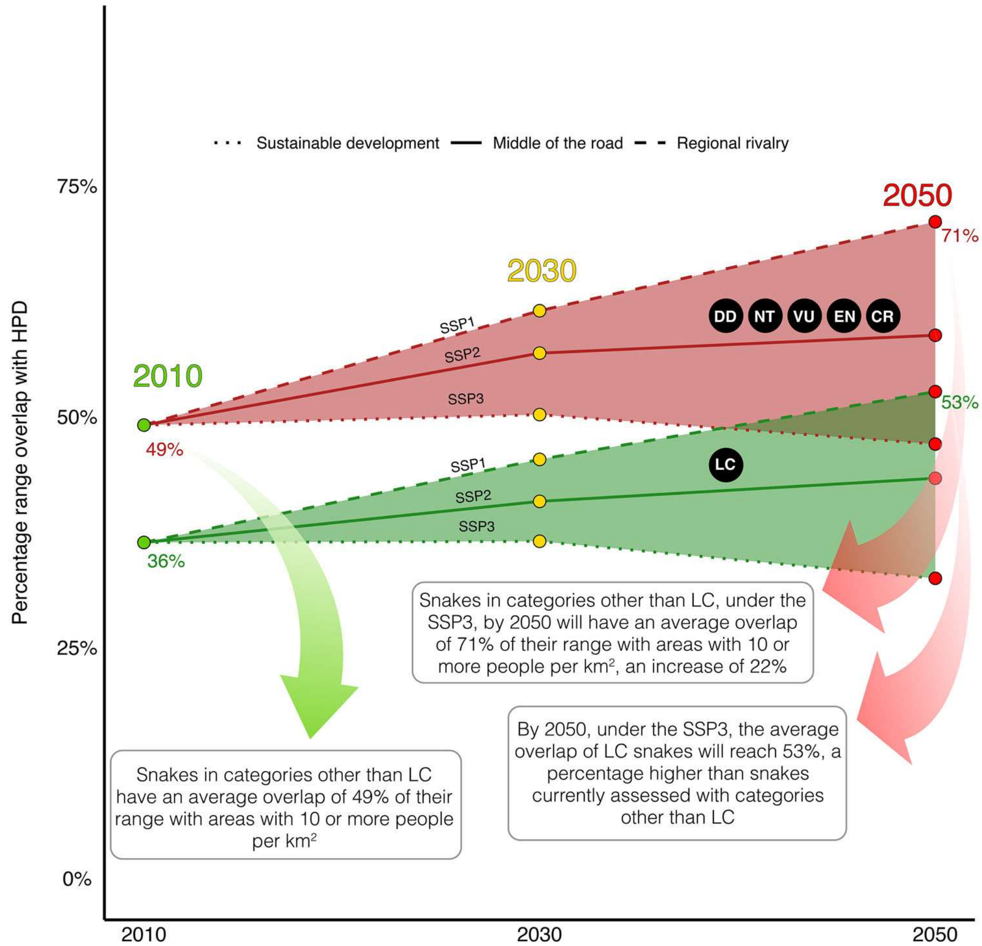

FIGURE 2 Increase in the percentage overlap of ranges with grid cells of HHPD through time. Red indicates non-LC species and green LC species. The solid line indicates the Middle of the road scenario, the line-segmented line the regional rivalry scenario, and the dotted line the sustainable development scenario. By 2050, under the SSP3, the average overlap for species assessed as LC will be 4% higher than the current overlap for species assessed with other categories.

et al., 2010). There are a few exceptions of species that can benefit from an increased abundance of human-associated prey such as rodents (Keesing & Young, 2014) or tolerate urbanization (Akani et al., 2002; Hauptfleisch et al., 2021). But protecting Africa's biodiversity, especially taxa that are sensitive to population density will require major shifts in socioeconomics. Measures such as empowering women, increasing accessibility to contraception, promoting accessibility and equality in children to schools, the promotion of global justice and sustainable economies, and improving child and maternal health have been shown to be effective and would be important to support (United Nations Population Fund, 2005). However, protecting biodiversity will also require a specific focus on biodiversity as an integral part of the development including making biodiversity education an integral part of the school curricula (Gayford, 2000; Puruleia et al., 2023).

For this analysis, we have used three different scenarios for human population growth in Africa that represent very different socioeconomic trajectories. Despite all three representing possible futures, the most recent developments suggest that the Regional rivalry scenario (SSP3) is the more realistic. The projection for human population growth in sub-Saharan Africa released in 2019 of 2.12 billion for 2050, (United Nations, 2019), has already been revised at least twice from 1.52 billion in 1998 and 1.75 billion in 2008 (Ezeh et al., 2020). Thus, the observed population changes over the last decade have even surpassed the predictions of SSP3 (Dorling, 2021). In addition, Africa is the second most unequal continent in the world. It continues to explore its resources in an unsustainable way where nearly 4 million hectares of African forests are cut down each year—almost double the speed of the world's deforestation average (Sacande et al., 2022). The SSP3 is characterized by a focus on domestic or at most, regional issues in detriment to global concerns. There are declines in investment in education and technology, slow economic development and persistence of inequalities. This will also mean environmental degradation in some regions fuelled by the lack of international

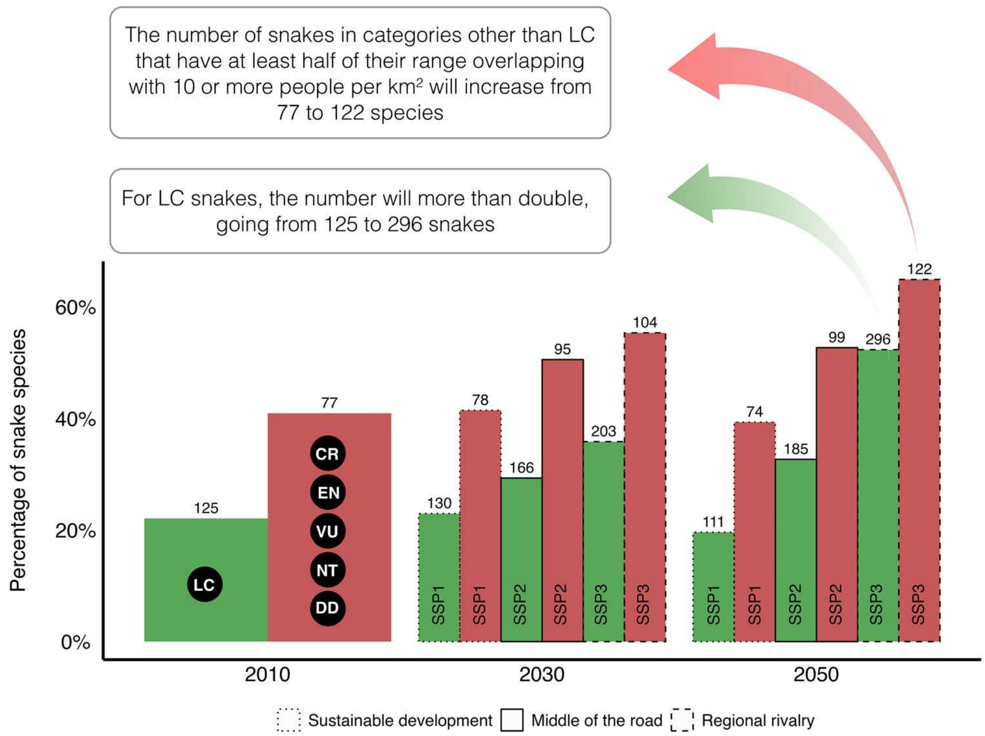

FIGURE 3 A figure showing the percentage of species with at least half of their range overlapping with HHPD areas for each scenario (SSP1-3) and for the years 2010, 2030, and 2050. The corresponding number of species is indicated by the numbers above the bars. Currently, 125 snakes assessed as LC (22%) overlap with such areas, however the number may increase to up to 296 (52%) by 2050.

priority for addressing environmental concerns (Riahi et al., 2017).

African snakes will very likely come under increased pressure over the next decade, resulting in an increased number of species likely to risk extinction. This presents a very real conservation challenge, as snakes more than other groups face these threats simply from coming into contact with people. Although the Sustainable development scenario (SSP1) seems less realistic, it shows that it can mitigate pressure on snakes and overall biodiversity. But to achieve this at the African level, there is a need for global cooperation, rapid technological development, strong environmental policies, low population growth, declines in inequality, focus on renewables and efficiency, dietary shifts and protection of forests (Riahi et al., 2017). We, however, do not believe that restricting human population growth for the sake of snakes is a viable strategy. Rather we propose a focus on education and awareness, which can affect the perceptions and willingness to support snake conservation measures (Knight, 2008), as a more viable strategy to reduce the impact of people on snakes. Such initiatives will not only benefit biodiversity but are also an essential part of any strategy to increase the livelihood of people.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data analyzed in this study was a reanalysis of existing data, which is openly available from the references cited. We also provide the outputs generated during the analysis.

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SUPPORTING INFORMATION

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

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