The importance of forests as microclimate refuges for mammals in Sumatra

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Abstract. The forests of Aceh are key habitat for several iconic, but critically endangered Sumatran mammals. Preserving these forests is vital to ensuring the continued survival of these species. In addition to the immediate threats of habitat loss and degradation, hunting and human-wildlife conflict, climate change will present further challenges to mammal conservation. A major focus of ecological research is to predict species ranges under future climate change using species distribution models, which correlate existing species distributions with environmental data. This enables us to identify and prioritise the most vulnerable habitats and species for protection, restoration or relocation and ensure the best use of limited resources. Producing these models in Sumatra is challenging due to a lack of species data and accurate environmental data. Furthermore, climatic conditions under tropical forest canopy are significantly cooler and less variable than background macroclimate conditions and can shield mammals from climatic extremes. This decoupling effect has been observed in both primary and secondary forests, although the full extent to which human activities is not known. Identifying microclimate refuges and characteristics which promote thermal buffering of forests will favour long-term mammal conservation under climate change by identifying key locations for habitat protection and restoration to protect climate sensitive species from climate extremes.

1. Introduction
The forests of Sumatra are home to several iconic and unique large mammals, which are internationally recognised and admired, but also Critically Endangered. These animals not only represent part of Indonesia’s natural and cultural heritage, but also play a major role in maintaining the function and stability of forest ecosystems. Tropical forests provide humans with vital goods and services, such as natural resources (i.e. food, timber, medicinal compounds) and climate and atmospheric regulation. Deforestation is a major source of carbon emissions and contributor to global climate change; preserving remaining primary forest and restoring degraded areas is essential to offset the effects of greenhouse gas emissions and reduce climate change [1]. Indonesia contains a large portion of the world’s remaining primary rainforests; however, it is currently undergoing one of the highest rates of deforestation globally [2]. The Leuser ecosystem in Sumatra is the largest remaining expanse of primary forest in South East Asia and the most important habitat for sustaining populations of large mammals in Sumatra. Preserving this ecosystem is of paramount importance to the continued survival of many iconic and unique Indonesian mammals. This article will provide a brief overview of
mammals in Sumatra and identify knowledge gaps which must be filled to ensure that conservation measures remain relevant in the long term.

Mammals comprise a sizable portion of the biomass in Sumatra’s forests and are hugely important in shaping physical habitat structure, community dynamics and ecosystem processes. Large herbivores, such as elephants, rhinoceroses and primates, which range over great distances and consume a diverse array of plant species are vitally important as seed dispersers [3]. Browsers play a key role in managing plant community dynamics through grazing and trampling of vegetation. Grazing by large mammals also prevents dominance by more competitive generalist plants, allowing rarer species to survive, as demonstrated by experimental removal of large grazers from tropical forest in Mexico [4]. Carnivores are important in managing herbivore populations to prevent overgrazing. The full long-term effects of removing large mammals from ecosystems are not well known, however there is compelling evidence that their presence is key to ecosystem functioning.

In addition to their many ecological roles, Sumatran mammals are excellent flagship species for forest conservation. Elephants, tigers, orangutans and rhinoceroses are iconic species which are widely admired by the general public. Conservation projects focussing on these animals are generally favoured over projects which focus on less charismatic or lesser-known species [5]. The presence of so many charismatic mammals makes Sumatra an attractive destination for travellers, and presents valuable opportunities for eco-tourism projects, which provide income and sustainable livelihoods for local communities along with forest and wildlife protection [6]. Furthermore, preserving viable populations of mammals requires protection of large areas of good quality forest habitat, and this will in turn benefit other forest dwelling species [7]. By focussing on mammals, conservationists can generate more funding revenue and increase public and political support for forest conservation.

2. Sumatran mammals: status, threats and current conservation
There are over 200 mammal species found on Sumatra and roughly one third are threatened with extinction (i.e. Vulnerable, Endangered or Critically Endangered) according to the IUCN red list, while over half have a declining population trend [8]. There are six Critically Endangered species which are endemic to Sumatra: Sumatran orangutan, Pongo abelii; Tapanuli orangutan, Pongo tapanuliensis; Sumatran rhinoceros, Dicerorhinus sumatrensis; Pig-tailed langur, Simias concolor; Sumatran elephant, Elephas maximus ssp. Sumatranus and Sumatran tiger, Panthera tigris ssp. sumatrae.

Habitat loss and fragmentation is the most immediate threat to Sumatran mammals. Indonesia has one of the highest rates of forest loss globally, with tree cover loss in Sumatra alone totalling 104,700km² between 2001-2017, equivalent to a 29.2% reduction since 2000 and CO₂ emissions of around 1.04 billion tonnes [9]. There is now significant overlap between human-dominated landscapes and mammal ranges, inevitably resulting in human-wildlife interactions, which often have negative consequences for the people and animals involved. Crop foraging by wild mammals has major economic and psychosocial consequences in poor farming communities, and frequently results in retaliatory killing of animals [10]. Strategies to prevent crop foraging (e.g. electric fencing, poison, domestic dogs and armed patrols) can be harmful to wildlife, as well as dangerous or costly to farmers [11]. Hunting is also a significant threat, although empirical data on this is limited. Tackling human-wildlife conflict relies on quantitative evidence of the actual threats posed by wildlife to local communities, coupled with community-based projects to mitigate the impact of human-wildlife conflict on local communities and promote a wider understanding and engagement of local people with large mammals and their role in forest ecosystems [12]. Further research is required to assess the full impact of human-wildlife interactions and illegal hunting on mammals and people across Sumatra in order to determine the most at-risk areas and develop appropriate strategies to mitigate the consequences.

The Leuser ecosystem comprises a substantial portion of the range for many Sumatran mammals. Much of this forest is afforded full legal protection as a National Park, however, many mammals still occur outside of the protected area, although the full extent of their range is not known [13].
Additionally, illegal activities, including logging, land clearance for agriculture and hunting are a common occurrence, particularly near the National Park boundaries and close to human settlements. Mammals are especially vulnerable to human disturbance and rapid environmental change due to their relatively large body size, generally low fecundity, low population density and great ranging distances [14]. In Sumatra, mammals are predominantly found in isolated populations with limited connectivity between patches, where they are experiencing heightened ecological and evolutionary pressure from lower resource availability, increased competition, human disturbance and inbreeding [15]. Sumatran mammals are already vulnerable to extinction from habitat loss, fragmentation and hunting or human-wildlife conflict and their survival depends on effective management of remaining forests, particularly the Leuser ecosystem.

Conservation measures generally focus on mitigating immediate threats, with an emphasis on protection of remaining primary habitat [16]. Additionally, it is often necessary to relocate animals which have become stranded in degraded or unsuitable areas. The rescue and rehabilitation of these individuals is hugely costly, and results in potentially fatal levels of stress to the animal [17]. This is not, therefore, an ideal long-term strategy, nor does it address the underlying cause of such incidents. Regeneration of degraded or cleared forest is being increasingly utilised in Sumatra, particularly in areas of land which have been cleared illegally [18]. Sumatra is now dominated by anthropogenic and secondary forest landscapes, however these landscapes are still valuable for biodiversity, provided they are well managed [19]. While monoculture plantations support relatively low numbers of species compared with primary forest, selectively logged forest and agroforests still maintain relatively high levels of biodiversity [20]. Increasing and maintaining connectivity in fragmented forests will enable wide ranging mammals to move between patches, thereby facilitating dispersal and gene flow, while restoring secondary forests provides further habitat for mammals and will reduce their dependency on human-dominated landscapes, thereby lowering their impact on forest farming communities.

3. Climate change
Climate change will become increasingly important over the coming century, and species must either adapt in situ, move to remain in favourable conditions or become extinct. There are many uncertainties in climate change predictions, however, most climate models agree that tropical regions will be disproportionately affected by climate change. More extreme changes in average annual temperature and precipitation are predicted in the tropics compared with temperate regions, with much of the tropics predicted to experience a temperature increase as much as 50% higher than the global average [21]. The likelihood and severity of extreme weather events, including tropical cyclones, flooding and drought is predicted to increase. The rate and extent of anthropogenic climate change will almost certainly fall outside of the historic or natural range of variability, meaning that mass extinctions are probable [22]. Climate affects species by determining their range, abundance at a given location, phenology and influencing microhabitat use and energy budgets. Mammals in the tropics are adapted to a relatively stable climate and likely have a much narrower fundamental niche than temperate species, making them especially vulnerable to climate change [23].

To date, most published studies on the effects of climate change on mammals have focussed on correlations between existing species distributions and relatively coarse-scale climate data to predict potential species ranges under climate change [24]. A major limitation of this approach is that it largely ignores other factors affecting distribution, such as dispersal ability and anthropogenic barriers preventing species from colonising newly suitable habitat [25]. Temperature and rainfall averages are typically obtained from open access, global datasets, such as BIOCLIM, which have the benefit of allowing rapid modelling of species-climate interactions over large geographic regions, but also have several limitations. Firstly, these datasets are interpolated from weather station data, where climatic conditions are recorded from above the earth’s surface and away from local climate influences, such as topography or vegetation, conditions which do not reflect those experienced by animals living under forest canopies [26]. Secondly, they have a relatively coarse spatial scale, and thirdly, there is limited weather station coverage in forested areas and remote, tropical regions. Few mammal studies
incorporate microclimate, broadly defined as fine-scale climate variations which differ from background averages [27]. Current models often use climate data at a coarser scale than environmental and biological data, resulting in inaccurate predictions of range shifts and extinction risks [24]. In heterogeneous forests, there are multiple microhabitats within a large grid square, with significant fine-scale climate variations, which are not captured by weather station data. The resolution of climate data has been shown to affect predictions of species distribution and extinction risk [28]. Understanding how climate shapes mammal biogeography requires the use of climate data at an ecologically relevant scale.

Forest microclimates buffer mammals against climate change. Using microclimate data in species distribution models has highlighted potential refugia for small mammals in areas which were deemed unsuitable by bioclimatic envelope models relying on weather station data alone [29]. Behavioural thermoregulation is often overlooked in attempts to model survival of endotherms under climatic extremes [30]. For example, koalas adjust their behaviour in hot weather by resting against cool tree trunks to increase conductive heat loss, thereby reducing the cost of metabolic thermoregulation, and increasing their chances of survival during periods of extreme heat [31]. Activity budgets are an important determinant of species survival, and increased demands of both behavioural and metabolic thermoregulation will impact fitness [32]. More data is required on the extent to which forest microclimates are decoupled from background macroclimate and how behavioural thermoregulation might allow mammals to adapt to climate change.

4. Conclusions & future recommendations for mammal research
This study revealed that teachers have positive view on online learning professional development through PPG SPADA Brightspace. However, lack of internet access has hindered their acceptance to the platform. Therefore, it is very important to provide a reliable internet access at schools in order to successfully implement teacher online professional development in Indonesia, particularly in Aceh province.

One of the major challenges to mammal conservation is the lack of empirical data. Tropical forests are a challenging environment to survey due to their relative inaccessibility, plus forest mammals tend to range over large distances and exist at low density, therefore meaningful, accurate population data requires substantial survey effort. In Sumatra, the only mammal species for which there are robust, up-to-date, country-wide estimates of population size and distribution is the Sumatran orangutan, for all other mammal populations, abundance and distribution estimates are either based on old survey data, unvalidated expert assessments or are simply unavailable. A priority of research should therefore be to determine the full distribution and range extent of mammals in Sumatra using robust and reliable survey methodology. Advances in remote sensing technologies can be utilised to achieve this, and mammal populations can be monitored using remote cameras and audio recorders. This requires less resource and survey effort than extensive field surveys, such as line transects and point counts, and would also provide data on multiple species, including extremely vigilant species. These data can then form the basis for species actions plans, which highlight areas of importance for endangered mammals, and areas where there is a high risk of human-wildlife conflict. This knowledge will inform spatial planning of conservation by highlighting key locations for protection, restoration, establishment of wildlife corridors, buffer zones and successful relocation or reintroduction of rehabilitated or captive bred animals.

Long term conservation requires an integrated approach which incorporates conservation of remaining habitat, restoration of degraded areas, establishment and maintenance of connectivity between patches, maintenance of genetic diversity and assisted colonization of unoccupied but suitable habitat. Conservation research should first focus on determining the full distribution and range extent of endangered mammals, to identify priority areas for protection. Additionally, it is vital to understand the full range of economic and social issues which face communities living in or near mammal habitat. This information is necessary to identify the drivers of deforestation, human-wildlife conflict and illegal wildlife trade. In order to prevent further wildlife declines, and allow populations of
Endangered mammals to recover, we must first identify the underlying causes of population declines and develop strategies which directly address them.

5. References

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