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Rapid decline and fragmentation of the distribution of an enigmatic small carnivore, the Owston's Civet, in response to future climate change

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Abstract

Indochina is known as one of the world's biodiversity hotspots, with populations of many endangered and/or endemic species dramatically declining due to a range of threats, such as illegal hunting, habitat destruction, and global climate change. Climate change is expected to alter the region's habitat and ecosystem conditions, force contraction of species ranges, and increase the likelihood of local extinctions. Maxent is a widely used modelling approach to predict the species' current potential distribution, project range shifts in response to climate change, and inform conservation planning. Here, we collated known records and built models for both present and future climatically suitable habitat of the Owston's Civet (*Chrotogale owstoni*), an endangered and poorly studied small carnivore occurring in Vietnam, eastern Laos, and a small part of southern China. Projections of climatically suitable habitat for the civet in most climate change scenarios and timeframes suggest significant habitat loss and fragmentation within its current range as a consequence of upward contraction. We recommend that future conservation efforts for *C. owstoni* focus on key refugia spreading along the Annamite Range in the border area between Vietnam and Laos. To mitigate climate-related extinction risk, close cooperation between Vietnam and Laos' governmental agencies, research institutions, and non-governmental conservation organizations will play an important role in conserving the remaining habitat of this endangered species.

Highlights

- Terrestrial mammals have already been negatively affected by climate change at the global scale. However, the threat has not been evaluated for most species in Vietnam and neighbouring countries.
- This study assesses the impacts of climate change on the endangered Owston's Civet by modelling its distribution under various climate change scenarios. Our results reveal significant habitat loss and fragmentation across the species distribution range, as it moves up to higher elevations in response to a warming climate.
- Remarkably, the number of protected areas with climatically suitable habitat for the species are projected to decline from 21 currently (3 in Laos and 18 in Vietnam) to 13 (3 in Laos, 10 in Vietnam) in future climate change scenarios.
- To better protect the species from this threat, future conservation efforts should focus on climatically stable areas situated along the border between Vietnam and Laos. Effective conservation measures to secure the climate refugia and reduce the current level of poaching and habitat loss would therefore require close cooperation between Vietnam and Laos.

Keywords: China, climate change, conservation management, Laos, Maxent, species distribution, transboundary conservation, Vietnam

Introduction

The Owston's Civet *Chrotogale owstoni* Thomas 1912, an endangered species of the family Viverridae and the only member of the monotypic genus *Chrotogale*, is facing a high risk of extinction in the wild (Timmins et al. 2016, Willcox et al. 2019). This

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species occurs across Vietnam (Roberton 2007, Can and Trai 2010), eastern Laos (Coudrat et al. 2014, Gray et al. 2014), and in a small part of southern China (Schreiber et al. 1989, Smith and Xie 2013). The presence of the Owston's Civet in China had long been questioned and some had suggested that it might be already extinct in this area due to the lack of recent records (Lau et al. 2010). However, this civet was documented again by camera traps in Xishuangbanna, Yunnan in 2018 (Tongkok and Alcantara 2019, Tongkok et al. 2020). Several previous studies suggested that the Owston's Civet is found mainly in northern Vietnam and Laos (Schreiber et al. 1989, Duckworth et al. 1999, Willcox et al. 2014), but others have confirmed that its geographical range extends southward (Rozhnov et al. 1992, Can and Trai 2010, Gray et al. 2014). Its distribution may potentially include eastern Cambodia based on museum records, but the species presence in Cambodia is debated (Can and Trai 2010), and extensive camera surveys have yet to record Owston's Civet within Cambodia (McCann et al. 2017, Loveridge et al. 2018).

Information regarding the ecology of the Owston's Civet (Fig. 1) is sparse. Limited data from field surveys, field interviews, and reintroduction programs have shown that the Owston's Civet is likely to be restricted to evergreen forests with a non-harsh dry season (Timmins et al. 2016). Although this species reportedly inhabits degraded forests, some studies have suggested that it may prefer primary forest (e.g., Schreiber et al. 1989, Roberton et al. 2002, Long and Hoang 2006, Johnson et al. 2009, Gray et al. 2014). Previously, *C. owstoni* was primarily recorded between 300 and 1,600 m, but more recent surveys have detected it in a broader range of elevations from 100 to 2,600 m (Timmins et al. 2016). It is a mainly ground-dwelling species, and therefore quite vulnerable to snaring (Timmins et al. 2016, Gray et al. 2018). The Owston's Civet has been hunted for meat and traditional medicine across its range (Sivilay et al. 2011, Gray et al. 2014, Willcox et al. 2019). Additionally, the loss, degradation, and fragmentation of evergreen forests have also severely threatened its populations, particularly in Vietnam and Laos (Timmins et al. 2016, Gray et al. 2018, Tilker et al. 2020). This species has, as a consequence, experienced a significant decline over the last 20 years and has been categorised as Endangered on the IUCN Red List of Threatened Species (Timmins et al. 2016).

Figure 1. Camera trap photo of an Owston's Civet in the Annamite region, Vietnam (Authors' own field data)

Climate change is likely to exert substantial impacts on species distributions and pose new challenges to biodiversity conservation (Heller and Zavaleta 2009, Velásquez-Tibatá et al. 2013). Many species are forced to move to higher latitudes or elevations where environmental conditions are more suitable for them to adapt to a rapidly warming climate (Lenoir et al. 2008, Chen et al. 2011, Boisvert-Marsh et al. 2014). In recent years, the effects of global warming on species geographic ranges have raised concerns over extinction risks many species are facing (Manish et al. 2016, Vaz and Nabout 2016, Alarcón and Cavieres 2018). However, the impacts of climate change, a direct major threat to terrestrial mammals (Ribeiro et al. 2016, Davidson et al. 2017, Pacifici et al. 2017, Pacifici et al. 2020), have never been assessed for the Owston's Civet. A similar species, the Hose's Civet (*Diplogale hosei*) is predicted to potentially lose up to 86% of its habitat as a result of climate change by the end of the century, making it highly susceptible to extinction (Mathai et al. 2019).

Species distribution models (SDMs) correlate species occurrence data with environmental conditions to characterize the climatically suitable environments for the species of interest (Elith et al. 2011). SDMs have been commonly used in many fields including biogeography, conservation biology, evolutionary ecology, and wildlife management (Zimmermann et al. 2010). Examples of applications of SDMs comprise: identification of highly suitable habitats for endangered species (Wang et al. 2015); analyses of the adaptability of an invasive species (Srivastava et al. 2019); determination of conservation priority areas (Prieto-Torres et al. 2018); and assessments of the impacts of climate change on species distribution (Hadgu et al. 2019). When combined with projected climate change scenarios, SDMs can help predict how distributions of species may change in the future, and therefore inform various aspects of conservation management (Jarvie and Svenning 2018). Maximum Entropy (Maxent) is a popular and high performing SDM approach (Urbina-Cardona et al. 2019), which has been demonstrated to produce robust predictions even with limited occurrence data and small sample sizes (Phillips et al. 2006, Phillips et al. 2017).

In this study, we compiled a comprehensive list of known localities of the Owston's Civet over its entire range. We then used Maxent to predict its current potential distribution to identify protected areas with high conservation value for this species in terms of climate suitability. We also projected the models using different future climate scenarios to assess the impacts of climate change on the Owston's Civet. As site prioritisation has been considered vitally important for future conservation of the species (Willcox et al. 2019), we provide provisional recommendations for site-based planning and management actions based on our results to support the conservation management of this endangered species. However, we did not attempt to determine other factors such as the feasibility of protecting the species in the identified areas. Thus, our results represent a first step towards a comprehensive recommendation of priority sites that should include additional analyses such as: a qualitative assessment of the threats to the sites (including direct threats such as hunting), the capacities to mitigate or prevent these threats, and the resources required to fund in-situ conservation to a level where the Owston's Civet could stabilize or recover.

Materials and Methods

We obtained records of the Owston's Civet by searching the Web of Science, Google Scholar, ResearchGate, GBIF, and iNaturalist using the following queries: "*Chrotogale owstoni*", "*Chrotogale*", "*Hemigalus owstoni*", "*Hemigalus*", "Owston's palm civet", "Owston's Civet". In addition, library archives, reports, and specimens from research and conservation institutions and organizations were also examined. All collected records were then evaluated, checked, verified, and filtered to remove erroneous and unreliable locations. We only used records with coordinate information (e.g., camera trapping surveys …) or verifiable location (e.g., field observations …), and did not include unconfirmed localities, such as those from media sources or interviews, or outdated records, in model training and only use them to discuss our modelling results to cross-validate the data and infer potential presence of the species in such locations.

To reduce spatial-autocorrelation stemming from possible sampling biases, we used the spThin package (Aiello-Lammens et al. 2015) in R (R Core Team 2020) to thin out localities within 10 km distance following Pearson et al. (2007), which reduced our dataset from 127 localities to a final set of 70 localities. The highest resolution available for current climate environmental covariates is much higher than that for future climates. To reduce issues regarding false precision, and to allow for spatial comparisons between current and future climate conditions, we used 19 bioclimatic variables at 2.5-minute resolution available from the WorldClim 2.1 database (Fick and Hijmans 2017). To only sample the areas that are likely to have been available to the Owston's Civet, we restricted the extent to a 2.5 degree buffer (Anderson and Raza 2010) around the minimum convex polygon of the occurrences. We ran all analyses in Maxent version 3.4.4 (Phillips et al. 2017).

As Maxent tends to produce overfitting models, we performed the following set of tuning steps to minimize this problem while also maximizing discriminatory ability: we used four feature class combinations (linear, linear and quadratic, linear and quadratic and hinge, and hinge features), and tested a range of regularization multipliers ranging from 1.0 to 10.0 by increments of 0.5. For other model parameters such as convergence threshold and background samples, we followed recommendations from model developers (Phillips et al. 2006). We then used the spatially partitioned fourfold cross-validation method, which is recommended for models that need to be projected into the future based on novel climate conditions, to train the model (Muscarella et al. 2014).

To assess model performance and select the most suitable one, we used the 10% omission rate threshold to select models that showed the least overfitting. Of this subset, we then chose the model with the highest AUC values. Final models were then compared using the Akaike information criterion (AIC), which balances complexity with model fitness (Warren and Seifert 2011). For the final model, we used the 10% training presence threshold to classify between suitable and unsuitable areas for the Owston's Civet (Pearson et al. 2007).

The optimal model was then projected to three future periods, 2041 – 2060, 2061 – 2080, and 2081 – 2100, using data for two global circulation models: BCC-CSM2-MR (Wu et al. 2019) and MIROC6 (Tatebe et al. 2019), which are models that simulate and forecast weather, climate, and climate change conditions. The two models are only distantly related to each other, so they may better demonstrate the uncertainties in future projections (Thuiller et al. 2019, Brunner et al. 2020). For each circulation model and timeframe, all four scenarios were used for each model, ranging from SSP1-2.6, which assumes there will be an increasing shift toward sustainable practices in the global economy, to SSP5-8.5, which assumes the world will adjust towards an energy-intensive, fossil fuel-based economy (Riahi et al. 2017). Individual binary maps for each scenario of the same model and the same duration were then summed and combined to generate consensus presence probability maps, which were ranked in a graduated colour scale, and showed the likelihood of the Owston's Civet presence. The highest value (100%) on the map means that area was estimated to be climatically suitable for the Owston's Civet in four scenarios for one particular timeframe from one circulation model.

Results

We obtained a total of 127 known records of the Owston's Civet (Fig. 2), and used 70 records for the modelling. A list of records is shown in Table S1 in the Supplementary Material. Of these records, 58% were from Vietnam, 40% from Laos, and 2% from China; 28% were from an elevation of 700 m or less, 50% were between 700 m and 1.400 m, and 22% from an elevation higher than 1.400m.

Maxent models showed reasonable prediction power, and the optimal model for the current potential distribution of the Owston's Civet had a regularization multiplier of 3.5, and the hinge feature class (average test omission rate at the 10% training presence threshold = 0.057, average evaluation AUC = 0.913, AIC = 1488, and delta AIC = 148.3). The final model successfully predicted the known range of *C. owstoni* but also overpredicted outside the current known range (Fig. 3). The actual distribution of the Owston's Civet within the modelled range limits will depend on various factors, including: habitat characteristics, species interactions, geographical barriers, and dispersal abilities. The bioclimatic variables that have

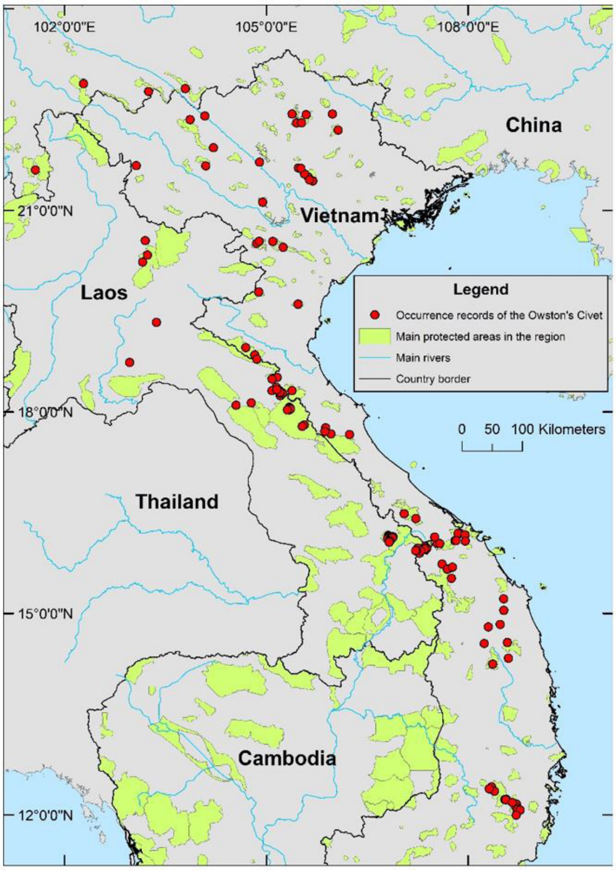

Figure 2. Occurrence records of the Owston's Civet in Laos, Vietnam, and southern China in relation to current protected areas (UNEP-WCMC and IUCN 2021).

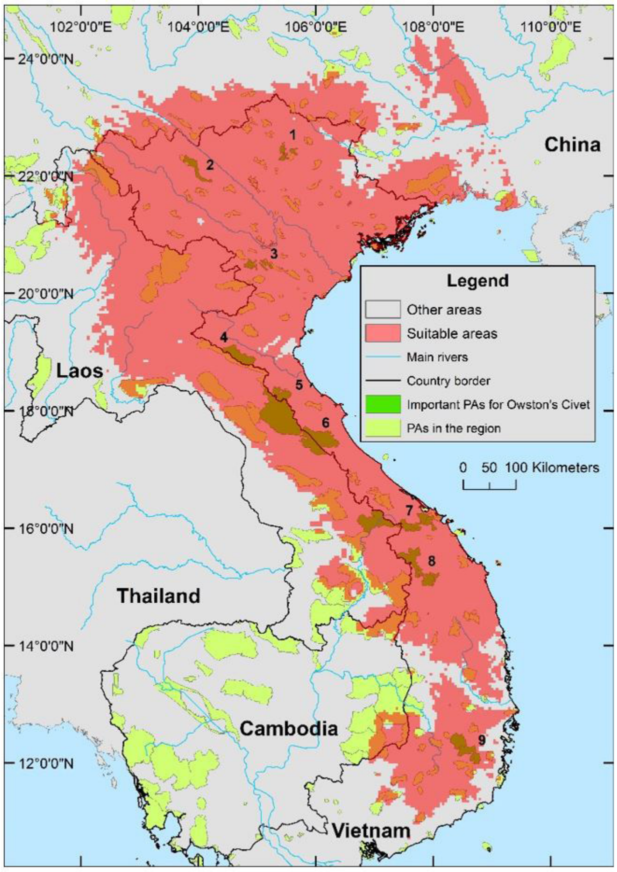

Figure 3. Current potential distribution of the Owston's Civet. The numbers denote different regions that are described in Table 1.

the higher percent contribution value for the optimal model include: mean diurnal range, max temperature of warmest month, temperature annual range, mean temperature of wettest quarter, mean temperature of coldest quarter, annual precipitation, and precipitation seasonality.

The current climatically suitable distribution for the Owston's Civet primarily covers Vietnam and eastern Laos; a narrow strip of land in the border region between Vietnam and China is also predicted to be suitable. In total, 21 key protected areas, 18 from Vietnam and three from Laos, fall within the current range of this species. These areas can be grouped in nine main regions (Table 1), as denoted in Fig. 3. Several protected areas in China, including Huanglian Mountain National Reserve (Luchun), Dawei Mountain National Reserve (Hekou), and Jinping Divide National Reserve (Jinping), lie on the edge of the species range (Figs. 2, 3).

Based on future model projections, it is clear that the Owston's Civet's distribution would shift in future climate change scenarios (Fig. 4). Although these model predictions differ on the overall rates of change, two trends could be observed. Firstly, the projected distribution is likely to shrink significantly compared to the current predicted range (Table 2), with an average decrease of approximately 42% (standard deviation ± 20.3%) in terms of total area coverage, even in the best-case scenario. Secondly, this species will likely move upwards to higher elevations of about 600 m or more. Such higher regions include the Hoang Lien Son Mountain Range in Vietnam and China, the Annamite Range in Vietnam and Laos, and the high plateaus of the Central Highlands in Vietnam. The populations in most of the currently predicted areas will become highly fragmented.

Under such changes, the most highly suitable areas for the Owston's Civet will be restricted to only 13 protected areas, down from the 21 sites covered by the contemporary predicted distribution, with three from Laos and ten from Vietnam, namely Pu Mat National Park (Vietnam), Vu Quang National Park (Vietnam) and Nakai – Nam Theun National Protected Area (Laos), Phong Nha – Ke Bang National Park (Vietnam) and Hin Nam No National Protected Area (Laos), Hue Saola Nature Reserve – Quang Nam Saola Nature Reserve – Bach Ma National Park (Vietnam) and Xe Sap National Protected Area (Laos), and Chu Yang Sin – Bidoup Nui Ba – Phuoc Binh National Parks (Vietnam). They are mainly located along the Annamite Range between Vietnam and Laos.

Table 1. Climatically suitable regions for the Owston's Civet

Climatically suitable regions for the Owston's Civet	Key protected areas in respective regions
Region 1	Na Hang Nature Reserve (Tuyen Quang Province, Vietnam) and Nam Xuan Lac Nature Reserve and Ba Be National Park (Bac Kan Province, Vietnam)
Region 2	Hoang Lien National Park and Hoang Lien – Van Ban Nature Reserve (Lao Cai, Vietnam)
Region 3	Pu Luong and Pu Hu Nature Reserves (Thanh Hoa, Vietnam)
Region 4	Pu Mat National Park (Nghe An, Vietnam)
Region 5	Vu Quang National Park (Ha Tinh, Vietnam) and Nakai – Nam Theun National Protected Area (Khammouane and Bolikhamsai, Laos)
Region 6	Phong Nha – Ke Bang National Park (Quang Binh, Vietnam) and Hin Nam No National Protected Area (Khammouane, Laos)
Region 7	Saola Nature Reserves (Thua Thien Hue and Quang Nam, Vietnam), Bach Ma National Park (Thua Thien Hue, Vietnam), Ba Na – Nui Chua Nature Reserve (Da Nang, Vietnam), and Xe Sap National Protected Area and Ban Pale (Laos)
Region 8	Song Thanh National Park and Ngoc Linh Nature Reserves (Quang Nam and Kon Tum, Vietnam)
Region 9	Chu Yang Sin, Bidoup - Nui Ba, and Phuoc Binh National Parks (Dak Lak, Lam Dong, and Ninh Thuan, Vietnam)

Table 2. The mean (and ranges) of future projected changes in climatically suitable habitat for *Chrotogale owstoni* across a range of different future scenarios, using data from two global circulation models: BCC-CSM2-MR and MIROC6.

Time-frame	Change in suitable habitat in conservation areas (%)	Total projected suitable habitat change (km^2)	Projected amount of shift in the centroid of suitable habitat (km)
2041-2060	-1.7 (-2.9 to -0.3)	-132,000 (-181,000 to -94,000)	54 (3 to 114)
2061-2080	-3.5 (-6.4 to -0.4)	-181,000 (-256,000 to -71,000)	77 (35 to 109)
2080-2100	-5.4 (-12.7 to 1.3)	-217,000 (-350,000 to -14,000)	256 (31 to 570)

Discussion

The bioclimatic-based SDMs constructed for the Owston's Civet showed high predictive performance and successfully predicted the known range, including recently discovered occurrences in southern China, but also including expected areas of overprediction to a much larger area. The variables that have the most significant contribution to the optimal model were largely related to temperature, with temperature-related variables comprising five out of the seven variables with important contributions to model training. Since the species is known to be associated with wet evergreen forests, temperature has been considered an important deciding factor in regions with a harsher dry season (Timmins et al. 2016). Future projections of optimal models showed an overall loss in total area of climatically suitable habitat across all different climate change scenarios. The BCC-CSM2-MR models estimated a more intense reduction in the Owston's Civet's climatically suitable habitat, compared to MIROC6 models in both 2041 – 2060 (-137,000 km^2 vs. -127,000 km^2) and 2061 – 2080 (-185,000 km^2 vs. -176,000 km^2) timeframes. Also, the suitable habitat loss is likely to be more severe in the 2061 – 2080 period, compared to the loss in the 2041 – 2060 period based on both global climate circulation models.

In Region 1 (Fig. 1), the presence of the Owston's Civet in northern Vietnam was reported from Tuyen Quang and Bac Kan provinces (Boonratana 1998, GIZ 2005, Thinh 2010). Because the distribution of this species in the north appears to be sparse, these limited records play an important role in both model validation and conservation. More studies are needed to investigate the status and threats to the Owston's Civet in these areas, and a biological corridor connecting Na Hang Nature Reserve, Ba Be National Park, and Nam Xuan Lac Nature Reserve is needed to create a large contiguous habitat block for this species.

In Region 2, the Owston's Civet was frequently recorded in a camera trap survey in the early 2000s. Because of this, Hoang Lien and Hoang Lien – Van Ban should be considered as one of the priority conservation areas for this species (Willcox et al. 2014, Timmins et al. 2016).

In Region 3, Pu Luong and Pu Hu reserves are characterized by a limestone mountain ecosystem

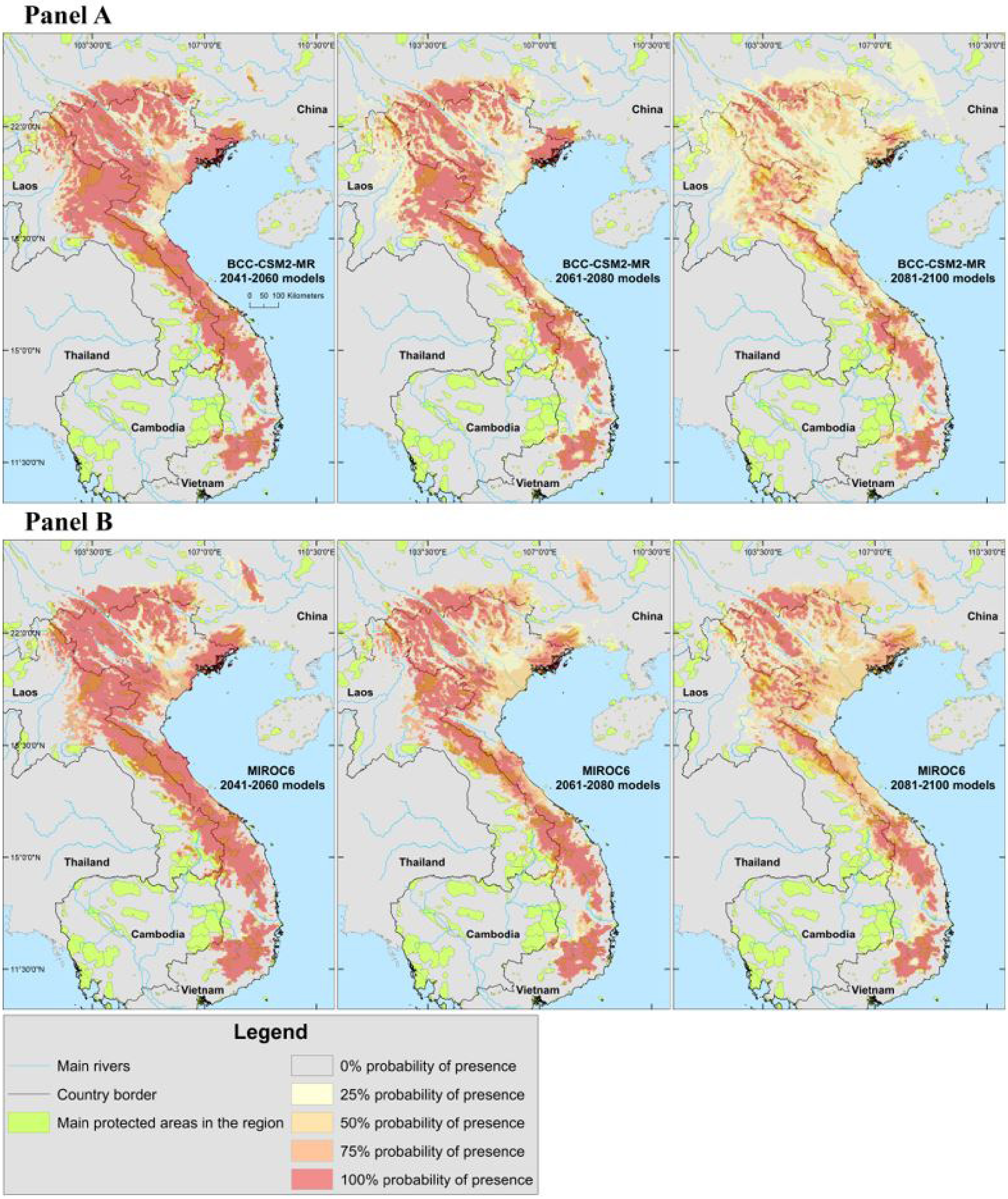

Figure 4. Future distribution of climatically suitable habitat for the Owston's Civet in different climate change scenarios. (A). BCC-CSM2-MR model in different timeframes. (B). MIROC6 model in different timeframes.

that is home to many valuable and endemic species, including the Owston's Civet (Willcox et al. 2014). However, few field surveys have been undertaken to investigate the distribution and habitat characteristics of this species in this area. According to field reports, a recent camera-trapping project recorded the Owston's Civet in Pu Luong Nature Reserve (Pu Luong Nature Reserve Management Board 2020), and other camera trap surveys have confirmed the presence of the Owston's Civet in Pu Hu Nature Reserve (Electrictity of Vietnam & World Bank 2008, Dong et al. 2018). Such detections demonstrate that the Pu Luong – Pu Hu area still maintains an important Owston's Civet population and conservation measures should be prioritized for this region.

The Owston's Civet has been consistently detected in Pu Mat National Park in Region 4 (Willcox et al. 2014, Saola Working Group 2019). Given that other conservation initiatives have been conducted in Pu Mat for other rare and/or endemic species, an Owston's Civet conservation program in Pu Mat will be highly beneficial and synergistic.

The distribution of Owston's Civet in Vu Quang National Park, in Region 5, is still uncertain, since this species was only camera trapped in the nearby Huong Son forest (Timmins and Cuong 2001). Nonetheless, Vu Quang National Park and Nakai – Nam Theun National Protected Area, where the largest number of the Owston's Civet records has been documented, form a large block of continuous forested area (Johnson and Johnston 2007, Coudrat et al. 2014). This habitat block probably contains a relatively large population and represents an important cross-border conservation area for this species.

Region 6 is also a critical transboundary conservation site. Although most records of the species in this area were collected through interviews, recent studies have indicated that Phong Nha – Ke Bang and Hin Nam No form a large continuous limestone landscape area that harbours many other endangered and endemic mammals (Dang et al. 2014, Vietnam Ministry of Culture Sport and Tourism 2014).

In Region 7, Bach Ma National Park, Quang Nam and Hue Saola Nature Reserves (Vietnam), and Xe Sap National Protected Area (Laos), are located in the Central Annamites Landscape, an area of outstanding biodiversity richness (WWF-Vietnam 2017). The presence of the Owston's Civet in these protected areas has recently been confirmed (Gray et al. 2014, Tilker et al. 2020). With substantial investments from both governmental and NGO institutions in recent years, including active patrolling and snare removal efforts, the Central Annamites Landscape will likely continue to support a healthy population of the Owston's Civet. Further south, Region 8 has also been regarded as a priority conservation area for this species (Chuong et al. 2010).

The adjacent national parks in Region 9, including Chu Yang Sin, Bidoup – Nui Ba, and Phuoc Binh, mark the southern distribution limit of the Owston's Civet (Birdlife International & Chu Yang Sin Park Management Board 2010, Department of Natural Resources and Environment of Ninh Thuan Province 2015, Southern Institute of Ecology 2017). The predicted distribution map indicates that the southern part of the Owston's Civet range is separated from the northern contiguous portion by an area of unsuitable habitat. The region is reasonably well-protected, with large continuous forested areas that may help facilitate conservation actions for this species.

It is important to note that those aforementioned regions have been provisionally identified by our modelling analyses. As a result of the widespread indiscriminate snaring activities, there may be no truly secure population in protected areas within the species range, and a steep decline in the species population has been documented even inside a reasonably protected forest (Willcox 2020, Willcox et al. 2020). Therefore, a qualitative assessment of all sites, including the local capacities to mitigate or prevent threats to the species, and the resources available to fund in-situ conservation actions are still vitally important to confirm priority sites.

The Owston's Civet also faces severe threat from habitat destruction, which ranges from illegal logging, agricultural activities, to infrastructure development, and the combined impacts of both hunting pressure and habitat destruction may be the reason for the disappearance of *C. owstoni* in previously recorded areas (Gray et al. 2014, Tilker et al. 2019). Also, as there are recent records of this species outside the protected area system, it is also important to add appropriate conservation measures to protect suitable habitats in such areas. One particular approach that has been demonstrated to be promising in Vietnam and Laos is the establishment of biological corridors that may connect suitable areas for endangered wildlife (WWF-Vietnam 2017).

The Owston's Civet has been recorded in areas close to the China – Vietnam border (in Hekou, Luchuns, and Jinping, Yunnan), before 2000, where it has been subjected to high hunting pressures (Schreiber et al. 1989). The species was detected again in 2018 from camera traps in Xishuangbanna, Yunnan (Tongkok and Alcantara 2019, Tongkok et al. 2020). More field surveys in the southern parts of China are needed to determine its presence in protected areas, and to assess the status of any populations, before including such sites in any conservation planning for the species.

The potentially negative impacts of future climate changes on carnivores have been reported in other studies. The Hose's Civet (*Diplogalehosei*), a vulnerable endemic civet of Borneo, was predicted to experience habitat losses of up to 86% by 2080 due to climate change (Mathai et al. 2019). The range of the Indian Brown Mongoose (*Herpestes fuscus*) was predicted to contract to higher elevations (Raman et al. 2020). Species that prefer montane habitat, or cooler climates, such as the Andean Mountain Cat (*Leopardus jacobita*), may face similar impacts (Bennett et al. 2019).

Our study predicts that the Owston's Civet will lose approximately 52% of its suitable habitat by the end of the century as a result of modelled climate change impacts. As this species retreats to higher elevations (600 m and above), its distribution will also become highly fragmented, with limited or no connections between different parts of its range (Fig. 3). A large block of suitable habitat in the border area between Laos and Vietnam (equivalent to regions 4-8; Fig. 1) will then be a crucial refugium for the species. With a large number of transboundary protected areas in a relatively remote region, the forested areas along the Annamite Range will play a key role in sustaining core populations of the Owston's Civet in the context of climate changes. Close transboundary cooperation between Vietnam and Laos, not only between governmental agencies but also research institutions and conservation organizations, will therefore need to be further developed to protect this endangered mammal from impending extinction.

In addition to the threat from future climate change, mammals in the Annamite Range are plagued with indiscriminate snare hunting, with species in Vietnam under more severe exploitation pressure compared to those in Laos (Gray et al. 2018, Tilker et al. 2019, Tilker et al. 2020). In this region, over the next decade, large-scale snaring is likely to have a more devastating effect on tropical mammals than that from the changes in habitat conditions (Tilker et al. 2019). Consequently, proactive protection programs, such as snare removals and anti-poaching patrols in the Annamites, will greatly benefit both short-term and long-term conservation measures for *C. owstoni*.

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Author contributions

ATN and ML designed the study. ATN and NTHC collected the data. ATN and PG ran the models. All authors wrote and revised the paper.

Supplementary Material

The following materials are available as part of the online article at https://escholarship.org/uc/fb.
Table S1. Known distribution records for the Owston's Civet

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