The conservation status of Owston's Civet *Chrotogale owstoni*

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Chapter 1: Introduction

The majority of small carnivores (here defined as mammals in the families Ailuridae, Eupleridae, Herpestidae, Mephitidae, Mustelidae, Nandiniidae, Prionodontidae, Procyonidae, and Viverridae) are not priorities for species conservation: 125 out of 172 are categorised as Least Concern or Near Threatened on the IUCN Red List of Threatened Species (IUCN 2021). However, the group contains several clear priorities for species conservation, including three Critically Endangered species. Madagascar contains the highest concentration of threatened carnivore species anywhere in the world. The country's deteriorating protected area network make it a priority for small carnivore conservation. The other geographic priority is South-east Asia where small carnivores are under significant pressure from hunting to supply the illegal wildlife trade, as well as habitat loss, and the interactions between these two factors.

Although Owston's Civet *Chrotogale owstoni* was recognised as a conservation priority as early as the late 1980s (Schreiber et al., 1989), the intervening 30 years have seen a significant decline in its status within its global range in Vietnam, Lao PDR and southern China (Timmins et al., 2016a). A significant cause of its decline is hunting for the illegal wildlife trade, particularly indiscriminate snaring (Roberton 2007; Timmins et al., 2016a). Annually, hundreds of thousands of snares are set illegally in protected areas in its two main range countries: Lao PDR and Vietnam (Gray et al., 2018). Owston's Civet is rarely the target of these hunting efforts and these snares have the capacity to capture anything over 500 grammes in weight; the consequences of this are a nearly wholesale defaunation of the region's ground-dwelling wildlife (e.g., Tilker et al., 2019), including carnivore species (e.g., Willcox et al., 2014). The primary driver of snaring in the region is not the subsistence use of wildlife or wild meat, but the commercial trade in wildlife (Drury 2011; WWF 2020), much of it enabled by a regulatory system that is unable to reduce risks to species conservation (e.g., Vietnam: WCS 2008). Recently, the commercial use of wildlife species in South-east Asia has gained increased notoriety because of its links to zoonotic disease, including coronaviruses (Huong et al., 2020).

As a consequence of a growing civil society in Vietnam and to a lesser extent in Lao PDR, and the increased use of camera-trapping in many sites that are within the range of Owston's Civet, there is now more information and data available on the status of this species. This has caused significant increases in knowledge on its current global range (e.g., Dang Ngoc Can & Le Trong Trai 2010), as well as on the threats it faces at these sites and possible solutions. This thesis is an attempt to consolidate this information and to try and answer three important questions:

1) What are the emerging threats to small carnivores globally, and where does Owston's Civet conservation sit within this? (**Chapter 2**)
2) What is the current state of knowledge on Owston's Civet, including its conservation status at global and national levels? (**Chapter 3**)
3) Can MaxEnt modelling help identify the *in-situ* conservation priorities for Owston's Civet? (**Chapter 4**)

Chapter 2: Conservation status, *ex-situ* priorities and emerging threats to small carnivores

2.1 Introduction

Small carnivores (here defined as mammals in the families Ailuridae, Eupleridae, Herpestidae, Mephitidae, Mustelidae, Nandiniidae, Prionodontidae, Procyonidae, and Viverridae) are a diverse and large group of mammals. 172 small carnivore species are currently recognised, all of which have been assessed on The IUCN Red List of Threatened Species (González-Maya, 2018). The most recent assessments of 2014 – 2016 categorised 39 species as globally threatened (IUCN 2021).

The majority of small carnivores are not priorities for species conservation: 125 are categorised as Least Concern or Near Threatened. The group contains species well-known for their ability to persist in human modified habitats, including urban centres (e.g., Northern Racoon *Procyon lotor*: Greenspan et al., 2018) and rural, peri-urban and urban landscapes (e.g., Eurasian Badger *Meles meles*: Sainsbury et al., 2019) as long as hunting and persecution are controlled. The return of Eurasian Otter *Lutra lutra* to Europe's waterways (e.g., Weinberger et al., 2016, Sainsbury et al., 2019), and the repopulation of Singapore's urbanised canals by Smooth-coated Otters *Lutrogale perspicillata* (Theng & Sivasothi 2016), is proof that some small carnivores are able to return and breed in human-dominated landscapes, if threats can be reduced.

However, the group does contain species that are priorities for conservation: many are distributed in regions or countries where mitigating or reducing threats to small carnivores will be a significant challenge. Although many of the more threatened small carnivore species are distributed within protected areas, in many cases these are in countries where governance is poor, corruption is rife and the protected areas are little more than 'paper parks' (e.g., Pedrono et al., 2009). In these circumstances, globally threatened small

carnivores will probably require some form of *ex-situ* conservation or management, but the needs and feasibilities of such actions need to be carefully assessed.

This chapter provides a rapid overview of the conservation status of Critically Endangered and Endangered small carnivores, as well as those categorised as Vulnerable (*sensu* IUCN 2021) but for which there are signs that there has been decline in status since the last Red List assessments. *Ex-situ* priorities are briefly discussed, principally based on which species are either already in captivity, or where, based on the level and type of threats, there is a strong rationale for immediately implementing an *ex-situ* recovery programme. Emerging threats to small carnivores are discussed in brief, but these are extremely speculative opinion-based statements based on current patterns in wildlife trade/demand, development, and geopolitics; more in-depth discussion on these topics is outside the remit of this article.

2.2 Madagascar

Madagascar is well-known for its large number of endemic plants and animals and it is a high priority for biodiversity conservation (e.g., Brooks et al., 2006). The threats facing the island's biodiversity are diverse, and include the unsustainable collection and export of reptiles for the pet trade (Robinson et al., 2015), illegal extraction of high-value hardwoods from protected areas for export (Ratsimbazafy et al., 2016), unsustainable fuel wood extraction, and slash-and-burn agriculture (Styger et al., 2007). Consumption of threatened wildlife, both as a luxury and for subsistence, is also a major threat, particularly for mammals and birds (Jenkins et al., 2011; Reuter et al., 2016). The documented decline in the rule of the law since 2009 has enabled and exacerbated many of these threats. Extractive industries, such as gem mining, occur inside Madagascan protected areas (Tullis, 2019): these are direct threats and provide increased opportunities for illegal hunting.

The country contains the highest concentration of globally threatened carnivores in the world and is a clear priority for mammal conservation, let alone for small carnivores. One species is already extinct (Giant fossa *Cryptoprocta spelea*), and of the remaining nine recognised species, only one is listed as non-threatened (Ring-tailed vontsira *Galidia elegans*). The last decade has seen an increase in the extinction risk these species face; three have shifted from Near Threatened to Vulnerable between 2008 and 2015. Of three Endangered small carnivores, two have extremely small ranges and are considered lowland species (Grandidier's Vos *Galidictis grandidieri* and Bokiboky *Mungotictis decemlineata*), and all three are threatened by habitat loss, hunting, and feral non-native carnivores, particularly dogs (Hawkins 2015a, b; 2016). Whilst the recently split Western Falanouc *Eupleres major* is difficult to assess fully, its relatively small distribution in northern Madagascar, and the high human population densities and associated threats within its suspected range, make it a priority species (as long as its species status is maintained). When hunting of carnivores has been researched in Madagascar, people have been found to be targeting carnivore-rich areas of forest within protected areas (Farris et al., 2015), but such research has so far mostly focused on the island's primates and reptiles.

The threats to Madagascar's small carnivores are complex, with drivers operating at national scales. The rapid decline in governance standards since the coup d'etat in 2009 significantly impacted the ability of the protected area network to conserve threatened wildlife (Jones et al., 2019), including small carnivores. 70% of the human population was assessed as below the poverty line in 2012 (World Bank, 2019); many of the threats are caused by demand for agricultural land, wild meat (for consumption and for trade), firewood collection and charcoal production. Addressing these threats in the context of weak and corrupt government institutes and high levels of human poverty is extremely challenging.

2.3 South-east Asia

South-east Asia has a high proportion of threatened vertebrates (Schipper et al., 2008). Several of its countries contain high numbers of Critically Endangered land vertebrates whose threats and extinction risks make this region a priority for species conservation (Duckworth et al., 2012).

The threats to small carnivores vary in intensity across the region, but the main one is hunting for the illegal wildlife trade. Although, there is very little primary data on offtake patterns and on the relative impacts of trade versus subsistence use of small carnivores in South-east Asia, nearly all species have a commercial value, particularly in the region's main demand country, Vietnam (Bell et al., 2004, Roberton 2007), and shifts from subsistence use to commercial trade have been documented in another taxon that faces similar threats, Pangolins (Manidae) (MacMillan and Nguyen 2013). South-east Asia's "snaring crisis" (Gray et al., 2018) is impacting wildlife across the region, particularly in Indochina (Lao PDR, Cambodia, and Vietnam) (Harrison et al., 2016). There is no evidence that there is any species-level targeting of small carnivores, rather that small carnivores form a part of the general offtake from indiscriminate snaring which are then, depending on their condition, sold on to wild meat restaurants or traders, traditional medicine outlets, or for the exotic pet markets. Indiscriminate snaring inside and outside protected areas to supply demand for this trade impacts nearly all ground-dwelling wildlife, including small carnivores (Harrison et al., 2016: Appendix S1). South-east Asia contains several countries which are centres of demand for wild meat as a luxury, exotic pets and for body parts to be used in Asian medicine (Sodhi et al., 2004; Nijman, 2010). Habitat loss is a threat to the lowland species, such as Large-spotted Civet *Viverra megaspila* (Timmins et al., 2016b) and the wetland-associated Otter Civet *Cynogale bennettii* (Ross et al., 2016), both as a direct threat and because it increases opportunities for hunting as well as potentially fatal interactions with domestic dogs.

A small carnivore species impacted by indiscriminate snaring (and the demand for wild meat that drives it) is Owston's Civet *Chrotogale owstoni*. This Indochinese endemic is found only in a relatively small part of southern China, Lao PDR and Vietnam. Within these countries it is thought to be restricted to evergreen forests with a benign dry season

(Timmins et al., 2016a). It is the only member of its genus, the threats are known and severe, and there are currently no functional protected areas within its range. In this context, it can be considered one of the most threatened of all the world's small carnivores. The required priority actions for conserving Owston's Civet were identified and agreed in Vietnam in 2019, and were published as a 10-year conservation strategy (see Willcox et al., 2019a).

The Endangered Large-spotted Civet is a lowland species, with the majority of records coming from below 300 m. Although thought primarily to be associated with deciduous forest (e.g., Jennings & Veron, 2011), this may in fact be an artefact of camera-trap placement/survey distribution (Timmins et al., 2016b and discussion therein). As a lowland ground-dwelling carnivore, it is very vulnerable to hunting (particularly ground-based traps and domestic dogs) and habitat destruction, and their interaction (Timmins et al., 2016b). Historically it probably occupied most of lowland Thailand, Vietnam, Lao PDR, Cambodia, Myanmar, peninsular Malaysia, and suitable habitat in southern China. Although recently recorded in southern China (Guo et al., 2017), its population there is assumed to be very poor: it is probably approaching national extinction there as well as in Vietnam and Lao PDR. Only Cambodia and Myanmar are thought to retain healthy populations, although what we know of Myanmar is speculative and based on available habitat rather than real evidence. Cambodia retains the largest known population but its status there is at risk from increased hunting pressures, domestic dogs and development pressures in the form of infrastructure or commercial plantations. This is true of many other lowland or open-habitat ground-dwelling vertebrates in Cambodia, such as Bengal Florican *Houbaropsis bengalensis* and Eld's Deer *Rucervus eldii*, both of which face catastrophic declines (S. Brook pers. comm. 2019). The future for this species is extremely precarious in Cambodia and its status is unconfirmed in Myanmar but likely to be poor. In its next Red List assessment, it may be categorised as Critically Endangered.

Hairy-nosed Otter *Lutra sumatrana* is the only Endangered otter in the region. It was erroneously stated as extinct in a number of range countries in the 1990s (Wright et al., 2008), only to be re-discovered later. This may in part be due to the wetland, flooded-

forest habitats it allegedly prefers (Sasaki et al., 2009), which have been less frequently surveyed relative to interior blocks of forest. There is a specimen from hill evergreen forest in Myanmar (Duckworth & Hills, 2008), as well as verified sightings from riparian evergreen forest in Taman Negar, Peninsular Malaysia (Baker 2013). Given the high potential for misidentification with the closely related Eurasian Otter (see Koepfli et al., 2008), as well as the two other Asian otters with which its distribution overlaps, it is conceivable that the Hairy-nosed Otter occurs in a greater number of protected areas than currently known. Confirmation of its presence within evergreen forest sites such as Taman Negar would improve the conservation outlook for this species, because blocks of evergreen forest are generally less threatened by habitat loss/conversion, a significant threat to the wetland peat-swamp forests it is assumed to favour. As with all otters in the region, human-otter conflict (because of perceived or actual damage to aquaculture) and hunting (to supply the illegal wildlife trade) are known threats.

Lowe's Otter Civet *Cynogale lowei* is not a valid taxon; the holotype and only specimen is actually a Eurasian Otter (Roberton et al., 2017). Thus, the only otter civet is the Endangered [Sunda] Otter civet *Cynogale bennettii*. Although large areas of suitable habitat for this species have been predicted using distribution modelling (Cheyne et al., 2016), there are very few records from within range countries. It is possibly nearing national extinction in Thailand (Chutipong et al., 2014). It is semi-aquatic, and its main threats are the ongoing loss of forested wetlands, particularly the conversion of peat-swamp forest to palm oil plantations, and damage to riparian ecosystems through pollution (Ross et al., 2015). As a ground-dwelling species, it is vulnerable to snares and other forms of ground-based hunting, although the exact impacts and off-takes are unknown and it is not thought to be targeted specifically. The 2015 assessment as Endangered was explicitly precautionary and based on some assumptions, i.e., that it is a lowland species, intolerant of habitat conversion and damage to waterways, and threatened by ground-based trapping. Should some of these assumptions not hold, it is more likely to qualify as Vulnerable rather than Endangered.

2.4 South and East Asia

South Asia (here defined as India, Bhutan, Bangladesh, Pakistan, Sri Lanka and Nepal) and East Asia (China, Japan, North Korea, South Korea) contain relatively few globally threatened species of small carnivore. Whilst there are several endemics in the region in the Western Ghats in India and on Sri Lanka, none are conservation priorities apart from Malabar Civet *Viverra civettina* and Red Panda *Ailurus fulgens*.

Malabar Civet is Critically Endangered and restricted to the Western Ghats in southern India. Its assessment in 2015 was done under the precautionary principle and the assumption that the taxon is valid. However, there is evidence that the specimens described as Malabar Civet are actually Large-spotted Civets traded into India from South-east Asia (Nandini & Mudappa, 2010). The threats to this species are speculative, based on an assumed ecological similarity to the Endangered Large-spotted Civet; i.e., habitat loss in the lowlands with a consequent increased exposure to human-wildlife conflict, domestic dogs and hunting (Mudappa et al., 2016). With no confirmed records, other than unverified sightings, it is difficult to judge what the priority actions should be. If its species status is confirmed, then the number and type of surveys (particularly camera-trapping) within suitable habitats in its range indicate strongly that it must be perilously close to extinction. Clarification of its taxonomic status, and attention to possible viverrid records from the Western Ghats are needed. It can be confused with the sympatric Small Indian Civet *Viverricula indica*, as it is with Large Indian Civet *Viverra zibetha* and Large-spotted Civet in other parts of its range.

Red Panda is one of the best-known small carnivores in Asia, possibly the world, and its conservation is funded by a large number of civil society organistions. Its crepuscular behaviour and photogenic qualities make it an ideal species for public engagement and outreach, either in captivity or through eco-tourism. The latter is developing as an important method for strengthening community protection of Red Pandas at sites in Nepal, and features strongly in Nepal's action plan (DOF & DNPWC, 2019). The species

is a model for what can be achieved by collaboration among the zoo community, range state governments and local civil society organisations. Zoos have funded and helped to facilitate Population Viability and Habitat Analyses for this species in all range states (Nepal, India, Bhutan, Myanmar, China) (Glatston et al., 2016). It is unlikely this is replicable for other globally threatened small carnivores because they do not possess the similar ecologies that enable eco-tourism, or are distributed in countries where the general level of support for wildlife conservation from governments, civil society organisations and the wider public is much weaker.

Although Red Panda conservation has benefited from a successful marrying of *in-situ* and *ex-situ* activities, it is still very threatened in the wild. Major threats are habitat loss and degradation, wildlife disease and potentially the illegal trade in pelts and pets (Glatston et al., 2016). Bamboo is the main dietary staple of Red Panda; loss of bamboo through livestock overgrazing, habitat loss, and collection by local communities are all threats. Changes in global and regional weather patterns, coupled with ongoing habitat loss/fragmentation, would cause an increased loss of bamboo from the region; Himalayan bamboos are sensitive to fire, deforestation and environmental degradation (Stapleton, 1996), all of which can be exacerbated by climate change. Although several trade reports were included in the 2015 assessment, the majority are anecdotal and low volume. A trade assessment in China found relatively few records (Xu & Guan, 2018), and there was a confiscation of six animals in Lao in 2018 (SCMP 2018). Whilst there is limited evidence that the trade is increasing, this potential threat should be monitored; the same characteristics that have made the species a success in linking *ex-situ* and *in-situ* conservation, could make it a target for the exotic pet trade, which is growing in the region.

Although there are relatively few small carnivore species of high conservation priority within these two regions, both India and Nepal support large populations of several species that are in overall global decline. Nepal, India, Bhutan, and Bangladesh hold globally significant populations of Smooth-coated Otter, Asian Small-clawed Otter and possibly multiple taxonomic units of Eurasian Otter, potentially to the species level. All Asian otters are threatened by the illegal wildlife trade, particularly for pelts, most of which

are sourced from the Indian subcontinent (Gomez et al., 2016). Wetlands, riverine ecosystems and protected areas in the Indian subcontinent continue to suffer from policies and development projects that do not support wildlife conservation (e.g., Mahurkar, 2017; Mazoomdaar, 2018); should these threats continue, then Asia's otter populations will decline.

2.5 Europe and Russia

Europe and Russia support populations of one global priority in mammal conservation, namely the Critically Endangered European Mink *Mustela lutreola*, which has undergone one of the largest range contractions of any mammal species in the Palearctic. Formerly widespread over much of Europe, its historical range was from Finland east to the Ural Mountains, south to northern Spain and the Caucasus Mountains (Maran et al., 2016 and references therein). Its current range is limited to small, isolated populations in western France, northern Spain, a reintroduced population in Estonia (Hiiuma Island), Ukraine, Russia, and the Danube Delta in Romania. Although there are few reliable data from Ukraine and Russia, it is thought that only the population in the Danube Delta can be considered viable. European Mink has been declared regionally extinct in 19 countries of its former range.

The causes of its decline and threats to extant populations are complex and interacting. Broadly the threats can be attributed to habitat loss, over-exploitation and the impact of the alien invasive American Mink *Neovision vision*. European Mink is sensitive to human-induced environmental change and disturbance, and loss of wetlands and other flooded lowland habitats is an ongoing threat to populations in Europe, particularly in the isolated populations in France and Spain. The deliberate introduction of American Mink and escapes from fur farms have had a catastrophic impact, and continue to be a major threat (e.g., Põdra & Gómez, 2018). American Mink farms exist in Romania (Ionescu et al., 2018), the only country thought to have a viable population of European Mink. Monitoring these farms, ensuring there is adequate regulation as well as legislation for preventing the expansion of the mink farm industry, and strict bio-security protocols for any

escapees, will be essential conservation actions for European Mink, as well as continuing to support and expand current reintroduction/recovery efforts.

2.6 Africa

Africa (excluding Madagascar) does not contain any Endangered or Critically Endangered small carnivores. Of the five species categorised as Vulnerable, four are distributed in West Africa and are threatened by habitat loss and the bushmeat trade, although large tracts of suitable habitat remain for all four (but see Laurence, 2018). The fifth, Sokoke Dog Mongoose *Bdeogale omnivora*, is distributed in Kenya and Tanzania, where the loss of its coastal forest habitat is considered the main threat. Ongoing monitoring of habitat loss for these five species will be needed, particularly in countries where governance is poor or deteriorating, as well as continuing efforts to reduce the known and significant impacts of the bushmeat trade (Doughty et al., 2015). Crested Genet *Genetta cristata* is still considered locally common within suitable habitat, though it is not known from any protected area within its range (Gaubert et al., 2015). The other four Vulnerable species are known from protected areas within their ranges.

2.7 North, Central and South America

North, Central and South America contain one Critically Endangered species, Pygmy Raccoon *Procyon pygmaeus* (see Helgen & Wilson, 2003), found only on the 488 km^2 Cozumel Island off the coast of Mexico. Hurricanes are the main threat to all the island's fauna, and these are increasing in frequency and intensity because of human-induced climate change (Moore et al., 2017). Ongoing habitat fragmentation, loss due to development (mainly for tourism) and domestic dogs (disease and predation), are also causing population declines, reducing the ability of Pygmy Racoon to recover after hurricane events (Cuarón et al., 2016).

Black-footed ferret *Mustela nigripes* has benefited from a significant government-sponsored recovery programme in the U.S. that includes establishing and protecting release sites, conservation breeding, genetic management, and artificial insemination (Santymire et al., 2014 and references therein). 8,000 Black-footed ferrets have been bred as part of this recovery programme, 4,100 of which were reintroduced at various sites in North America (Santymire et al., 2014). However, despite this enormous effort, the most recent estimates of the wild population are in the low hundreds (Belant et al., 2015). The main threats include disease (which impacts both the species and its main prey, Prairie-dog *Cynomys*), over-hunting of its main prey and habitat loss. The impacts of disease and the low/declining prey base have been particularly difficult to counter (Miller & Reading, 2012). Black-footed Ferret conservation will be dependent on ongoing management of its captive population and associated recovery efforts, particularly efforts to maximise genetic diversity and protect its prey.

Mountain Coati has been split into Eastern *Nasuella meridensis* (endemic to Venezuela) and Western Mountain Coati *N. olivacea* (in Columbia and Ecuador: Helgen et al., 2009). Only the former is considered globally threatened, categorised as Endangered (Gonzalez-Maya & Arias-Alzate, 2016), although this was based on a small known range of less than 800 km^2. Predictive modelling of potential habitat suggested that the range could be far larger, too large for it to be categorised as Endangered under the relevant criterion. Threats within its range are largely unknown, but habitat loss, fragmentation and conversion have been listed, as well as hunting (Gonzalez-Maya & Arias-Alzate, 2016). This would be anomalous compared to the other three described coati species, all of which appear to be relatively tolerant of habitat loss and fragmentation, and which are listed as non-threatened (IUCN 2021). It is probable that additional locality data and a better assessment of threats would result in this species being listed in a lower threat category, potentially as non-threatened.

The other remaining Endangered species are all otters (Lutrinae): Marine Otter *Lontra felina*, Southern River Otter *Lontra provocax* and Giant Otter *Pteronura brasiliensis*. Marine and Southern River Otters have relatively small extant ranges compared to other

otter species, both threatened by ongoing habitat loss and fragmentation, as well as human-otter conflict because of perceived or actual damage to local and industrial fisheries and other forms of aquaculture. Human-otter conflict is considered to be a greater threat to Marine Otter, with a large list of potential sources of conflict from the fish, bivalve, and shrimp fisheries (Valqui & Rheingantz, 2015). Poor enforcement of species protection laws and weak application of existing regulations on fishing zones, development, and habitat conversion are contributing to ongoing declines in both species. Giant Otters inhabit lowland wetlands in the Amazon basin, and are in decline due to a range of threats within their range: human-otter conflict, habitat loss/conversion (including from the development of hydropower dams) and pollution (particularly from artisanal and industrial gold mining) are all cited in Groenendijk et al. (2015).

2.8 Taxonomic uncertainties

Resolving the taxonomy of otters so that conservation units can be better identified has been identified as a research priority for a global conservation strategy (Duplaix & Savage, 2018). Eurasian Otter *Lutra lutra* has one of the largest distributions of any carnivore species. The taxonomic status of some of its populations are unknown, but there are seven described subspecies (Pocock 1941). Although Eurasian Otter is globally categorised as Least Concern, its populations in Asia are severely threatened (Roos et al., 2015). Asian Small-clawed Otter has two described subspecies (Pocock 1941); the taxonomic status of its populations on the islands of Java and Palawan are uncertain, but have been proposed as subspecies in the past (Pocock 1941: 315 – 317). Smooth-coated Otter *Lutrogale perspicillata* has three subspecies, one of which (*L. p. maxwelli*) occurs in the marshlands of Iraq and is very threatened (Moretti et al., 2017 and references therein). If subspecies of otters described from parts of Asia, the Middle East and South-east Asia are valid, and if further research confirms them as separate species, then these would become immediate priorities for mammal conservation.

The taxonomy of Owston's Civet has been researched using a single mitochondrial DNA marker, sampled from animals from either northern Vietnam or of unknown provenance (Veron et al., 2004a). There have since been a number of confirmed records from southern Vietnam (e.g., Dang Ngoc Can & Le Trong Trai 2010), that have significantly extended the known limits of its distribution. Based on the taxonomy of mammals and birds with similar distributions and ecologies, the southern population probably represents a different taxonomic unit (Willcox et al., 2019a). Any split would have significant implications for *in-situ* conservation of this species, and for management of the conservation breeding programme.

There are two proposed subspecies of Binturong *Arctictis binturong* that need investigation: *A. b. kerkhoveni* of Bangka (Indonesia), and *A. b. whitei* of the Palawan island group (Philippines). Both have very small distribution ranges, and if either of these proposed subspecies are valid conservation units, then they will be priorities for small carnivore conservation.

The Small-toothed Palm Civet *Arctogalidia trivirgata* is not considered threatened, as its arboreal life style insulates it from most types of hunting, and it has been recorded in a variety of forest types (e.g., Willcox et al., 2012). However, the morphologically distinct Javan subspecies (see Eaton et al., 2010) is now being targeted by wildlife traders (R. Wirth pers. comm. 2019). Its small distribution and the numbers of live animals traded through Indonesia's wildlife markets (Shepherd 2012) will make it very vulnerable. Its taxonomic status needs to be urgently clarified.

Any taxonomic investigation into these or any other small carnivores should use modern integrative taxonomy, i.e., with molecular as well as ecological, distributional and morphological data (e.g., Wilting et al., 2015). Most approaches have so far tended to use only mitochondrial DNA (e.g., Veron et al., 2004a); this may fail to provide the resolution needed, particularly for rare species where there are likely to be few samples dependent on captive animals of unconfirmed provenance. Some groups of these small carnivores have conservative morphologies, such as the otters, which limits the application of

morphology-based taxonomy. An integrative approach will help avoid the mistakes of the past, which sometimes resulted in conservation resources being spent on invalid conservation units (e.g., Wilting et al. 2015).

2.9 Emerging threats

Vietnam and China are two of the global centres of demand for wildlife, sourcing and trafficking wildlife from across Asia and increasingly across the world in Africa (EIA 2018) and South America (Reuter et al., 2018; Verheij 2019). South-east Asia's protected areas have been gutted by this demand, and consequently the region has some of the most threatened carnivore populations in the world. To date, the lessons learnt from the extinction of the last rhinoceros in mainland South-east Asia (Brook et al., 2014) have not been applied in any meaningful way, and wildlife continues to be threatened by hunting to supply the demand. Indiscriminate snaring has been cited as the main cause of decline in a wide range of ground-dwelling vertebrates in South-east Asia (Harrison et al., 2016; Gray et al., 2018), including carnivores (e.g., Willcox et al., 2014). Enforcement units have extracted hundreds of thousands of snares from protected areas (Gray et al., 2018), and this, combined with the general inadequacy of site-level protection and a parallel, mostly unregulated, legal trade in "farmed" wildlife (WCS 2008), are all contributing to ongoing declines in South-east Asia's wildlife.

The overall declines of traded wildlife in depleted countries such as Vietnam are causing increases in hunting in other regions such as border areas adjacent to demand countries (e.g., O'Kelly et al., 2018; Gray & Gauntlett 2019), and as far as Latin America (Reuter et al., 2018; Verheij 2019). There are Chinese- and Vietnamese-led criminal networks illegally trafficking high-value wildlife and plants from Africa, and more recently from Latin America, to markets in Asia. The larger carnivores are a known target (e.g., Jaguar *Panthera onca*: Reuter et al., 2018), and declines in these species may cause shifts towards others including non-felid small carnivores. This is a speculative assessment of a potential threat, but traffickers and consumers are evidently able to show plasticity;

Jaguars are not part of traditional Asian medicine, and demand for this species is probably due to dwindling or locally extinct Tiger *Panthera tigris* populations in demand countries (Bale 2018).

The emergence of China as a global political and economic power has led to the country financing various large-scale infrastructure projects in other Asian countries (e.g., Nepal: WTO 2018) under its “belt and road” initiative, as well as in Africa (Chen et al., 2018) and Latin America (Ellis 2015). Whilst most of this investment is principally linked to geo-politics and trade, the potential impacts of Chinese-funded or -constructed infrastructure projects on wildlife conservation should not be underestimated. There are both direct impacts of large-scale infrastructure development and increased opportunities for legal or illegal wildlife trade from these infrastructural developments (Mowbray 2015; Alamgir et al., 2017; Laurence 2018). Any increases in wildlife hunting/trade, either directly of small carnivores, or of indiscriminate hunting methods known to cause rapid declines, such as snaring, will need to be carefully monitored. Several small carnivores occur in politically volatile countries where governance is poor; the emergence of large infrastructure projects inside protected areas, or on their periphery, could result in increased threats to wildlife. Similar patterns have been observed in other countries (e.g., Gray & Gauntlett, 2019). Small carnivores living in lowland habitats, including wetlands, are particularly vulnerable to this threat.

A gap in global policy and enforcement action is the ongoing failure to address the consumption of luxury wild meat at local levels (i.e., at wild meat restaurants outside protected areas) and to link this demand explicitly to the snaring crisis in South-east Asia. Whilst there has been a relative increase in activities and programmes aimed at addressing the illegal wildlife trade in Vietnam, China, and the wider region, nearly all focus on higher-profile mammals traded by trans-national wildlife-trafficking networks, e.g., pangolins, Tiger, elephants and rhinos (e.g., USAID 2018). Additionally, there have been relatively few interventions on the public health implications of wildlife “farms” and wild meat consumption, particularly any involving small carnivore species (Wicker et al., 2017).

The impacts of climate change on small carnivore conservation are difficult to predict. The majority of small carnivores, like many mammal species, are very adaptable given the opportunity. However, the more threatened species are patchily distributed, and some only persist in small fragmented populations representing a fraction of their historical range, and in ecosystems that are already facing a battery of threats. It is unknown, for example, how well semi-aquatic species such as European Mink will be able to adapt to changes in the seasonality of waterbodies induced by climate change.

2.10 *Ex-situ* conservation and small carnivores

The majority of small carnivores are not threatened with extinction. The group contains a large number of species tolerant of significant human-induced changes in their habitats, and if not unduly persecuted, are able to survive and breed in a variety of rural, peri-urban and urban landscapes. The majority of the 172 described species are therefore not priorities for conservation breeding or other forms of *ex-situ* action.

However, there are several species, or species groups, whose conservation is probably dependent on *ex-situ* support. Madagascar contains the highest concentration of threatened carnivores in the world. Its carnivores are in decline and its deteriorating protected area network provides a strong justification for *ex-situ* activities to support conservation of its more threatened species. Based on range, known threats and conservation status, the immediate priorities are Bokiboky, Western Falanouc and Grandidier's Vontsira. Efforts should be made to identify in-country leads or partners that can support the implementation of an integrated conservation strategy within Madagascar for these three species.

European Mink remains a priority for conservation breeding; the threats it faces, particularly of habitat loss and the invasive American Mink, will be hard to counter or

reverse in many current and former-range states. Recovering populations will depend upon the use of captive-bred animals as an ongoing activity.

There are no secure protected areas within the range of Owston's Civet, and conservation breeding was agreed as a priority activity, both to act as an insurance against extinction, and to produce a healthy captive stock for reintroductions or reinforcements (Willcox et al., 2019a). Large-spotted Civet is not presently in captivity in any significant numbers, though its declining status may warrant some form of *ex-situ* action in the near-future; careful attention to any indication of a poor/declining status in Myanmar would probably justify such an action, given the probable deterioration of its population in Cambodia since its last Red List assessment. Red Panda is arguably one of the most successful linkages between *in-situ* and *ex-situ* conservation. The known threats facing its wild populations are still severe and, in the case of climate change, difficult to predict; ongoing support and management of its conservation breeding programme will be required.

The main direct threat facing Pygmy Raccoon (hurricanes) is beyond the control of conservation practitioners, aside from highlighting the impacts of human-induced climate change on biodiversity conservation. The role of an *ex-situ* programme for Pygmy Raccoon, and how to structure it, needs careful consideration. If suitable partners can be found either on the island or in mainland Mexico, then an *ex-situ* needs assessment should be undertaken. Black-footed ferret conservation will require ongoing support for its recovery programme, including captive breeding efforts; threats to its small wild population persist across its range and are difficult to control. However, there is limited role for captive institutes outside of North America.

Smooth-coated Otter is a lowland species approaching national extinction in a number of range countries; it is already in captivity in a number of institutes. There is a strong rationale for *ex-situ* management to support recovery efforts in some range countries. The situation is more complicated for Hairy-nosed Otter. It is a conservation priority, but efforts to keep it in captivity have so far failed, with high rates of captive mortality from unknown causes. Research on its ecology and distribution are needed to fill information

gaps, particularly whether protected areas in lowland evergreen forest support populations. Asian Small-clawed Otter is common in captivity, but the taxonomic status of some of these populations is unknown; this needs to be clarified before management decisions can be made. The European populations of Eurasian Otter are not priorities for *ex-situ* conservation, apart from where there are ongoing or planned efforts to reintroduce or reinforce populations within Europe. Should there be new conservation units of Eurasian Otter described from other parts of its large range, particularly in regions such as South-east Asia where otters are severely threatened, then these would become immediate conservation priorities, and *ex-situ* activities might be justified.

2.11 Summary

Madagascar contains the highest concentration of threatened carnivore species anywhere in the world. The country's deteriorating protected-area network makes it a priority for small carnivore conservation, and several species may need some form of *ex -situ* action. Small carnivores in South-east Asia are under significant pressure from hunting to supply the illegal wildlife trade, as well as habitat loss, and the interactions between these two factors. Owston's Civet is the conservation priority from this region. The rapidly declining status of Large-spotted Civet needs careful monitoring, as it may warrant intervention soon. Otters in Asia are in decline and there may exist as yet undescribed conservation units that are extremely threatened. Hairy-nosed Otter is not yet a priority for *ex-situ* conservation because of low feasibility; efforts should focus on managing the populations of Smooth-coated Otter and Asian small-clawed Otter already in human care. The future of European Mink and Black-footed Ferret will depend on ongoing support to conservation breeding efforts, as well as threat reduction. To a lesser extent, Red Panda conservation is also dependent on continued support to its integrated conservation plan. There are no obvious candidate species for *ex-situ* conservation of small carnivores from Africa, though the bushmeat trade, planned large-scale infrastructure projects and a growing transnational wildlife trade link to Asia may change this assessment in the near future. It is unclear what role *ex-situ* conservation would have for Pygmy raccoon: the main threat to this species is hurricanes. A speculative

assessment of emerging threats to small carnivores includes: infrastructural development in the tropics, illegal wildlife trade networks that include Latin American, African and Asian markets, and the growing Vietnamese and Chinese diasporas that operate in other Asian countries, Africa and Latin America, and the interactions between all of these factors.

Chapter 3: The conservation status of Owston's Civet *Chrotogale owstoni*: current knowledge of its distribution, ecology, and threats.

3.1 Introduction

Owston's Civet *Chrotogale owstoni* Thomas, 1912, is an Endangered (*sensu* the IUCN Red List of Threatened Species) small carnivore distributed in South-east Asia. It is a member of the civet family Viverridae, sub-family Hemigalinae, which is comprised of the four genera *Hemigalus*, *Chrotogale*, *Diplogale* and *Cynogale*.

Owston's Civet was originally placed in the genus *Hemigalus* because of its superficial resemblance in pelage and morphology to the Banded Civet *Hemigalus derbyanus* (Corbet & Hill 1992). Genetic analysis of the mitochondrial cytochrome *b* marker confirmed that *Chrotogale* is a distinct genus (Veron & Heard 2000; Veron et al., 2004a). Subsequent analysis of two nucleic and two mitochondrial markers support this treatment (Veron et al., 2017). Using samples of animals of mostly unknown or unproven provenance (Veron et al., 2004a; Veron et al., 2017), intraspecific taxonomic variation suggests the presence of two clades within Vietnam, as well as a possible third in China; however, this third clade was based on a single sample submitted to GenBank (Veron et al., 2017). The taxonomy will remain unresolved until samples from animals of known provenance can be obtained and an integrative taxonomic assessment completed (e.g., see Wilting et al., 2015). Although sometimes called Owston's Palm Civet, Duckworth &

Pine (2003) recommend 'Owston's Civet' because the species is not closely related to the palm civets (Paradoxurinae) and it is not associated with palms (Arecaceae). It is the sole representative of the monospecific genus *Chrotogale* (Veron et al., 2004a; Veron et al., 2017).

Owston's Civet is distributed in Lao PDR, Vietnam, and a small part of southern China (Timmins et al., 2016a). Its status in Cambodia is recorded as "Presence Uncertain" in Timmins et al. (2016a). The species is an Indochinese endemic. The known threats to the species are hunting for the illegal wildlife trade, in which civets form a significant part in the region (Bell et al., 2004; Roberton 2007; WWF 2020), habitat loss, and the interactions between these two factors (Timmins et al., 2016a). Although very little is known about its ecology, it is thought to be primarily ground-dwelling, spending a significant amount of time on the ground foraging for prey; this increases its vulnerability to hunting traps, many of which are indiscriminate, as well as to Domestic Dogs *Canis familiaris*, often used by illegal hunters in the region.

Owston's Civet is not listed in CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) nor in CMS (Convention on Migratory Species). The only protections it has are at a national level, summarised in Table 3.1.

Table 3.1. Legal protections given to Owston's Civet *Chrotogale owstoni* in the countries of its known and possible range.

Country	**Law number / title**	**Protection granted**	**Implementation**
Cambodia	None – species is not listed and presence in Cambodia is uncertain.	n/a	n/a
China	List of Wildlife under Special State Protection (revised 2021) – an adjunct to the Wildlife Protection Law. [in Chinese]	Group 1 / first-class protection	Hunting and trade of the species is prohibited.

Lao PDR	Prime Minister Decree 81, 2008; Wildlife hunting regulation. [in Lao]	Group 1	Hunting of the species is prohibited.
Vietnam	Decree 130/2013/ ND-CP Decree 64/2019/ND-CP *On criteria to determine species and the regime of managing species under lists of endangered, precious and rare species prioritized for protection*. [In Vietnamese]	Included on the species list in Decree 64, which is an update to Decree 130.	Prioritises species for protection at a national level. Limited protection for the species within the decree: mostly focused on criteria for listing species in the decree.
Vietnam	Decree 06/2019/ND-CP *On the management of endangered, precious and rare wild fauna and flora, and the implementation of the Convention on International Trade in Endangered species of Wild Fauna and Flora*. [in Vietnamese]	Included on IIB (2B)	Confiscations of species listed on IIB can be legally sold, including to commercial wildlife farms. Commercial rearing of species listed on IIB is legal.

Within the range of Owston's Civet, there are no protected areas that yet provide effective protection to wildlife species vulnerable to snaring and other forms of hunting (Willcox et al., 2019a; Belecky & Gray 2020). This is evidenced by the ongoing declines and local extinctions of a large range of ground-dwelling, hunting-sensitive vertebrates in South-east Asia (Duckworth et al., 2012; Harrison et al., 2016; Tilker et al., 2019). The distribution of Owston's Civet overlaps with the Critically Endangered Saola *Pseudoryx nghetinhensis*, Large-antlered Muntjac *Muntiacus vuquangensis* and Edwards's [Vietnam] Pheasant *Lophura edwardsi* (IUCN 2021), all of which are endemics to Indochina, all threatened by illegal hunting or snaring inside protected areas, and all precariously close to extinction. Larger bodied, more widely distributed carnivores such as Tiger *Panthera tigris* and Leopard *Panthera pardus* are now considered extinct, or functionally extinct, within this range, with hunting for the illegal wildlife trade the main

cause (e.g., Rostro-García et al., 2016; Rasphone et al., 2019). The ongoing declines and imminent extinctions of ground-dwelling vertebrates in South-east Asia have led this region to be identified as a priority for species conservation (Duckworth et al., 2012).

Owston's Civet is a global priority for small carnivore conservation (Willcox et al., 2019a; Willcox 2020; Willcox et al., 2020). Although first formally described in the early 20th Century (see Thomas 1912), there have been few conservation interventions and little targetted research. Knowledge about its ecology, distribution and threats are mostly based on compilations of incidental records and camera-trap 'by-catch' collected as part of survey efforts for other species or species groups (e.g., Roberton 2007; Coudrat et al., 2014; Gray et al., 2014).

Since 2017 there has been a concerted effort to reinvigorate the conservation programme for Owston's Civet, including an *ex-situ* component focused on conservation breeding, which remains a priority given the state of protected areas within its range (see Willcox et al., 2019a). Part of the process for conservation includes identifying its status within protected or conservation areas, and where efforts for its *in-situ* conservation should be directed, based on a combination of factors including determinants of conservation feasibility. This paper forms part of this process: it includes a collation and review of locality records, including non-detections from survey efforts at sites within its range. All information that could be traced on its ecology is also included. Discussion follows on the current state of knowledge on Owston's Civet and the priority conservation interventions needed for the species.

3.2 Methods

Records of Owston's Civet from the early 1900s to 2005, including museum specimens, were collated and reviewed in Roberton (2007). These records, particularly any with locality information or coordinates, were included in this paper but have not been

reviewed again. Records from post-2005 were collated using a combination of a systematic review of online literature and engagement with individuals and organisations known to be working at appropriate sites and using methods which might generate verifiable records. The systematic literature review followed methods described in Willcox et al. (2019b): country biases in displayed results were removed from google.com using /ncr (= no country region) and searches performed for any mention of the phrases “Chrotogale owstoni” or “Owston’s civet” or “Owston’s palm civet” or “Owston’s banded civet” or “Owston’s banded palm civet”, as well as its only known synonym “Hemigalus owstoni”. Filetypes searched for comprised of MS Word, MS Excel, MS PowerPoint and any .pdf file. This enabled a wide range of grey literature to be searched, including non-peer-reviewed technical papers, birdwatching reports, and presentations, and did not limit the review to records included in peer-reviewed academic journals. Neither the Vietnamese name nor the Lao name for the species were used in any search terms; although this would have limited the results it did not exclude Vietnamese language technical reports for example, which would often cite the scientific name of the species.

Carnivore diversity in South-east Asia is high (Corbet & Hill 1992) and many small carnivore species look superficially similar to one another, share similar or identical vernacular names in a local language, and/or leave signs that cannot be reliably identified to species level. Records based on community interviews or the visual identification of faeces or other animal signs were therefore not considered as confirmed records. Confirmed records comprised: camera-trap records, faecal DNA, eDNA (such as those based on records from leech DNA, see Schnell et al., 2018), as well as direct observations of either live or hunted animals, including observations of animals in captivity or the wildlife trade. Direct observations were only included as confirmed records when the observer had either supported their observation with photographs and/or descriptive notes, or were known to be familiar with the species and the small carnivore community of the country or site. Known confusion with other species include the Spotted Linsang *Prionodon pardicolor*, which occurs across the entire known range of Owston’s Civet. Several verbal reports of the latter during the time of this review, based on camera-trap images as well as a road-kill, turned out on inspection to be Spotted Linsangs (DW pers. obs.).

Prior to the 1990s the distribution of Owston's Civet was thought to be restricted to northern Vietnam, northern Lao PDR, and south Yunnan and southwest Guangxi provinces in southern China (Schreiber et al., 1989). As these countries opened up to international collaboration and survey efforts for wildlife increased, new locality records for the species were generated; the distribution is now known to extend into central and southern Vietnam (Timmins et al., 2016a). The majority of verifiable records for Owston's Civet have come from camera-trap 'by-catch' of surveys targeting other species or taxonomic groups; only one of the traced camera-trap records were from efforts targeting Owston's Civet itself (SVW unpublished data: Pu Mat National Park). Since 2013 there has been particular emphasis on identifying remnant populations of the Critically Endangered Saola and Edwards's Pheasant using camera-traps and these efforts have helped to generate information on the status of co-occurring wildlife, such as Owston's Civet.

3.3 Results

All traced records of Owston's Civets are presented by country and include all known site records, as well as non-detections where suitable survey techniques have been used and within confirmed or probable Owston's Civet habitat (Figure 3.1).

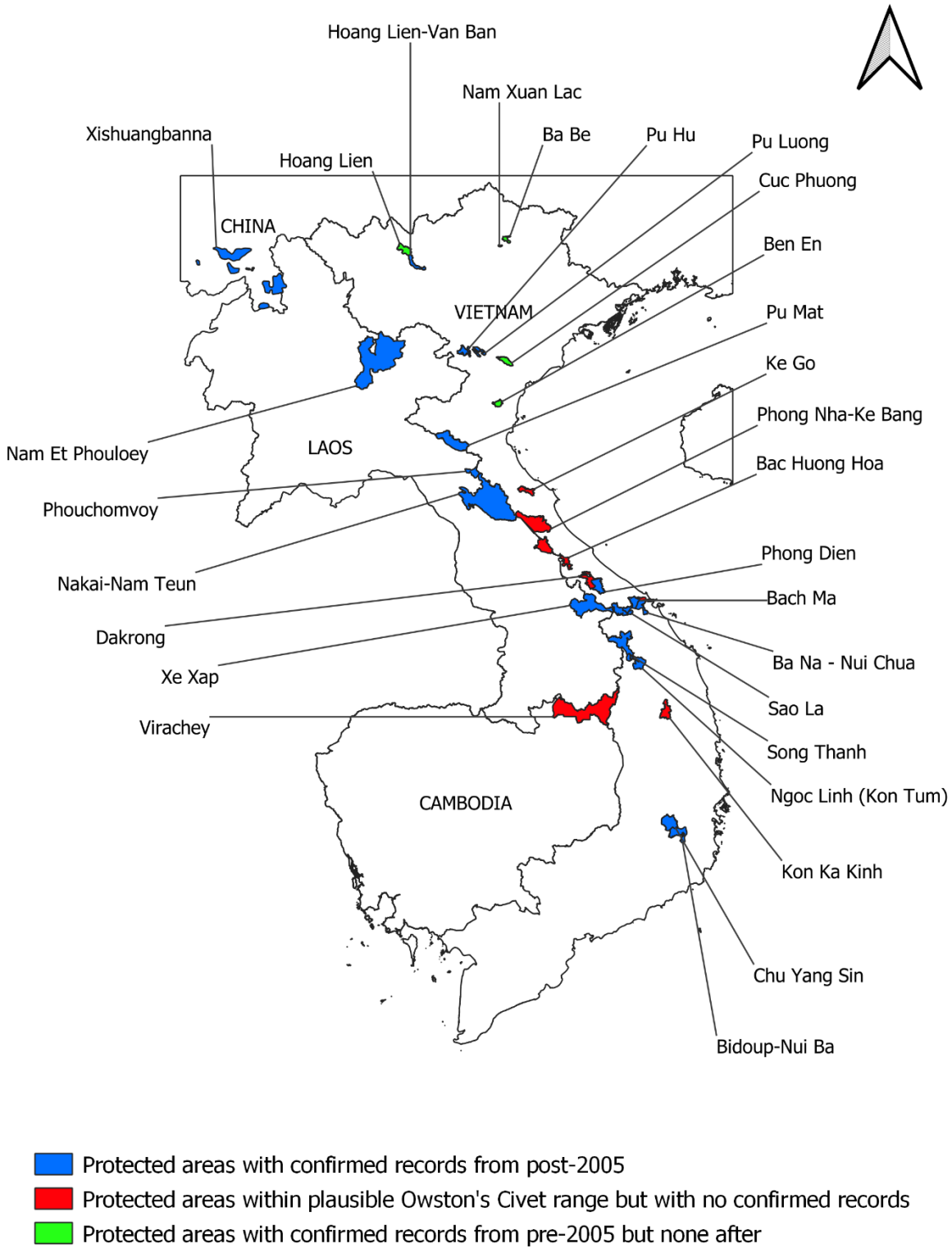


Figure 3.1. Protected areas with confirmed Owston's Civet *Chrotogale owstoni* records and non-detections.

3.3.1 Distribution

China

Schreiber et al. (1989) included 19 museum specimens of Owston's Civet from China in their collation of known records: 17 in the Kunming Institute of Zoology and two in the Beijing Institute of Zoology. All of the specimens in the Kunming Institute of Zoology were considered to have originated in Yunnan, 16 of which were bought from local hunters (Schreiber et al., 1989: 43). All were treated as confirmed records by the authors, leading to southern Yunnan and south-west Guangxi provinces being considered within the distribution of Owston's Civet. None of these records were reviewed in Roberton (2007). A rapid review of the status of carnivores in South China (Guangdong, Gaungxi and Hainan) did not produce any confirmed records, and the status of Owston's civet was declared as "uncertain" (Lau et al., 2010), but their review did not include Yunnan province. The absence of any confirmed records, and the poor conservation status of some wildlife in this part of China (e.g. Li et al., 2007), led Timmins et al. (2016a) to declare that Owston's Civet was "Possibly Extinct" in the country. However, two sets of camera-trapping efforts in Xishuangbanna National Nature Reserve (NNR) in Yunnan province produced several confirmed Owston's Civet records in 2018 (Tongkok et al., 2019; 2020). These records resulted from a camera-trapping effort of approximately 7,450 camera-trap-nights (Supparat Tongkok pers. comm. 2020) (Table 3.2). A high camera-trapping effort of 14,814 trap-nights by 147 camera-trap stations in the Tengchong Section of Gaoligongshan National Nature Reserve (Yunnan) did not detect the species (Li et al., 2019); this site is very probably outside the global range for Owston's Civet. The relatively low number of records of Owston's Civet from China, including historical specimens with accurate locality data, make it difficult to confirm the extent of its range in the country, but discontinuity in the climate to the north and west probably restrict the species to the provinces of Yunnan, Guangxi, and possibly Guangdong.

Table 3.2. Confirmed camera-trap records of Owston's Civet *Chrotogale owstoni* from China.

Reference / source	**Site name**	**Survey years**	**Target** **Camera-trapping method** **Height**	**Camera-trap Stations** **Camera-trap Days** **Altitude range (mean)**	**Owston's Civet records**	**Record altitude(s) (m asl)**	**Notional independence**	**Other carnivores recorded by camera-traps**
Tongkok et al., (2019)	Xishuangbanna NNR	2018	General biodiversity Unknown: 49 camera-traps in 1 km^2 plot Varied depending on topography and shrub height (all camera-traps <1 m from ground)	49 camera-traps 4,772 days 696 – 1035 m asl (mean 811)	9 records from 8 camera-traps. Distance of 150 - 700 m between these eight camera-traps.	713 – 912 m asl	30 minutes	ferret badger, Leopard Cat, Crab-eating Mongoose, Masked Palm Civet, Common Palm Civet

Tongkok et al., (2020).	Xishuangbanna NNR	2018	Frugivores of *B. ramiflora* tree Targeted: 36 camera-traps installed on 9 focal trees (3 to 5 camera-traps per focal tree) Height varied depending on focal tree	36 camera-traps 2,678 days 739 – 869 m asl; (mean 821)	10 records from four camera-traps.	739 – 868 m asl	30 minutes	Masked Palm Civet, Small Indian Civet, ferret badger, Leopard Cat

Vietnam

Roberton (2007) traced 29 confirmed site records for the species from Vietnam, 11 of which were from post-1990. 14 of these 29 records were from 10 protected areas (Table 3.3). Since 2015 there has been a significant increase in camera-trapping in Vietnam, and although Owston's Civet was only once the survey target, these efforts have produced site records from an additional 11 sites, comprising: Ba Na Nui Chu Nature Reserve (NR), Bach Ma NP, Bidoup Nui Ba NP, Elephant Species and Habitat Conservation Area (SHCA), Hue Saola NR, Kong Plong district, Mu Cang Chai SHCA, Muong La Watershed Protection Forest (WPF), Ngoc Linh NR (Kon Tum province), Phong Dien NR, and Pu Hu NR (Table 3.4). Owston's Civet has been redetected in Pu Mat NP (SVW, unpublished data) and Pu Luong NP (Pu Luong FPD, unpublished data); Roberton (2007) traced records from these two sites from 1998 and 2004 respectively. Song Thanh NR has records from 2003 (Long et al., 2005) and from 2017 and 2020. Additional modern records from Vietnam comprise observations of two individuals: one in Chu Yang Sin NP (Dang Ngoc Can & Le Trong Trai 2010) and one in Pu Mat NP (Dinets 2018). Based on habitat, Roberton (2007: 100) predicted that the species would extend into the lowland Dong Nai watershed forest; this has been validated by a record from Chu Yang Sin NP (Dang Ngoc Can & Le Trong Trai 2010), and the multiple camera-trap records from the nearby Bidoup Nui Ba NP (SIE / Leibniz-IZW / Saola Working Group / Bidoup Nui Ba NP, unpublished data). A camera-trapping effort of 7,767 camera-trap-nights in Cat Tien National Park, which is dominated by semi-evergreen forest types, has not produced any Owston's Civet records (J. Masseloux pers. comm. 2020). The climatically wetter forest types associated with Chu Yang Sin NP, Bidoup Nui Ba NP and possibly Phuoc Binh NP probably represent the global southern distribution limit for this species.

Table 3.3. Confirmed Owston's Civet *Chrotogale owstoni* records from protected areas in Vietnam, collated in Roberton (2007). Localities are in Figure 3.1.

Locality[1]	**Record type**	**Record year**	**Reference / Source**
Ba Be NP	"Specimen"; though probably remains seen during interviews.	1996	Hill et al., (1996).
Ban Thi - Nam Xuan Lac SHCA*	Specimen	1976	IEBR Museum - Hanoi, Vietnam: M.74.1471 (5)
Ban Thi - Nam Xuan Lac SHCA*	Specimen (Skull)	1963	Vietnam National University-Hanoi, Zoological Musuem. (HS125, 4.163.0)
Ben En NP	Camera-trap	1999	Tordoff et al., (2000).
Cuc Phuong NP	Observation	2001	Roberton, S. pers. obs.
Cuc Phuong NP	Interview & remains	1997	Vietnam National University-Hanoi, Zoological Musuem. (HS125, 4.122.56)
Cuc Phuong NP	Specimen (Stuffed skin & skull)	1970	Vietnam National University-Hanoi, Zoological Musuem. (PTB, 4.121.55)
Cuc Phuong NP	Specimen (Stuffed skin & skull)	1963	Vietnam National University-Hanoi, Zoological Musuem. (PTB, 4.122.56)
Hoang Lien NP	Interview & remains	1998	Tordoff et al., (1999).
Na Hang NR	Interview & observed	2002	Le Trong Trai et al., (2004).

Pu Luong NR	Camera-trap	2004	Do Ngoc Cuong. (2004).
Pu Mat NP	Camera-trap	1998	SFNC (1998).
Song Thanh NR	Camera-trap	2003	Long et al., (2004).
Van Ban NR [Hoang Lien – Van Ban]	Camera-trap	2002	Swan & O'Reilly (Eds). (2004).

[1] *NR = Nature Reserve, NP = National Park, SHCA = Species and Habitat Conservation Area.*

** Parts of which are now gazetted as Nam Xuan Lac Nature Reserve. Omitted Vu Quang NP (Eve et al., 1998); listed as "confirmed" in a supplementary data table to Roberton 2007, but no details given.*

Since 2007 there have been at least 17 survey efforts of 1,000 camera-trap-nights or greater, totalling to a minimum 148,000 camera-trap-nights in 11 sites within the known range of Owston's Civet that have failed to detect the species (Table 3.5). Where stated, all but two survey efforts had small-bodied, ground-dwelling mammals and/or birds as the targets; the majority of the non-detections for Owston's Civets are unlikely to be because of camera-trap heights, or other differences in methods, and represent the genuine rarity of Owston's Civets at these sites.

Table 3.4. Confirmed camera-trap records of Owston's Civet *Chrotogale owstoni* from Vietnam.

Reference / source	**Site name**	**Survey years**	**Target** **Camera-trapping method** **Height**	**Camera-trap Stations** **Camera-trap Days** **Altitude range (mean)**	**Owston's Civet records**	**Record altitude(s) (m asl)**	**Notional independence**	**Other carnivores recorded by camera-traps**
Dickinson & Van Ngoc Thinh 2006	Bach Ma NP	2005, 2006	General biodiversity Assumed to be targeted; no maps or details on spacing. Height not stated.	N# stations not stated. 180 days Altitude range not stated.	Recorded; no other details	Not stated	Not stated	Masked Palm Civet, Common Palm Civet, Large Indian Civet, Leopard Cat
GreenViet, unpublished data	Ba Na Nui Chu NR	2016, 2017	Ground-dwelling mammals "especially small carnivores" Targeted. Distance between stations was 100 - 500 m. 50 – 100 cm.	24 stations 3,812 days 117 – 1,081 m asl	24 records from 6 stations	506 – 1,030 m asl (mean 722)	Not stated but all records separated by at least a day.	Masked Palm Civet, Common Palm Civet, Yellow-throated Marten, ferret badger sp., Spotted Linsang, Crab-eating Mongoose, Leopard Cat

Reference / source	**Site name**	**Survey years**	**Target** **Camera-trapping method** **Height**	**Camera-trap Stations** **Camera-trap Days** **Altitude range (mean)**	**Owston's Civet records**	**Record altitude(s) (m asl)**	**Notional independence**	**Other carnivores recorded by camera-traps**
WWF-Vietnam, unpublished data	Bach Ma NP	2019, 2020	Target not stated. Systematic (2.5km). Two cameras per station. Height not stated.	N# stations not stated. N# days not stated. Altitude range not stated.	One record	Not stated	Not stated	Not stated
SIE (Southern Institute of Ecology, Vietnam), unpublished data	Bidoup Nui Ba NP	2014, 2015	Ground dwelling mammals Targeted. Distance from each station vary, from 50 to 250m; 1 camera-trap at each station. 30 – 40 cm	10 stations 1,179 days 1458 – 1600 m asl	23 records from 5 stations	1520 – 1576 m asl	60 minutes	Common Palm Civet, ferret badger, Yellow-bellied weasel, Yellow-throated Marten, Masked Palm Civet, Crab-eating Mongoose

Reference / source	Site name	Survey years	Target Camera-trapping method Height	Camera-trap Stations Camera-trap Days Altitude range (mean)	Owston's Civet records	Record altitude(s) (m asl)	Notional independence	Other carnivores recorded by camera-traps
SIE / Leibniz-IZW / Saola Working Group / Bidoup Nui Ba NP, unpublished data	Bidoup Nui Ba NP	2016, 2017	Large-antlered muntjac Targeted. Single camera-trap per station: 200 to 10,000 m apart. 20 – 30 cm	14 stations 648 days 900 – 1600 m asl	8 records from 4 stations	1264 – 1482 m asl	60 minutes	Yellow-throated Marten, ferret badger, [Greater] Hog Badger, Masked Palm Civet, Large Indian Civet, Crab-eating Mongoose, Leopard Cat
Leibniz-IZW / SIE / Bidoup Nui Ba NP, unpublished data	Bidoup Nui Ba NP	2019, 2020	Ground-dwelling mammals and birds Systematic (2.5km). Two cameras per station. Approx. 30cm	103 stations. 13,632 days 697 – 2128 m asl	44 records from 7 stations	1249 – 1954 m asl	60 minutes	Asian Small-clawed Otter, Common Palm Civet, Crab-eating Mongoose, ferret badger, [Greater] Hog Badger, Large Indian Civet, Leopard Cat, Masked Palm Civet, Small Indian Civet, Spotted Linsang, Sun

Reference / source	Site name	Survey years	Target Camera-trapping method Height	Camera-trap Stations Camera-trap Days Altitude range (mean)	Owston's Civet records	Record altitude(s) (m asl)	Notional independence	Other carnivores recorded by camera-traps
								Bear, Yellow-bellied Weasel, Yellow-throated Marten
WWF Vietnam, unpublished data	ElePhant SHCA	2019	Not stated	N# stations not stated. N# days not stated. Altitude range not stated.	Records from 5 stations	Not stated	Not stated	Not stated
WWF Vietnam, unpublished data	Hue Saola NR	2019, 2020	Target not stated. Systematic (2.5km). Two cameras per station.	N# stations not stated. N# days not stated.	One record	Not stated	Not stated	Not stated

Reference / source	Site name	Survey years	Target Camera-trapping method Height	Camera-trap Stations Camera-trap Days Altitude range (mean)	Owston's Civet records	Record altitude(s) (m asl)	Notional independence	Other carnivores recorded by camera-traps
			Height not stated.	Altitude range not stated.				
CRES, unpublished data.	Hue Saola NR	2015, 2016, 2017	Edwards's Pheasant and other galliforms. Targeted; spacing not stated. One camera-trap per station. Average distance between stations was 194 m. 40 – 60 cm	46 stations 16,468 days 142 – 451 m asl	22 records from six stations	165 – 363 m asl	30 minutes	Common Palm Civet, Crab-eating Mongoose, ferret badger, Leopard Cat, Masked Palm Civet, weasel sp., Spotted Linsang, Yellow-bellied Weasel, Yellow-throated Marten

Reference / source	Site name	Survey years	Target Camera-trapping method Height	Camera-trap Stations Camera-trap Days Altitude range (mean)	Owston's Civet records	Record altitude(s) (m asl)	Notional independence	Other carnivores recorded by camera-traps
Timmins & Trinh Viet Cuong (2001)	Huong Son SFE	1999	Large mammals and birds Targeted. Spacing not stated. Receivers at 15 to 30 cm, cameras to a maximum of 50 cm	7 camera-traps Approx. 77 camera-trap-nights (data given in trapping-hours) 350 – 650 m asl	One record	400 m asl	n/a - single record	No others, other than a provisional Masked Palm Civet.
Leibniz-IZW / FFI-Vietnam, unpublished data	Kon Plong. Community forests, watershed protection forests, forest enterprises.	2019, 2020	Ground-dwelling mammals and birds. Systematic (2.5km). Two cameras per station.	121 stations.	73 records from 10 stations	Not stated	60 minutes	Asian Small-clawed Otter, Asiatic Black Bear, Common Palm Civet, Crab-eating Mongoose, Ferret Badger, Yellow-bellied Weasel, Leopard Cat, Masked Palm Civet,

Reference / source	Site name	Survey years	Target Camera-trapping method Height	Camera-trap Stations Camera-trap Days Altitude range (mean)	Owston's Civet records	Record altitude(s) (m asl)	Notional independence	Other carnivores recorded by camera-traps
			8 - 150cm (mean = 26cm)					Spotted Linsang, Yellow-throated Marten
FFI Vietnam, unpublished data	Mu Cang Chai (MCC) SHCA and Muong La (ML) WPF	2014, 2015	Clouded Leopard Targeted? Spacing unknown. Unknown if paired/single camera-traps. Height not stated.	59 stations; 7,746 days. 42 stations and 4809 days in MCC. 17 stations and 2937 days in ML. 1582 – 2449 m asl (mean 2123)	131 records from 21 stations.	1863 – 2449 m asl	60 minutes	Asiatic Black Bear, Marbled Cat, Leopard Cat, Masked Palm Civet, Yellow-throated Marten, ferret badger, Spotted Linsang, Small Indian Civet
Nguyen Trang / FFI Vietnam, unpublished data	Ngoc Linh NR, Kon Tum	2013	Clouded Leopard Systematic. Stations spaced at 2.5 km.	19 stations (1 stolen)	52 photographs from 5 stations. Most	Unknown: data lost	Unknown: data lost.	Leopard Cat, Yellow-throated Marten, Common Palm Civet, Crab-eating Mongoose,

Reference / source	Site name	Survey years	Target Camera-trapping method Height	Camera-trap Stations Camera-trap Days Altitude range (mean)	Owston's Civet records	Record altitude(s) (m asl)	Notional independence	Other carnivores recorded by camera-traps
			Paired camera-traps at stations. Unknown: data lost	Unknown: data lost	commonly recorded small carnivore.			Masked Palm Civet. Spotted Linsang, [Greater] Hog Badger
Leibniz-IZW / WWF-Vietnam / Phong Dien NR / USAID, unpublished data.	Phong Dien NR	2018	Ground-dwelling mammals and bird Systematic, course (2.5 km). Two cameras per station Approx. 30 cm	51 stations 3,060 days 59 – 1269 m asl (420 mean)	11 records from six stations	82 – 619 m asl	60 minutes	Common palm civet, Crab-eating mongoose, ferret badger, Leopard cat, Masked palm civet, Yellow-throated Marten
WWF-Vietnam, unpublished data	Phong Dien NR	2020	Target not stated. Systematic (2.5 km). Two cameras per station. Height not stated.	Not stated	Records from 12 camera-trap stations	Not stated	Not stated.	Not stated.

Reference / source	**Site name**	**Survey years**	**Target** **Camera-trapping method** **Height**	**Camera-trap Stations** **Camera-trap Days** **Altitude range (mean)**	**Owston's Civet records**	**Record altitude(s) (m asl)**	**Notional independence**	**Other carnivores recorded by camera-traps**
Viet Nature, unpublished data.	Phong Dien NR	2016, 2017, 2019	Edwards's Pheasant and other galliforms. Targeted. Spacing unknown. single camera-traps. 25-30 cm	91 stations 9,684 days Not stated.	Two records in 2016 and one record in 2017.	322, 383 and 236 m asl,	Not stated.	Large-spotted Civet, Large Indian Civet, Masked Palm Civet, Common Palm Civet, Crab-eating Mongoose, ferret-badger, Yellow-throated Marten, Yellow-bellied Weasel, Leopard Cat.
Dong Le Khac et al., (2018).	Pu Hu NR	2017	Target not stated Targeted / non-systematic. Height not stated.	Four camera-traps set between Oct – Nov No other information.	Single Owston's Civet record (photograph included in report: 30 October 2017)	Not stated.	Not stated	Asiatic Black Bear (photograph included in publication)

Reference / source	Site name	Survey years	Target Camera-trapping method Height	Camera-trap Stations Camera-trap Days Altitude range (mean)	Owston's Civet records	Record altitude(s) (m asl)	Notional independence	Other carnivores recorded by camera-traps
Pu Luong FPD, unpublished data.	Pu Luong NR	Between 2017 to 2020	Target not stated. Unknown but probably targeted Height not stated	18 stations. No other information.	1 camera-trap station** FPD stated 69 individuals based on camera-traps, signs/faeces, and interview records	Not stated.	Not stated	Asiatic Black Bear; others unknown
Do Ngoc Cuong, unpublished report (2004).	Pu Luong NR	2003, 2004, 2005	General Biodiversity Unknown "Variable height" but up to 50cm. Trigger beams set at 15 - 30cm	21 stations. N# of days unknown. 290 - 710 m asl; the majority over 600m	Two station records	638 and 610 m asl	Not known	Large Indian Civet, [Greater] Hog Badger, Crab-eating Mongoose, ferret badger sp., Leopard Cat, Asiatic Golden Cat, Clouded Leopard

Reference / source	Site name	Survey years	Target Camera-trapping method Height	Camera-trap Stations Camera-trap Days Altitude range (mean)	Owston's Civet records	Record altitude(s) (m asl)	Notional independence	Other carnivores recorded by camera-traps
SVW (Save Vietnam's Wildlife), Pu Mat NP, unpublished data	Pu Mat NP	2019	Owston's Civet Targeted; single camera-traps at each station. Variable spacing. Approx. 30 cm	21 stations 3,834 days 558 – 1047 m asl (mean 777)	15 records from 2 stations	924 and 966 m asl	60 minutes	Bear sp., Common Palm Civet, Crab-eating Mongoose, ferret badger, Greater Hog Badger, Large Indian Civet, Leopard Cat, Marbled Cat, Masked Palm Civet, weasel sp., Yellow-bellied Weasel, Yellow-throated Marten
SFNC (2000). SFNC (1998). Additional information from B. Long (1999), Unpublished field notes.	Pu Mat NP	1998, 1999	Large mammals Seven efforts, in six locations, using 9 - 15 camera-traps each. Spacing varied; not a grid. 30 – 40 cm	Camera traps were left at each location for an average of 49 nights (range 7 - 83). Unknown, but 9 camera-traps	"At least seven individuals" recorded in all four survey blocks/areas (Khe Khang, Khe Bu, Thac Khe, Khe Toi).	Camera-trapped between 400 and 1,000 m asl Three records at camera-	Not stated	Dhole, Asiatic Black Bear, Sun Bear, Yellow-throated Marten, [Greater] Hog Badger, Large Indian Civet, Spotted Linsang, Common Palm Civet, Masked Palm Civet, Binturong, Leopard Cat,

Reference / source	Site name	Survey years	Target Camera-trapping method Height	Camera-trap Stations Camera-trap Days Altitude range (mean)	Owston's Civet records	Record altitude(s) (m asl)	Notional independence	Other carnivores recorded by camera-traps
				set between 280 – 540.		trap number 4 (1999) at 540 m asl		[Asiatic] Golden Cat, Tiger
Vinh University/ SWG / Pu Mat NP, unpublished data.	Pu Mat NP	2018 2019 2020	Saola Targeted. One camera trap at each station. Average camera-trap densities of 8 per km^2. 50-80cm	156 stations 46,174 days 292 to 1361 (majority towards the upper limit)	Seven records from four stations (Khe Thoi), two records from one station (Khe Pong)	1202 – 1293 (Khe Thoi only) 968 (Khe Pong)	60 minutes	Asiatic Black Bear, Stripe-backed Weasel, Common Palm Civet, Crab-eating Mongoose, ferret badger, [Greater] Hog Badger, Leopard Cat, Marbled Cat, Masked Palm Civet, Otter sp., Spotted Linsang, Yellow-bellied Weasel, Yellow-throated Marten

Reference / source	**Site name**	**Survey years**	**Target** **Camera-trapping method** **Height**	**Camera-trap Stations** **Camera-trap Days** **Altitude range (mean)**	**Owston's Civet records**	**Record altitude(s) (m asl)**	**Notional independence**	**Other carnivores recorded by camera-traps**
Long, B 2005. Long and Minh Hoang 2006. Record details for felidae, canidae and ursidae in Long at al. 2005.	Quang Nam province. Various localities including Song Thanh NR	2002, 2003, 2004, 2005	General biodiversity? Eight sites with four to nine camera-traps in each. Spacing varied; not a grid. 30 – 40 cm	N# of stations unknown. 6,337 days (Long and Minh Hoang 2006) 210 – 1640 m asl	Single camera-trap record (Song Thanh NR)	625 m	n/a - single record	Yellow-bellied Weasel, ferret badger, Large Indian Civet, Spotted Linsang, Common Palm Civet, Masked Palm Civet, Crab-eating Mongoose (Long and Minh Hoang). Leopard Cat, Asian [SIC] Golden Cat and Asiatic Black Bear listed as camera-trapped in Long et al., 2005
Leibniz-IZW / WWF-Vietnam / Song Thanh NR / USAID, unpublished data.	Song Thanh NR	2017	Ground-dwelling mammals and bird Systematic, course (2.5 km). Two cameras per station.	67 stations 7,54 days 175 – 1271 m asl (767 mean)	4 records from one station	1,178 m asl	60 minutes	Asian [SIC] Black Bear, Common Palm Civet, Crab-eating Mongoose, ferret badger, Leopard Cat, Masked Palm Civet, Spotted Linsang,

Reference / source	Site name	Survey years	Target Camera-trapping method Height	Camera-trap Stations Camera-trap Days Altitude range (mean)	Owston's Civet records	Record altitude(s) (m asl)	Notional independence	Other carnivores recorded by camera-traps
			30 cm					Yellow-bellied Weasel, Yellow-throated Marten
WWF-Vietnam, unpublished data	Song Thanh NR	2020	Target not stated. Systematic (2.5 km). Two cameras per station. Height not stated.	Not stated	One record	Not stated	Not stated	Not stated
Swan & O'Reilly (Eds.) (2004).	Van Ban NR	2001	Target not stated. Not stated; all camera-trapping in Nam Xay commune Height not stated.	N# of stations not stated. Reported as 1,126 days in unpublished report (Long and Roberton, unpublished).	18 photographs, reported in unpublished report (Long and Roberton).	900 – 2600 m asl	Not stated	Common Palm Civet, Masked Palm Civet, Crab-eating Mongoose, Leopard Cat

Reference / source	Site name	Survey years	Target Camera-trapping method Height	Camera-trap Stations Camera-trap Days Altitude range (mean)	Owston's Civet records	Record altitude(s) (m asl)	Notional independence	Other carnivores recorded by camera-traps
				Altitude range not stated.				

Table 3.5. Camera-trapping efforts of 1,000 camera-trap-days or greater that failed to detect Owston's Civet *Chrotogale owstoni* in Vietnam.

Reference / source	Site name	Survey years	Camera-trapping method	Target	Stations Days	Altitude (m asl) range Mean	Camera-trap Height	Confirmed carnivore camera-trap records
Leibniz-IZW / WWF-Vietnam / Bac Hai Van / USAID, unpublished data	Bac Hai Van watershed protection forest	2018	Systematic, course (2.5 km). Two cameras per station.	Ground-dwelling mammals and birds	27 stations 3,106 days	113 - 1192	~30 cm	Common Palm Civet, ferret badger, Leopard Cat, Small Asian Mongoose, Spotted Linsang, Yellow-throated Marten

Reference / source	Site name	Survey years	Camera-trapping method	Target	Stations Days	Altitude (m asl) range Mean	Camera-trap Height	Confirmed carnivore camera-trap records
CRES, unpublished data	Bac Huong Hoa NR	2016, 2017	Targeted. One camera-trap per station. Average spacing was 2379 m	Edwards's Pheasant and other galliforms	9 stations 1,995 days	269 - 389	40 – 60 cm	Common Palm Civet, Crab-eating Mongoose, Ferret Badger, Large Indian Civet, Leopard Cat, Masked Palm Civet, Spotted Linsang, Yellow-throated Marten
Viet Nature, unpublished data.	Bac Huong Hoa NR	2015, 2018, 2019	Targeted, Spacing 200-250m. Single camera-traps	Ground-dwelling mammals and birds	180 stations 10,067 days	120 - 1100	25 – 40 cm	Large Indian Civet, Masked Palm Civet, Common Palm Civet, Crab-eating Mongoose, ferret badger, Yellow-throated Marten, Spotted Linsang, Yellow-bellied Weasel, Stripe-backed Weasel, Leopard Cat
Leibniz-IZW / WWF-Vietnam/ Bach Ma NP, unpublished data.	Bach Ma NP	2015	Systematic, fine grid (0.5 – 1 km). Two cameras per station.	Ground-dwelling mammals and birds	64 stations 9,229 days	132 - 1186 (418 mean)	30 cm	Common Palm Civet, Masked Palm Civet, Spotted Linsang, Yellow-throated Marten, Crab-eating Mongoose, ferret badger, Leopard Cat
Leibniz-IZW / WWF-Vietnam / Bach Ma NP,	Bach Ma NP	2014, 2015	Systematic, course grid (2.5 km). Two cameras per station.	Ground-dwelling mammals and birds	53 stations 6,805 days	59 - 1380 (509 mean)	30 cm	Common Palm Civet, Crab-eating Mongoose, ferret badger, Masked Palm Civet, Spotted Linsang, Yellow-throated Marten

Reference / source	Site name	Survey years	Camera-trapping method	Target	Stations Days	Altitude (m asl) range Mean	Camera-trap Height	Confirmed carnivore camera-trap records
unpublished data.								
Viet Nature, unpublished data.	Dakrong NR	2016, 2019	Targeted. Spacing 200-250m. Single camera-traps	Edwards's Pheasant and other	60 stations 3,905 days	50 - 300	25 - 40cm	Large Indian Civet, Masked Palm Civet, Common Palm Civet, Crab-eating Mongoose, Small-toothed Ferret-badger, Yellow-throated Marten, Leopard Cat.
Report to CEPF by World Pheasant Association (WPA)	Dong Chau-Khe Nuoc Trong NR	2011, 2012	Targeted; 150 to 200m between stations	Edwards's Pheasant	70,813 images 1681 days	Not stated	Not stated	Common Palm Civet, Crab-eating Mongoose, Leopard Cat, Large Indian Civet, Masked Palm Civet, Mongoose sp.
Viet Nature, unpublished data.	Dong Chau-Khe Nuoc Trong NR	2012 to 2020	Targeted. Spacing 200-250m. Single camera-traps. Exception was two Forest Compartment: grid 500x500 during 2017-2020 as monitoring programme.	Edwards's Pheasant and other	910 stations 56,395 days	58-1043	25-40cm	Large Indian Civet, Masked Palm Civet, Common Palm Civet, Crab-eating Mongoose, ferret badger, Yellow-throated Marten, Spotted Linsang, Yellow-bellied Weasel, Leopard Cat.

Reference / source	Site name	Survey years	Camera-trapping method	Target	Stations Days	Altitude (m asl) range Mean	Camera-trap Height	Confirmed carnivore camera-trap records
Leibniz-IZW / WWF-Vietnam/ Hue Saola NR / QN Saola NR, unpublished data	Hue and Quang Nam Saola NRs	2015	Systematic, course (2.5 km). Two cameras per station.	Ground-dwelling mammals and bird	46 stations 5,933 days	183 - 1304 (689 mean)	~30 cm	Common Palm Civet, Crab-eating Mongoose, ferret badger, Leopard Cat, Spotted Linsang, Yellow bellied Weasel Yellow-throated Marten.
Leibniz-IZW / WWF-Vietnam/ Hue Saola NR / QN Saola NR unpublished data	Hue and Quang Nam Saola NRs	2015, 2016	Systematic, fine (0.5 - 1km). Two cameras per station.	Ground-dwelling mammals and bird	64 stations 7,979 days	235 - 915 (658 mean)	~30 cm	Common Palm Civet, Crab-eating mongoose, ferret badger, Leopard Cat, Spotted Linsang, Yellow-bellied Weasel, Yellow-throated Marten
Willcox et al., (2015)	Ke Go - Khe Net	2006, 2007, 2010	Targeted; single camera-traps at each station. ** 101 hours spotlighting	Small carnivores	21 stations 1,171 days	100 - 420	20 – 30 cm	Stripe-backed Weasel, Yellow-throated Marten, Common Palm Civet, ferret badger
Viet Nature, unpublished data.	Ke Go NR	2015, 2019, 2020	Spacing 150-200m. single camera-traps.	Vietnam Pheasant and other	Number station: 187; Survey efforts: 15,443 days	50 - 180	30 cm	Masked Palm Civet, Common Palm Civet, Crab-eating Mongoose, Small-toothed Ferret-

Reference / source	Site name	Survey years	Camera-trapping method	Target	Stations Days	Altitude (m asl) range Mean	Camera-trap Height	Confirmed carnivore camera-trap records
								badger (identified in hand), Yellow-throated Marten, Leopard Cat.
GreenViet, unpublished data,	Kon Ka Kinh NP	2017, 2018, 2019	Targeted? 15 camera-traps at 30 stations. Distance between stations not stated.	Not stated	30 stations 1,830 days	> 1000 m asl Range not provided	Not stated	Masked Palm Civet, Common Palm Civet, Yellow-throated Marten, Ferret badger sp., Crab-eating Mongoose
Nguyen Xuan Dang et al., (2012).	Phong Nha Ke Bang NP	2012	Targeted, set 300 – 400 m apart.	Large mammals	6761 photographs; estimated at 1670 days; unknown no. of effective days.	318 to 748 m; majority over 400m	30 - 80 majority above 60 cm	Yellow-throated Marten, Crab-eating Mongoose, Common Palm Civet, Masked Palm Civet, ferret badger.
Pu Mat NP, unpublished report (in Vietnamese)	Pu Mat NP	2017	Five clusters spread throughout park, with camera-traps on average 500 - 700m apart	Not stated; assumed to be large mammals	72 stations N# of days not stated	315 to 1289; mean 780m	50 – 60 cm	Yellow-throated Marten, ferret badger [given in the report as *Melogale moschata*], Spotted Linsang, Common Palm Civet, Masked Palm Civet, Crab-eating Mongoose, Leopard Cat, Weasel sp.

Reference / source	Site name	Survey years	Camera-trapping method	Target	Stations Days	Altitude (m asl) range Mean	Camera-trap Height	Confirmed carnivore camera-trap records
SVW / Leibniz-IZW Pu Mat NP, unpublished data.	Pu Mat NP	2018	Systematic, fine (0.5 - 1km). Two cameras per station.	Ground-dwelling mammals and birds	64 stations 7,534 days	340 - 1311 (814 mean)	~30 cm	Asiatic Black Bear, Marbled Cat, Leopard Cat, Greater Hog Badger, Masked Palm Civet, Common Palm Civet, Spotted Linsang, ferret badger, Stripe-backed Weasel, Yellow-bellied Weasel, Yellow-throated Marten
Leibniz-IZW / SVW / Pu Mat NP / Vinh University / CRES, unpublished data	Pu Mat NP	2018, 2019	Systematic, course (2.5 km). Two cameras per station.	Ground-dwelling mammals and birds	110 stations 13,493 days	114 - 1762 (706 mean)	~30cm	Stripe-backed Weasel, Yellow-bellied Weasel, Yellow-throated Marten, Common Palm Civet, Masked Palm Civet, Hog Badger, ferret badger, Spotted Linsang, Leopard Cat, Marbled Cat, Crab-eating Mongoose
Leibniz-IZW / FFI-Vietnam / Pu Mat, unpublished data	Pu Mat NP	2019, 2020	Systematic, fine (0.5 – 1 km). Two cameras per station.	Ground-dwelling mammals and birds	52 stations N# of days not stated.	200 - 1300m	30	Common Palm Civet, Crab-eating Mongoose, Ferret Badger, Striped-backed Weasel, Large Indian Civet, Leopard Cat, Masked Palm Civet, Spotted Linsang, Yellow-bellied Weasel, Yellow-throated Marten

Lao PDR

Owston's Civet was historically collected in Ban Phonsavan, northern Lao PDR (Osgood 1932), but this is a market record so its precise origin is unclear. Deuve (1972) recorded the species for Lao PDR, but gave no details (Duckworth 1997). There were captive records from the Carnivore Preservation Trust's Ban Lak captive facility in Bolikhamxay province, where many were held between 1994 and 1998 (Duckworth et al., 1999). King (2002) details 14 animals held at this facility between 1997 and 1998, nine of which were allegedly collected from banana gardens (L. King, pers. comm. to S. Roberton 2005), though a more accurate habitat description would be of small (less than an acre) village banana stands in areas that retained forest (W. Duckworth pers. comm. to S. Roberton 2005). The first verifiable field records for Lao PDR came when the species was camera-trapped in 2003 in Nam Et-Phou Louey National Park (then a National Protected Area) in north-eastern Lao PDR (Johnson et al., 2009). It has since been camera-trapped again in Nam Et-Phou Louey NP (Rasphone et al., 2019), as well as from the following areas: Ban Pale, adjacent to Xe Sap NPA (Saola Working Group, unpublished data), Nakai-Nam Theun NP (formerly an NPA) (Coudrat et al., 2014; Association Anoulak 2019; Coudrat 2020), Phouchomy PPA (Sisongkham 2010), middle Nam Ngiep catchment area (Duckworth, pers. comm.) and Xe Sap NPA (Gray et al., 2014; Leibniz-IZW / WWF - Laos / WWF – Vietnam / Government of Lao PDR, unpublished data) (Table 3.6). There is a trade record from near Ban Muanglong in Vientiane province: a freshly killed Owston's Civet was photographed at a market stall selling wildlife products (Sivilaly et al., 2011); based on the freshness of the kill, it is likely to have been sourced locally, although this is unconfirmed. There are several survey efforts of more than 1,000 camera-trap-nights that have either produced very few, or no records of Owston's Civets (Table 3.7). However, some of these non-detections might be because drier forest habitats within evergreen biomes were targeted during the surveys or were in areas outside of the distribution range in Lao PDR.

Table 3.6. Confirmed camera-trap records of Owston's Civet *Chrotogale owstoni* from Lao PDR.

Reference / source	**Site name**	**Survey years**	**Target** **Camera-trapping method** **Height**	**Camera-trap Stations** **Camera-trap Days** **Altitude range (mean)**	**Owston's Civet records**	**Record altitude(s) (m asl)**	**Notional independence**	**Other carnivores recorded by camera-traps**
SWG, WWF Laos, Government of Lao PDR, unpublished data.	Ban Pale area Xekong province; south of and adjacent to Xe Sap NPA.	2018, 2019	Saola Targeted. Single cameras, no systematic placement, clustered; density ca. 2-10 ct/km2. ~50cm**	167 stations N# of days unknown. 846 – 1801 m asl (1312)	Recorded; unknown number of records / stations	Not stated	30 minutes	Not stated
Coudrat (2019).	Nakai – Nam Theun NPA (Thong Khacheng)	2018, 2019	Ground mammals Systematic, course (2.5 km) Paired camera-traps at each station.	49 stations 11,186 days 612 – 1705 m asl	181 records from 24 stations	708 – 1658 m asl	60 minutes	Binturong, [Greater] Hog Badger, Large Indian Civet, Sun Bear, ferret badger, Common Palm Civet, Masked Palm Civet, Yellow-throated Marten, Crab-

Reference / source	Site name	Survey years	Target Camera-trapping method Height	Camera-trap Stations Camera-trap Days Altitude range (mean)	Owston's Civet records	Record altitude(s) (m asl)	Notional independence	Other carnivores recorded by camera-traps
			~20 to 60 cm					eating Mongoose, Spotted Linsang, Weasel sp., Leopard Cat, Asiatic Black Bear
Association Anoulak 2019	Nakai – Nam Theun NPA (Thong Khacheng)	2018, 2019	Ground mammals Non-systematic: set up close to eDNA sampling sites to compare species detections. ~20 - 40 cm	32 stations 1,837 days 1034 – 1671 m asl	4 records from 2 stations	1281 and 1299 m asl	60 minutes	Common Palm Civet, Crab-eating Mongoose, Leopard Cat, Masked Palm Civet, Spotted Linsang, Hog Badger, Large Indian Civet, Sun Bear, Yellow-throated Marten
Coudrat et al., (2014).	Nakai-Nam Thuen NPA	2006 through to 2011	Large mammals Systematic: 1km apart, 1 camera-trap per station/locality	429 stations 20,452 days	60 records from 15 stations	1033 – 1675 m asl	30 minutes	Large Indian Civet, Common Palm Civet, Masked Palm Civet, Binturong, Spotted Linsang, Yellow-

Reference / source	Site name	Survey years	Target Camera-trapping method Height	Camera-trap Stations Camera-trap Days Altitude range (mean)	Owston's Civet records	Record altitude(s) (m asl)	Notional independence	Other carnivores recorded by camera-traps
			~ 45 cm	530 – 1940 m asl				throated Marten, ferret badger, [Greater] Hog Badger, Crab-eating Mongoose.
Coudrat (2020)	Nakai-Nam Thuen NPA (Thong Khacheng)	2020	Ground mammals Systematic, course (2.5km) Paired camera-traps at each station. 10 – 50 cm	50 stations 10,731 days 622 – 1709 m asl	141 records from 24 stations	886 – 1709 m asl	60 minutes	Asiatic Black Bear, Binturong, Common Palm Civet, Crab-eating Mongoose, ferret badger, [Greater] Hog Badger, Large Indian Civet, Leopard Cat, Masked Palm Civet, Spotted Linsang, Sun Bear, Weasel sp., Yellow-throated Marten
Rasphone et al., (2019)	Nam Et-Phou Louey NPA	2013, 2014, 2015,	Mainland Clouded Leopard and similar sized carnivores	60 – 80 stations per sampling	12 station records in	Not stated	30 minutes	Dhole, Asian [SIC] Golden Cat, Mainland Clouded Leopard,

Reference / source	Site name	Survey years	Target Camera-trapping method Height	Camera-trap Stations Camera-trap Days Altitude range (mean)	Owston's Civet records	Record altitude(s) (m asl)	Notional independence	Other carnivores recorded by camera-traps
		2016, 2017	Systematic. Spaced at 1 – 1.5 km between each station. Pairs of cameras at each station. ~35cm	block. 300 locations in total. 32,027 days 629 – 2185 (68% above 1500)	Nam Poung – Na Vaen 3 station records in Pha Daeng			Leopard Cat, Marbled Cat, Tiger, Crab-eating Mongoose, ferret badger, Greater Hog Badger, Yellow-throated Marten, Spotted Linsang, Asian [SIC] Black Bear, Sun Bear, Binturong, Common Palm Civet, Large Indian Civet, Masked Palm Civet, Small Indian Civet
Johnson et al., (2009).	Nam Et-Phou Louey NPA	2003 through to 2006	Tiger and prey populations. Systematic; 50 camera-traps set in	273 stations 8,499 days	One	1687 m asl	30 minutes	Stripe-backed Weasel, Yellow-throated Marten, [Greater] Hog Badger, Oriental [SIC] Small-clawed Otter, Large

Reference / source	**Site name**	**Survey years**	**Target** **Camera-trapping method** **Height**	**Camera-trap Stations** **Camera-trap Days** **Altitude range (mean)**	**Owston's Civet records**	**Record altitude(s) (m asl)**	**Notional independence**	**Other carnivores recorded by camera-traps**
			five 100 km^2 sampling blocks. One camera-trap-pair per 4 km^2 sub-unit ~45 cm	543 - 2,288 m. (77% were below 1,500 m in mixed evergreen–deciduous forest)				Indian Civet, Small Indian Civet, Spotted Linsang, Masked Palm Civet, Common Palm Civet, Crab-eating Mongoose, Leopard Cat, Asian [SIC] Golden Cat, Marbled Cat
Sisongkham (2010). [record also cited in cited in Sivilay et al. 2011.]	Phouchomvoy PPA	2010	Target not stated. Targeted. Spacing unknown, but based on Figure 2, some are very close together, within 100 metres. Height not stated.	32 camera-traps, assumed to be equivalent to stations. 982 days, but unclear if "effective days" or not.	20 photographs of 12 individuals; no basis for individual identifications or number of camera-trap stations.	Not stated	Not stated	Large Indian Civet, Crab-eating Mongoose

Reference / source	**Site name**	**Survey years**	**Target** **Camera-trapping method** **Height**	**Camera-trap Stations** **Camera-trap Days** **Altitude range (mean)**	**Owston's Civet records**	**Record altitude(s) (m asl)**	**Notional independence**	**Other carnivores recorded by camera-traps**
				Altitude range not stated.				
Leibniz-IZW / WWF - Laos / WWF – Vietnam, unpublished data.	Xe Sap NPA	2016	Ground-dwelling mammals and birds Systematic (2.5 km). Two cameras per station. ~30 cm	39 stations 6,684 days 618 - 1420 m asl (689 mean)	1 record	1379 m asl	60 minutes	Asian [SIC] Black Bear, Common Palm Civet, Crab-eating Mongoose, ferret badger, Leopard Cat, Masked Palm Civet, Spotted Linsang, Yellow-bellied weasel, Yellow-throated marten
Gray et al., (2014)	Xe Sap NPA	2012, 2013.	Ungulates and ground-dwelling carnivores Systematic; one camera-trap in a 1 km^2 grid cell (39 cells	39 stations 4,630 days 614 – 1492 m asl (mean 1096)	42 records from 11 camera-trap stations	1,066 - 1,492 m asl	30 minutes	Yellow-throated Marten, [Greater] Hog Badger, ferret badger, Large Indian Civet, Common Palm Civet, Masked Palm Civet, Spotted

Reference / source	Site name	Survey years	Target Camera-trapping method Height	Camera-trap Stations Camera-trap Days Altitude range (mean)	Owston's Civet records	Record altitude(s) (m asl)	Notional independence	Other carnivores recorded by camera-traps
			in total; randomly selected) 20 – 130 cm, mean = 45 cm					Linsang, Crab-eating Mongoose

Table 3.7. Camera-trapping efforts of 1,000 camera-trap-days or greater that failed to detect Owston's Civet *Chrotogale owstoni* in Lao PDR.

Reference	Site name	Survey years	Camera-trapping method	Target	Stations Days	Altitude (m asl) range (mean)	Camera-trap height	Other carnivores camera-trapped
SWG, Lao WCA, ICBF, Government	Khoun Xe–Nongma PPA	2018	Targeted. Clustered in the 'core area'; density 2-10 camera-trap/km^2.	Saola	120 stations 13,127 days	572-971	~50 cm	Asiatic Black Bear, Binturong, Common Palm Civet, Crab-eating Mongoose, ferret badger,

Reference	Site name	Survey years	Camera-trapping method	Target	Stations Days	Altitude (m asl) range (mean)	Camera-trap height	Other carnivores camera-trapped
of Laos, unpublished data.			All camera stations single.					[Greater] Hog Badger, Large Indian Civet, Leopard Cat, Masked Palm Civet, otter sp., Spotted Linsang, Sun Bear, Yellow-throated Marten, weasel sp.,
SWG, Lao WCA, ICBF, Government of Laos, unpublished data.	Khoun Xe–Nongma PPA	2019	Targeted. Clustered in the 'core area'; density 2-10 camera-trap/km^2. All camera stations single.	Saola	45 stations 6,606 days	591-887	~50 cm	Asiatic Black Bear, Common Palm Civet, Crab-eating Mongoose, ferret badger, Hog Badger, Large Indian Civet, Masked Palm Civet, Spotted Linsang, Yellow-throated Marten, weasel sp.,
SWG, ICBF, AA, Government of Laos, unpublished data.	Khoun Xe–Nongma PPA	2020	Targeted. Two to ten cameras clustered within 250m of a central point; effective density ca. 50 camera-traps/km^2. All camera stations single.	Saola	Not stated	Not stated	Not stated	Not stated
SWG, Lao WCA, ICBF, BCC,	Khoun Xe–Nongma PPA	2017, 2018	Targeted. Cameras clustered in 6 areas; density of 2-10 camera-	Multiple including: Crested	89 stations 16,000 days	487-963 (714)	~30 cm	Asiatic Black Bear, Binturong, Common Palm Civet, Crab-eating Mongoose, ferret badger, Hog

Reference	Site name	Survey years	Camera-trapping method	Target	Stations Days	Altitude (m asl) range (mean)	Camera-trap height	Other carnivores camera-trapped
Government of Laos, unpublished data.			trap/km^2. All camera stations single.	Argus, Edward's Pheasant, Owston's Civet, Large-antlered Muntjac, Saola				Badger, Large Indian Civet, Masked Palm Civet, otter sp., Spotted Linsang, Yellow-throated Marten.
SWG, Lao WCA, ICBF, Government of Laos, unpublished data.	Khoun Xe–Nongma PPA	2018, 2019	Targeted. Clustered in 'core area'; density ca. 2-10 camera-trap/km2. All camera stations single.	Saola	157 stations 22,771 days	572-930	~50cm	Asiatic Black Bear, Binturong, Common Palm Civet, Crab-eating Mongoose, ferret badger, Hog Badger, Large Indian Civet, Leopard Cat, Masked Palm Civet, otter sp., Spotted Linsang, Sun Bear, Yellow-throated Marten, weasel sp.,
Coudrat (2019).	Nakai – Nam Theun NPA (Nam Chae)	2018	Systematic, course (2.5 km) Paired camera-traps at each station.	Ground mammals	33 stations 4,509 days	542 – 1187	20 - 40 cm	ferret badger, Common Palm Civet, Masked Palm Civet, Yellow-throated Marten, Crab-eating Mongoose, Spotted Linsang, weasel sp., Sun Bear, Leopard Cat

Reference	Site name	Survey years	Camera-trapping method	Target	Stations Days	Altitude (m asl) range (mean)	Camera-trap height	Other carnivores camera-trapped
Coudrat (2017)	Nakai – Nam Theun NPA (Nam Chae)	2016, 2017	Mixed: 45 camera-traps with one camera in 1km^2. 6 additional camera-traps targeting otters and Sambar.	Ground mammals	49 stations 3,383 days	650 - 1044	20 - 40 cm	Common Palm Civet, ferret badger, weasel spp., Yellow-throated Marten, Crab-eating Mongoose, Masked Palm Civet, Large Indian Civet, Marbled Cat, Leopard Cat, Spotted Linsang
Coudrat (2019).	Nakai – Nam Theun NPA (Thong Khouang)	2019	Systematic, course (2.5 km) Paired camera-traps at each station.	Ground mammals	49 stations 4,488 days	539 - 1687	15 - 60 cm	ferret badger, Common Palm Civet, Masked Palm Civet, Yellow-throated Marten, Crab-eating Mongoose, Weasel sp., Large Indian Civet, Leopard Cat, Asiatic Black Bear
Coudrat (2020)	Nakai-Nam Thuen NPA (Nam Chae)	2020	Systematic, course (2.5 km) Paired camera-traps at each station.	Ground mammals	34 stations 5,734 days	549 - 1183	20 – 40 cm	Common Palm Civet, Crab-eating Mongoose, ferret badger, Large Indian Civet, Leopard Cat, Masked Palm Civet, Spotted Linsang, Weasel sp., Yellow-throated Marten
Coudrat (2020)	Nakai-Nam Thuen NPA (Thong Khouang)	2020	Systematic, course (2.5 km) Paired camera-traps at each station.	Ground mammals	49 stations 4,329 days	551 - 1708	15 – 40 cm	Common Palm Civet, Crab-eating Mongoose, ferret badger, [Greater] Hog Badger, Large Indian Civet, Leopard Cat, Masked Palm Civet, Spotted

Reference	Site name	Survey years	Camera-trapping method	Target	Stations Days	Altitude (m asl) range (mean)	Camera-trap height	Other carnivores camera-trapped
								Linsang, Weasel sp., Yellow-throated Marten
Vongkhamheng & Duckworth (2016).	Nam Mouane Area (Nam Ngiep 1 offset area)	2016	Targeted; unclear how many camera-traps / locality	Ground-dwelling wildlife	96 camera-traps 7200 days.	528–1296 (Thongnachang), 777–1500 (Nam Lak)	Variable but set for ground-dwelling wildlife	Binturong, Yellow-throated Marten, Striped-backed Weasel, weasel sp., otter sp., Spotted Linsang, Common Palm Civet, Masked Palm Civet, Large Indian Civet, Small-toothed Palm Civet, Crab-eating Mongoose, Leopard Cat, Hog Badger [provisional], ferret badger sp.,
SWG, Government of Laos, unpublished data.	Northwestern Bolikhamsai Province; Ban Thongmisay village use area	2019, 2020	Targeted. All camera stations single.	Saola	4 stations, Unknown number of days	649 - 894	~ 50 cm	Information not provided
SWG, WCS, IEWMP unpublished data.	Phou Sithone Endangered Species	2019, 2020	Targeted. All camera stations single.	Saola	46 stations, Unknown number of days	745-1431 (1000)	# 50 cm	Information not provided

Reference	Site name	Survey years	Camera-trapping method	Target	Stations Days	Altitude (m asl) range (mean)	Camera-trap height	Other carnivores camera-trapped
	Conservation Area							

Cambodia

Listed as “Presence Uncertain” in Timmins et al. (2016a), the only evidence of the possible presence of Owston’s Civet in Cambodia is two stuffed specimens seen in Phnom Tamao Zoo (Phnom Penh) in the late 1990s, and thought unlikely to have originated from outside the country (C.M. Poole pers. comm. in Dang Ngoc Can & Le Trong Tai 2010). The only protected area likely to hold the species is Virachey National Park; other Annamite or Indochinese species have been recorded here, including a form of Red-shanked Douc *Pygathrix nemaeus* with atypical morphology (McCann 2018). Extensive camera-trapping in Virachey National Park in the late 1990s and 2000s did not detect Owston’s Civet (see Gray et al., 2012). Subsequent efforts totalling to 12,475 camera-trap-nights from 2014 to 2020 have detected a range of other carnivores, including hunting-sensitive species such as Mainland Clouded Leopard *Neofelis nebulosa* (McCann et al., 2020), but no Owston’s Civets (G. McCann pers. comm. 2020). However, the far-eastern portion of Virachey National Park remains relatively under-surveyed (e.g., see Figure 1 in McCann et al., 2020); it is possible that it occurs there.

3.3.2 Habitats and Ecology

There has been no successful research on the ecology of Owston’s Civet. There was an attempt to radio-track two animals in 2000 in Cuc Phuong National Park, but neither were monitored for long enough to produce any insights into its ecology, and both died soon after release, one possibly eaten by a larger carnivore, and the second apparently shot (B. Long pers. comm. to DW 2019). All information on habitats, diet and other aspects of its ecology have been taken from camera-trap records, observations made in captivity and a very small number of observations of wild animals.

Elevational range

The lowest recorded elevations are approximately 80 to 90 m asl. (Thomas 1925; Table 3.7). The highest elevation recorded is 2,600 m asl and is based on a camera-trap record from the Van Ban district of Lao Cai province in Vietnam (S. Swan pers. comm. to S.

Roberton; Timmins et al., 2016a). Roberton (2007) traced 29 records from Vietnam, only 7 of which had elevation data: these were from 100 to 1850 m asl. Recorded elevation ranges for this species are dependent on camera-trap placement, relative survey effort within an elevation range, and the levels of historical and current hunting pressures, particularly in the more accessible lowlands. Of the 21 survey efforts that had stated or provided a camera-trapping elevation range, 67% were above 500m (Table 3.7 and Figure 3.1), with the majority between 500 to 2000m. Of the seven survey efforts that had elevation limits below 500 m, only two had the majority of their camera-trapping within lowland areas, in Hue and Quang Nam Saola Nature Reserves (CRES, unpublished data), and in Phong Dien Nature Reserve (Leibniz-IZW / WWF-Vietnam / Phong Dien NR / USAID, unpublished data). The majority of lowland records are from the Vietnamese portion of its range.

Table 3.7. Elevation ranges for camera-trapping efforts and recorded elevation ranges for Owston's Civet *Chrotogale owstoni* in China, Vietnam, and Lao PDR.

Reference / source	**Site name***	**Country**	**Survey year(s)**	**Camera-trapping elevations (m asl)**	**Owston's Civet record elevations (m asl)**
Tongkok et al., 2019. [in Chinese]	Xishuangbanna NNR	China	2018	696 – 1,035 (mean = 811)	713 – 912
Tongkok et al., 2020.	Xishuangbanna NNR	China	2018	739 – 869 (mean = 821)	739 – 868
Coudrat 2019.	Nakai – Nam Theun NP (Thong Khacheng)	Lao PDR	2018, 2019	612 – 1,705	708 – 1,658
Association Anoulak 2019	Nakai – Nam Theun NP (Thong Khacheng)	Lao PDR	2018, 2019	1,034 – 1,671	1,281 and 1299 (two stations only)
Coudrat et al., 2014.	Nakai-Nam Thuen NP	Lao PDR	2006 to 2011	530 – 1,940	1,033 – 1,675

Reference / source	Site name*	Country	Survey year(s)	Camera-trapping elevations (m asl)	Owston's Civet record elevations (m asl)
Coudrat 2020	Nakai-Nam Thuen NP (Thong Khacheng)	Lao PDR	2020	622 – 1,709	886 – 1,709
Leibniz-IZW et al., unpublished data	Xe Sap NPA	Lao PDR	2016	618 – 1,420 (mean = 689)	1,379 (one station only)
Gray et al., 2014.	Xe Sap NPA	Lao PDR	2012 2013	613 – 1,492 (mean = 1,096)	1,066 – 1,492
GreenViet, unpublished data	Ba Na Nui Chu NR	Vietnam	2016, 2017	117 – 1,081 (mean = 722)	506 – 1,030
SIE, unpublished data	Bidoup Nui Ba NP	Vietnam	2014, 2015	1,458 – 1,600	1,520 – 1,576
SIE et al., unpublished data.	Bidoup Nui Ba NP	Vietnam	2016, 2017	900 – 1,600	1,264 – 1,482
Leibniz-IZW et al., unpublished data.	Bidoup Nui Ba NP	Vietnam	2019, 2020	697 – 2,128	1,249 – 1,954
CRES, unpublished data.	Hue Saola NR	Vietnam	2015, 2016, 2017	142 – 451	165 – 363
Timmins & Trinh Viet Cuong 2001.	Huong Son SFE	Vietnam	1999	350 – 650	400
FFI Vietnam, unpublished data	Mu Cang Chai SHCA and Muong La WPF	Vietnam	2014, 2015	1,582 – 2,449 (mean = 2123)	1,863 – 2,449
Leibniz-IZW et al., unpublished data	Phong Dien NR	Vietnam	2018	59 – 1,269 (mean = 420)	82 – 619
Do Ngoc Cuong. 2004.	Pu Luong NR	Vietnam	2003, 2004, 2005	290 – 710 (majority over 600)	638 and 610 (two stations only)

Reference / source	Site name*	Country	Survey year(s)	Camera-trapping elevations (m asl)	Owston's Civet record elevations (m asl)
SVW et al., unpublished data	Pu Mat NP	Vietnam	2019	558 – 1,047 (mean = 777)	924 and 966 (two stations only)
SFNC (2000).	Pu Mat NP	Vietnam	1998, 1999	Unknown	400 – 1,000
Vinh University et al., unpublished data	Pu Mat NP	Vietnam	2018, 2019, 2020	292 – 1,361 (majority towards the upper limit)	968 – 1293
Long 2005. Long & Minh Hoang 2006.	Quang Nam province (various areas)	Vietnam	2002, 2003, 2004, 2005	210 – 1,640	625 (one station only)
Leibniz-IZW et al., unpublished data	Song Thanh NR	Vietnam	2017	175 – 1,271 (mean = 767)	1,178 (one station only)
Swan & O'Reilly (Eds.) (2004).	Van Ban NR (Hoang Lien – Van Van Ban)	Vietnam	2001	Unknown	900 – 2,600

** NP = National Park, NPA = National Protected Area, NR = Nature Reserve, NNR = National Nature Reserve, SFE = State Forestry Enterprise, SHCA = Species and Habitat Conservation Area, WPF = Watershed Protection Forest.*

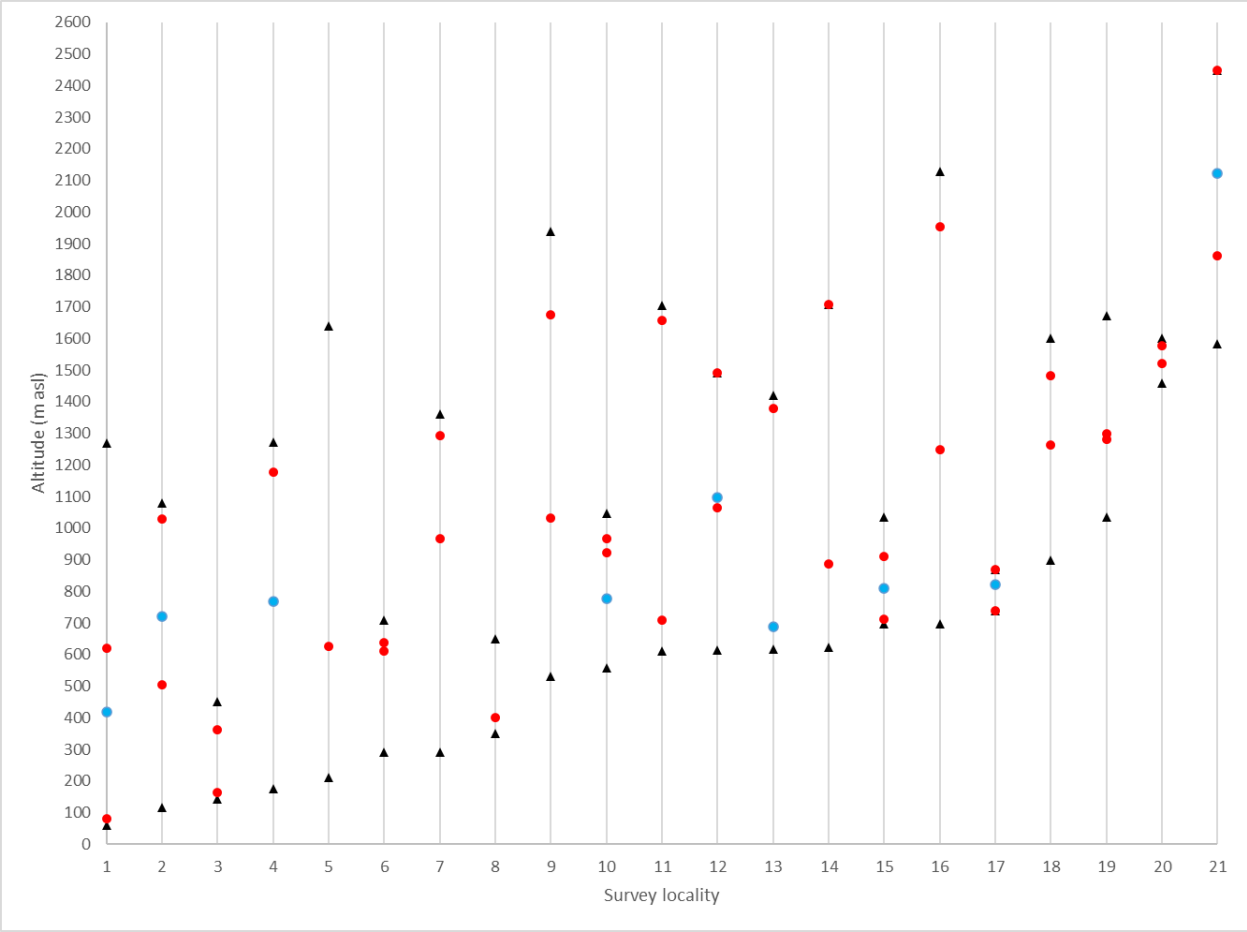


Figure 3.1. Altitudinal spread of survey effort using camera-traps and Owston's Civet *Chrotogale owstoni* records. Black triangles = lower / upper altitude camera-traps were set at. Red dots = altitude range that Owston's Civet was recorded at, if only one record then there is only a single red dot. Blue dots = average altitude that camera-traps were set at during the survey. Survey localities as follows: 1) Phong Dien NR, 2) Ba Na Nui Chu NR, 3) Hue Saola NR, 4) Song Thanh NR, 5) Quang Nam province, 6) Pu Luong NP, 7) Pu Mat NP, 8) Huong Son SFE, 9) Nakai Nam Theun NP, 10) Pu Mat NP, 11) Nakai Nam Theun NP, 12) and 13) Xe Sap NPA, 14) Nakai Nam Theun NP, 15) Xishuangbanna NNR, 16) Bi Doup NP, 17) Xishuangbanna NNR, 18) Bi Doup NP, 19) Nak Nam Theun NP, 20) Bi Doup NP and 21) Mu Cang Chai SHCA and Muong La WPF.

Habitats

Owston's Civet is strongly linked to evergreen forest biomes that have a non-harsh dry season (see Timmins et al. [2016a] for a full discussion). Historically it was more widely distributed in Vietnam than it currently is, reflecting the greater availability of wet

evergreen forest type habitats there. On the Lao PDR side, this habitat is more patchily distributed, even within blocks of evergreen forest (e.g., Coudrat et al., 2014). The majority of records in Lao PDR are from the Annamite Mountains, but the climate is much drier on the Lao PDR side of this mountain range than on the Vietnamese side; within evergreen forest biomes in Lao PDR, there are transitions into dry evergreen forest, and then into semi-evergreen forest as the elevation descends into the plains. The distribution of Owston's Civet in Lao PDR gives the clearest evidence of its affinity with climatically wet evergreen forest habitats. Records from China have been too few, and too often with inaccurate locality data, to make any conclusions about the habitats it is, or was, found in the country. The only site in China known to have produced recent verifiable records, Xishuangbanna NNR (Tongkok et al., 2019; 2020), is in the south of Yunnan province, and is part of the same broad ecoregion as other parts of its global range, i.e., tropical and sub-tropical moist broadleaf forests (Olson et al., 2001; Dinerstein et al., 2017). Xishuangbanna NNR represents some of the most northerly tropical evergreen forest within the Indochinese region.

Roberton (2007: Table 3.3) identified the following habitats based on records from across the range: montane evergreen forest (above 900 m asl), lowland evergreen forest (below 900 m asl), evergreen forest on limestone, and bamboo. No definitions or sources were provided for these habitat types, other than the altitudinal limits for montane and lowland evergreen forests. Although caution is needed in interpreting a camera-trap presence record as equivalent to use of a habitat, records collated from this review broadly support the macro-level habitats identified in Roberton (2007), and discussed in more detail in Timmins et al. (2016a). The only addition to habitat types are two records from pine forest within an evergreen forest biome: the species was recorded at high-altitude pine forest in Xe Sap NPA, Lao PDR (A. Tilker pers. comm. to DW, 2020) and in Bidoup-Nui Ba NP, Vietnam (Nguyen An pers. comm. to DW, 2020).

Diet

There has been no structured research on the diet of Owston's Civet in the wild, and most information comes from observations of captive animals and a few anecdotal observations. The skull and dentition suggest an invertebrate diet (Thomas 1927). It has been stated that Owston's Civet specialises in a diet of earthworms (Osgood 1932) because two collected specimens had earthworms in their stomachs. Roberton et al. (2002: 9) stated that "Hunters have reported that the stomach of Owston's palm civets always contains earthworms": no evidence or reference is given for this statement, and it is unclear if Osgood (1932) was the source for this. Evidence of earthworms, some fruits, and plant matter were found in faeces from two animals in a semi-wild area in Cuc Phuong National Park (Vietnam), placed there prior to a full release (Hill 1998; Rosenthal, in prep in Roberton et al., 2002). It is unclear how these faeces were distinguished from other co-occurring mammal or carnivore species which may have also been present, depending on the size and connectivity of the semi-wild area. High fruit content in captive diets has caused severe dental disease and premature mortalities in captivity (Clark 2012), leading to recommendations to increase the relative proportions of invertebrates and vertebrates. Captive animals in Vietnam (DW pers. obs.) and in the U.K. will readily take earthworms (J. Meek pers. comm. 2014 in Timmins et al., 2016a). In captivity, Owston's Civets will forage amongst leaf litter for live invertebrates (Roberton et al., 2002). Although there are very limited data, particularly from wild animals, the above suggests quite strongly that invertebrates form a significant part of the diet. It is unknown what proportion of the diet is made up of vertebrates. Long and Minh (2005) reported seeing a wild Owston's Civet hunting frogs in a streambed, but a captive animal broke a tooth when offered an adult chicken on the bone (L. King pers. comm. in Roberton et al., 2002).

Home range, habitat use and activity patterns

There is no information or data available on the home range or use of micro-habitat types. If the distribution and use of certain habitats is linked to the availability of wet or moist leaf litter, then Owston's Civet is likely to have localised habitat use within drier evergreen forest types, a theory partly supported by the distribution of camera-trap records within Lao PDR. Although primarily ground-dwelling, it has been observed to climb well in

captivity (Roberton et al., 2002; DW pers. obs.), and there is one observation of a wild animal seen 3 metres up a tree (Dang Ngoc Can & Le Trong Trai 2010). The evidence that it is primarily ground-dwelling comes from the relatively large number of records when in suitable habitats with relatively healthy populations of hunting-sensitive wildlife, as well as its absence in camera-trap surveys where ground-level hunting and the use of snares has been intense. It is thought to be mainly nocturnal (Timmins et al., 2016a), with observations of activity in captivity, including of wild-caught animals, from approximately 17:30 to 05:00 ICT (Indochina Time) (Roberton 2002). Data from the reviewed camera-trap records support that the species is predominantly nocturnal: records ranged from approximately 18:00 to 06:00 ICT. The only record outside of this range was a camera-trap record at 09:02 from Pu Luong NP, northern Vietnam (Do Ngoc Cuong 2004).

Breeding biology and ecology

The majority of camera-trap records are of solitary animals, photographed at night. The only duos that have been camera-trapped were in Nakai Nam-Thuen NP, Lao PDR in April 2007 and in May 2007 (Coudrat et al., 2014: Table 4), and in Bidoup Nui Ba NP, Vietnam in December 2016 (SIE et al., unpublished data). The following information on breeding biology comes from observations on captive animals bred in northern Vietnam and in the U.K. It has a gestation length of 75 – 90 days and reaches sexual maturity at around 12 - 18 months (Roberton et al., 2002). Once mature, adult males develop a bright-red colour and females a yellow colour on their underside, and females become orange around the vulva (Veron et al., 2004b). Captive females in northern Vietnam are reproductively active from January, with births from April to July, typically giving birth to one or two young, although triplets have been recorded (Roberton et al., 2002). Breeding attempts have been recorded as early as November in northern Vietnam. The reproductive cycles of Owston's Civet, and possible latitudinal differences, need to be clarified in view of the limited data, because the lack of knowledge is limiting the success of its conservation breeding programme (Willcox et al., 2019a), a priority action for small carnivore conservation (Willcox 2020; Willcox et al., 2020). Although its breeding is thought to be seasonally triggered with animals only giving birth once a year, it is found

as far south as Bidoup Nui Ba NP, an area without the strong winters of northern Vietnam; it is possible that the species could breed throughout the year within parts of its range.

3.3.3 Threats

The primary threat to Owston's Civet is general non-specific hunting, which is common and mostly uncontrolled across its distribution (e.g., Harrison et al., 2016; Tilker et al., 2019; Belecky & Gray 2020). This typically takes the form of snares, many thousands of which are set illegally inside protected areas in the region (see Gray et al. 2018).

Habitat loss, degradation and fragmentation has affected large parts of the range of Owston's Civet (Hansen et al., 2013; Namkhan et al., 2021); there is now very little lowland wet evergreen forest outside the protected areas in Indochina. It is unknown what, if any, tolerance it has towards habitat degradation, but it is unlikely to persist well outside non-forested habitats. However, habitat degradation and fragmentation often have a secondary, often overlooked, impact: they increase accessibility to hunting (Suarez et al., 2009; Alamgir et al., 2017; Hughes 2018). Habitat loss and fragmentation are likely to have an interactive effect on hunting within the range.

The main cause of illegal hunting in the range is the regional demand for wildlife, which affects nearly all ground-dwelling mammal species weighing 500 g or more (Bell et al., 2004). Although Owston's Civet is not thought to be specifically targeted, civets and other small carnivores are, and hunted civets are either processed and their meat sold to restaurants / traders, or if live, sold directly to restaurants or commercial facilities (so called 'wildlife farms'), where the laundering of illegally caught wildlife into legal facilities is common practice (WCS 2008). In the region, wild meat is consumed as a luxury and to confer social status (Drury 2011; Sandalj et al., 2016); it is rarely consumed for subsistence, particularly if the animal has a trade value. In Tam Ky town in Quang Nam province (Vietnam), five restaurants sold up to 364 kg of civet meat monthly (Bell et al., 2004). In Vinh city (Nghe An province, Vietnam), four restaurants reported selling 600 kg of civet meat per month between them (Roberton et al., 2003). Interview surveys in 2020

in Con Cuong town in Nghe An province revealed a similar level of demand; civets were one of the most consumed groups of wildlife, second only to wild pigs (SVW, unpublished data). There are similar levels of demand in larger urban centres and cities, where civet meat features prominently in wildlife demand and consumption surveys (WWF 2020).

There is some evidence to suggest that Owston's Civet is being impacted by Vietnam's growing online trade in live wildlife, most of which are sold as exotic pets. Between January and December 2020, systematic monitoring of the online small carnivore trade in Vietnam identified at least 16 cases of Owston's Civets being sold online (SVW unpublished data). However, this equates to only 3% of all civets observed or advertised in the online trade: the more common species traded or advertised were Common Palm Civet (113 records) and Small Indian Civet (76 records). The numbers of Owston's Civets being traded online is a small fraction of the number affected by uncontrolled snaring and other forms of hunting inside protected areas in the region, but it warrants ongoing monitoring. It is clear from the wildlife pet markets in Thailand and Indonesia that this type of demand can shift rapidly between species and become a significant threat within a short period of time, representing an issue for which solutions are difficult to provide once established.

Another potential threat is disease, including zoonoses. Viverridae have been identified as hosts or intermediates for a wide range of pathogens (Clark 2012; Wicker et al., 2017). This includes SARS (Guan et al., 2003), as well as H5N1 (Roberton et al., 2006), both of which are highly pathogenic. The latter was identified from captive Owston's Civets in Vietnam. Although research is ongoing into the origins of SARS-CoV-2 (Covid-19), it is highly probably that a mammal will be identified as the intermediate between the original host and humans. The use and consumption of civets increases the risk of disease spill-over to humans and so is a major public health concern, as well a significant threat to the long-term viability of the Owston's Civet conservation breeding programme (Willcox et al., 2020). An unknown threat is the risk of disease to wild populations. As human infractions and habitat loss increase, the distances between wildlife and human communities decrease. There is therefore a potential for diseases to impact wild Owston's Civet

populations, particularly if there are any nearby commercial breeding operations for mammals. However, this potential threat may be limited to lowland populations of Owston's Civets, including reintroduced populations; the majority of the populations are now mostly restricted to hill and montane forests in protected areas, where this threat will be of very limited impact relative to the main threat of snaring and other forms of illegal hunting.

3.4 Discussion

The majority of the historical distribution of Owston's Civet was in Vietnam, because this had the greatest availability of its main habitat of moist or wet evergreen forests. The current distribution above 500 m, particularly in Vietnam and China, is probably an artefact of hunting pressures in the lowlands (which are more accessible for snaring and other ground-based hunting methods), as well as habitat loss and the interactive effects of both factors, and the consequent survey biases towards higher elevation areas that are likely to retain healthier wildlife populations. The majority of historical records for Owston's Civet (Table 3.1), including records from the early to mid-1990s are from lowland habitats (e.g. Cuc Phuong National Park) or were from surveys that predominately targeted the lowlands at a site (e.g. Pu Mat National Park). Owston's Civet is no longer recorded in the majority of lowland sites, despite significant survey effort in some localities; this supports the statement that the current distribution of above 500m is mostly linked to overhunting and local extinction in the lowlands. However, this pattern is far easier to detect in Vietnam, where the species main habitat type is more homogenously distributed and therefore easier to detect. In Lao PDR some of the detection patterns at sites will reflect changes in rainfall patterns and therefore vegetation or habitat: over-hunting may not always be the main factor behind the apparent absence of Owston's Civets during camera-trapping efforts.

The records from Xishuangbanna NNR give some cause for optimism; prior to this, it was thought that the species was close to national extinction in China (Timmins et al., 2016a).

China's investment in its nationally important protected areas (e.g., areas that hold emblematic or high-profile species, such as the Asian Elephants *Elephas maximus* present in Xishuangbanna NNR), and its capacity for action is probably significantly higher than all other range states for Owston's Civet (DW pers. obs.). Whilst Vietnam is the priority country for Owston's Civet conservation, followed by Lao PDR, there appears to be significant potential to secure its *in-situ* conservation in China. Although its presence in northern Cambodia remains uncertain, it is not a priority country for surveys or for *in-situ* conservation; the species, if present, will only have a marginal occurrence in this part of its range.

The non-detections in Vietnam are all in habitat that historically would have supported the species (see Table 3.4); none of the sites retain any hunting-sensitive or trade-threatened species, and the small carnivore community is evidently now impoverished. It has been made locally extinct or reduced to very low numbers in a large number of protected areas within its global range. However, there are some sites that have retained relatively significant populations of the species. Bourret (1944) considered it to be the most common civet between the Fansipan mountains and the Black River in the northern highlands of Vietnam. Subsequent camera-trapping at sites within this area have, on two occasions 10 years apart, produced multiple records during non-targeted camera-trapping. Other sites that seem to have retained significant populations are Bidoup Nui Ba NP in southern Vietnam and Nakai Nam Theun NP in Lao PDR. However, of these three localities, only Nakai Nam Theun NP currently receives any significant conservation or protection efforts likely to be benefit Owston's Civet (see Association Anoulak 2020). The two sites that have produced significant numbers of Owston's Civet records in northern Vietnam, Mu Cang Chai SHCA and Muong La WPF, do receive some protection efforts, but these are directed at an arboreal primate, the Northern Black-crested Gibbon *Nomascus concolor*, and so are unlikely to benefit ground-dwelling species such as Owston's Civet. Bidoup Nui Ba NP in Vietnam has received increasing attention over the last five years because it appears to retain significant populations of globally threatened species, including the Critically Endangered Large-antlered Muntjac, but current efforts are focused on camera-trapping and other research. Other than government efforts, there

are no known attempts to protect the site, and the state typically under-funds relative to the scale of the threats and what is needed for functional protected areas.

The main threat to Owston's Civet remains hunting for the commercial wildlife trade and the use of snares set within protected areas to supply this demand. Although there has been significant investment since 2010 at some sites to establish snare removal teams, this is a resource-intensive enforcement intervention and it is essentially unproven. Sites within Owston's Civet range that have received sustained snare-removal are: Pu Mat NP (2016 – present), the Hue and Quang Nam Saola nature reserves (2014 – present), both in Vietnam, and Nakai Nam Thuen NP in Lao PDR (2016 – present). None of these sites can yet provide evidence that such efforts can reverse declines or even stabilise populations, including of Owston's Civets. The realisation that none of the protected areas that retain the species can be considered secure, led to the creation of a number of priority actions within the conservation strategy, focused on understanding some of the cultural drivers for snaring within local communities, increasing awareness at the national and policy level, and taking a more critical approach to current snare-removal efforts within protected areas (see Willcox et al., 2019a). Efforts to integrate wildlife crime prevention techniques into snare-removal efforts in protected areas will also be important (Viollaz et al., 2019).

A significant legal gap is its protection status in Vietnam; although one decree lists it as a priority species for conservation, a second decree, which regulates the commercial use of wildlife, allows Owston's Civet to be commercially farmed, and for confiscations of any live animals to be commercially traded (Table 3.1.). Given Vietnam's importance to its global conservation, this legislative gap needs addressing. The species may benefit from being listed on CITES; there is some trade in the species online in Vietnam and China and it is unknown whether these animals are sourced nationally or not. A CITES listing may also help to leverage better national protection in Vietnam. Additionally, the public health risks from trading and consuming civets are too high to justify and a complete ban on all civet trade and consumption within the region, including in China, now seems the only logical step; this would also benefit Owston's Civet conservation. There should be

efforts made to incorporate risk management and planning into the decision-making process for legal trade in small carnivore species, including within international conventions such as CITES.

Chapter 4: Application of MaxEnt species distribution modelling to Owston's Civet *Chrotogale owstoni*

4.1 Introduction

Maximum entropy (MaxEnt; Phillips et al., 2006) is a widely used technique for modelling species distribution and ecological niche modelling, including the potential impacts of future climate change scenarios. Recent updates to the model include the inclusion of a complementary log-log (cloglog) transform, which produces a habitat suitability between 0 and 1 (Phillips et al., 2017). The wide application of MaxEnt is partly because it allows modelling of presence-only data through the use of pseudo-absences by random sampling; this has enabled its application to a wide range of datasets including museum specimens, interview-derived occurrence data, and records of rare or poorly-known animal and plant species (Elith et al., 2011). It is easy to use and is generally thought to produce robust results when occurrence data with minor locality errors are used (Elith et al., 2006; Elith et al., 2011; Merow et al., 2013).

Species distribution models, including MaxEnt, include an important assumption: that the entire area being modelled for has been systematically or randomly sampled for the species of interest (Phillips et al., 2009; Royle et al., 2012). In practice this is rarely true and sampling tends to be biased towards areas that are accessible, with accessibility often determined by multiple geographic and socio-political factors (Barnes et al., 2014, Petersen et al., 2021). Additionally, publication bias in focal taxa and/or geographic scope (Hicksich et al., 2019) is another determinant of the availability of records for inclusion in species distribution models. These biases influence the levels of spatial autocorrelation, and therefore can lead to both false negatives (omission errors) and false positives (commission errors) in the predictive outputs of MaxEnt (Kramer-Schadt et al., 2013). As MaxEnt and other types of species distribution modelling are frequently used to identify management units or areas that are priorities for conservation (e.g., Hughes 2017),

failures to account for any sampling biases, and therefore the weaknesses in the predictive outputs of MaxEnt, can lead to misallocation of resources for species conservation.

Owston's Civet *Chrotogale owstoni* is a rare, globally Endangered species of civet (Viverridae) found only in Vietnam, Lao PDR and southern China (Timmins et al., 2016a). It is restricted to wet evergreen forests within these three countries. To assess the application of species distribution modelling to the conservation of Owston's Civet, confirmed occurrence records were used as input to MaxEnt. This was primarily to test whether the modelling algorithm could predict areas in northern Lao PDR and southern China which have historically received very low survey effort, but (based on the recent records of Owston's Civet from Xishuangbanna Nature Reserve in Yunnan province of China) could retain potentially significant populations and be priorities for surveys.

4.2 Methods

4.2.1 Occurrence records

Species occurrence records used for the model were collated and reviewed as part of the process for reviewing the global conservation status of Owston's Civet (Chapter 3): record inclusion followed Willcox et al. (2014). Since small carnivore diversity is high within Owston's Civet range, and therefore the potential for species misidentification is high, only verified records were included. This limited the dataset to camera-trap records and direct observations either supported by photographs and/or detailed field notes, or by observers familiar with the local or regional small carnivore community.

As the majority of modern Owston's Civet records are the product of camera-trap 'by-catch', locality accuracy was high (<1km) for the majority of records included. However, a small, but important subset of confirmed records had very limited locality data, particularly museum specimens and field records from between 1990 to 2005 (i.e. before

camera-trapping increased in application and intensity within the global range of the species). All of these records had locality information limited to a site e.g. “Cuc Phuong National Park, Vietnam”. For these, random coordinates were generated within the polygon for the protected area or district (Table 4.1); records which only had the province listed for locality were not included. Although the accuracy of these records was significantly less than more recent occurrence data, their inclusion was considered to be important for reducing the sampling or spatial bias that exists within the dataset (Figure 4.1). The majority of the sites in Table 4.1 are relatively small protected areas with uniform habitats (evergreen forest) and small altitudinal ranges; their inclusion is unlikely to have influenced model performance. Once duplicate records from the same camera-trap station were removed, the final occurrence data set was 217 confirmed records for Owston’s Civet.

Table 4.1. Confirmed records for Owston’s Civet *Chrotogale owstoni* that did not have coordinates but were included in the occurrence dataset.

Reference / source	Site / locality	Record type	Record Year
Hill, M, Hallam, d, Bradley, J (1996).	Ba Be NP	Confiscation - local hunters	1996
IEBR Museum - Hanoi, Vietnam: M.74.1471 (5)	Ban Thi-Xuan Lac NP	Specimen	1976
Vietnam National University-Hanoi, Zoological Museum. (HS125, 4.163.0)	Ban Thi-Xuan Lac NP	Specimen (Stuffed skin & skull)	1970
BMNH: 1927.12.1.90. Delacour & Lowe	Ngan Son (district)	Specimen (Skin & skull)	1927
Eve, R., Nguyen Viet Dung, Meijboom, M. (1998).	Vu Quang NP	Observation	1998
Timmins, RJ & Trinh Viet Cuong. (2001).	Huong Son SFE	Camera-trap	1999
Vietnam National University-Hanoi,	Chi Ne (commune)	Specimen (Skull)	1960

Reference / source	Site / locality	Record type	Record Year
Zoological Musuem. (HS125, 4.327cv79)			
AMNH, New York (87372).	Phong Tho (district)	Specimen (Skin)	1931
IEBR Museum - Hanoi, Vietnam: M.95.1350 (5)	Thien Hoa (commune)	Specimen	1974
Swan, SR and O'Reilly SMG (Eds). (2004).	Van Ban NR	Camera-trap	2002
Tordoff, A. Swan, S. Grindley, M. Siurua, H. (1999).	Hoang Lien NP	Interview & remains	1997
BMNH: 1933.4.1.229. Delacour & Lowe	Sa Pa (Chapa) (district)	Specimen (Skin & skull)	1933
SFNC, EC. (1998).	Pu Mat NP	Camera-trap	1998
Roberton, S. *pers. obs.*	Cuc Phuong NP	Observation	2001
Vietnam National University-Hanoi, Zoological Musuem. (HS125, 4.122.56)	Cuc Phuong NP	Specimen (Skull)	1963
Vietnam National University-Hanoi, Zoological Musuem. (PTB, 4.121.55)	Cuc Phuong NP	Specimen (Stuffed skin & skull)	1963
Vietnam National University-Hanoi, Zoological Musuem. (PTB, 4.122.56)	Cuc Phuong NP	Specimen (Stuffed skin)	1963
IEBR Museum - Hanoi, Vietnam: M.77.1376 (5)	Kha Cuu (commune)	Specimen	1975
SEE Vietnam Forest Programme (1997).	Ben En NP	Direct observation - skin	Unknown
SEE Vietnam Forest Programme (2000).	Ben En NP	Direct observation - remains	Unknown
Tordoff, A. Fanning, E. & Grindley, M. (2000).	Ben En NP	Interview & remains	1998
Dickinson and Van Ngoc Thinh (2006).	A Roang (commune)	Camera-trap	2006

Reference / source	Site / locality	Record type	Record Year
Le Trong Trai et al., (2004).	Na Hang NR	Interview & observed	2002
Cox (1994)	Na Hang NR	Photographed - villages	Unknown
Le Trong Dat *pers. obs.*	Cuc Phuong NP	Direct observation - locally caught animal	1994
Le Trong Dat *pers. obs.*	Cuc Phuong NP	Direct observation - wild animal	1998
Pu Luong FPD unpublished report, 2020	Pu Luong NP	Camera-trap	2020

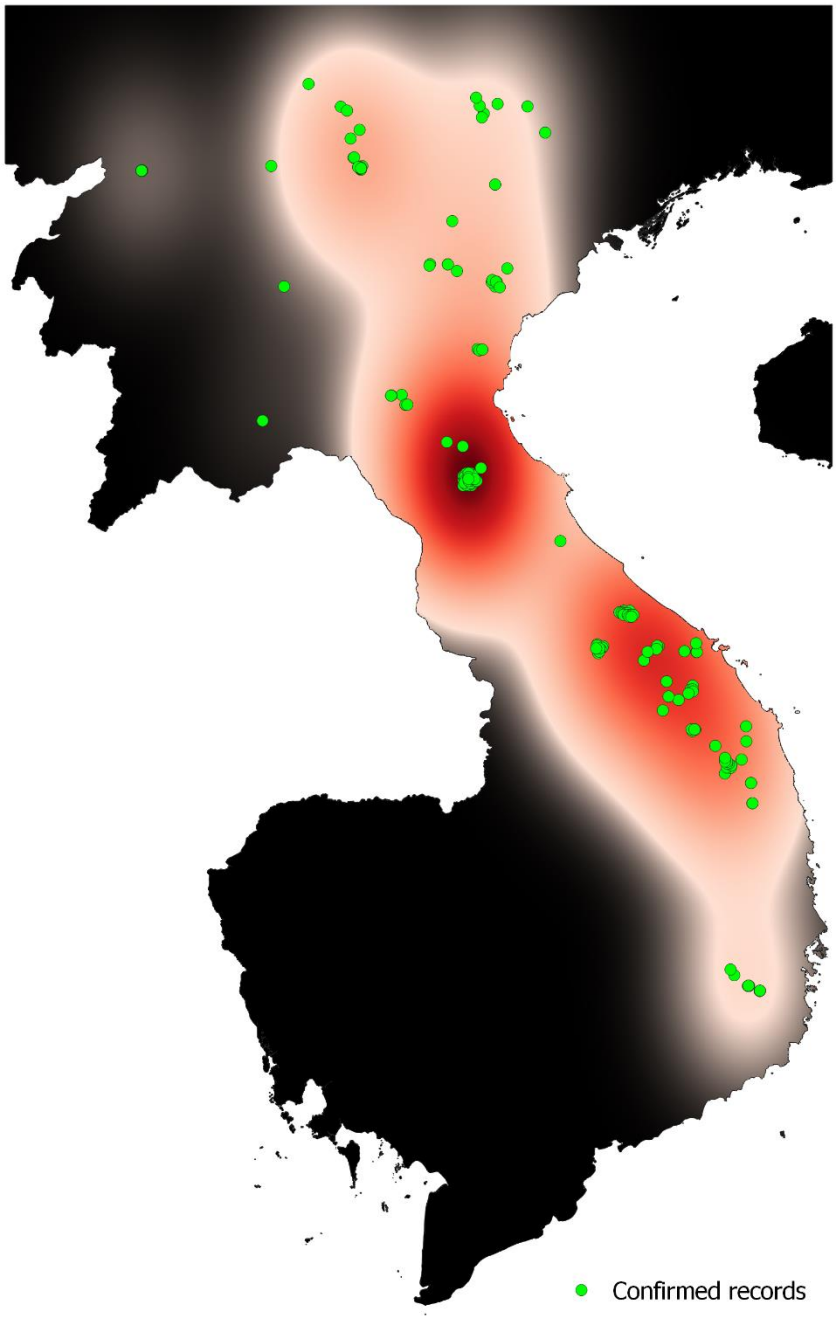


Figure 4.1. Confirmed Owston's Civet *Chrotogale owstoni* records and kernel density, which was used to produce a "bias file" for input into MaxEnt.

4.2.2 Variables

33 possible predictor variables were selected for based on the likelihood that these would have some influence on Owston's Civet occurrence / distribution. These included climatic variables (BioClim 1 – 19), elevation, terrain ruggedness, habitat, land cover classifications, euclidian distance from a protected area and human footprint (an index based on settlements, population density, roads). A full list of variables used is in Table 4.2.

Table 4.2. Predictor variables used in developing and testing the species distribution model for Owston's Civet *Chrotogale owstoni*.

Variable	Description	Extent, resolution	Reference
Bioclim maps (1 – 19)	Annual, range, minimum and maximum climatic variables	Global, 1km	Fick, S. E. & Hijmans, R. J. 2017. WorldClim 2: new 1km spatial resolution climate surfaces for global land areas. International Journal of Climatology 37 (12): 4302-4315. https://www.worldclim.org/data/worldclim21.html
Distance from protected area boundary	Euclidean distance from the boundary of a protected area polygon	Global, n/a	UNEP-WCMC. 2021. Protected Area Profile for Europe from the World Database of Protected Areas, June 2021. https://www.protectedplanet.net
Ecoregions	Ecoregions as defined by Olsen et al. 2001, and updated by Dinerstein et al. 2017	Global, n/a	Dinerstein et al., 2017. An Ecoregion-Based Approach to Protecting Half the Terrestrial Realm, BioScience, Volume 67, Issue 6, June 2017, Pages 534–545, https://doi.org/10.1093/biosci/bix014 https://ecoregions.appspot.com/
Elevation	Continuous elevation (median aggregation). GMTED2010	Global, 1km	Amatulli, G. et al., 2018. A suite of global, cross-scale topographic variables for environmental and biodiversity modeling. Scientific Data volume 5, Article number: 180040. DOI: doi:10.1038/sdata.2018.40. http://www.earthenv.org/topography
Human Footprint	Derived from built environment, Population density, Electric infrastructure, Croplands / pastures, Railways / roadways, Navigable waterways.	Global, 1km	Venter, O. et al., 2018. Last of the Wild Project, Version 3 (LWP-3): 2009 Human Footprint, 2018 Release. Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC). https://doi.org/10.7927/H46T0JQ4. https://sedac.ciesin.columbia.edu/data/set/wildareas-v3-2009-human-footprint

Variable	Description	Extent, resolution	Reference
	Scaled from 0 (lowest) to 50.		
Discrete classification (land cover)	23 classes of land cover based on the Land Cover Classification System (LCCS) developed by the United Nations (UN) Food and Agriculture Organization (FAO)	Global, 100m	Buchhorn, M. et al., 2019. Copernicus Global Land Service: Land Cover 100m: collection 3: epoch 2019: Globe 2020. https://zenodo.org/record/3939050#.YMW-nEylYhc
Fractional cover layers (forests)	% of a 100m pixel that is filled with forest class	Global, 100m	Buchhorn, M. et al., 2019. Copernicus Global Land Service: Land Cover 100m: collection 3: epoch 2019: Globe 2020. https://zenodo.org/record/3939050#.YMW-nEylYhc
Forest type	Discrete values of 0 to 5 for all pixels where the % cover in a 100m pixel exceed 1%.	Global, 100m	Buchhorn, M. et al., 2019. Copernicus Global Land Service: Land Cover 100m: collection 3: epoch 2019: Globe 2020. https://zenodo.org/record/3939050#.YMW-nEylYhc
Habitat heterogeneity: evenness	Evenness of EVI (Enhanced Vegetation Index), between 0 and 1	Global, 1km	Tuanmu, M.-N. & Jetz, W. 2015. A global, remote sensing-based characterization of terrestrial habitat heterogeneity for biodiversity and ecosystem modeling. Global Ecology and Biogeography. DOI: 10.1111/geb.12365. http://www.earthenv.org/texture
Habitat heterogeneity: dissimilarity	Difference in EVI between adjacent pixels, greater than 0	Global, 1km	Tuanmu, M.-N. & Jetz, W. 2015. A global, remote sensing-based characterization of terrestrial habitat heterogeneity for biodiversity and ecosystem modeling. Global Ecology and Biogeography. DOI: 10.1111/geb.12365. http://www.earthenv.org/texture
Habitat heterogeneity: variance	Dispersion of EVI combinations, between adjacent pixels, greater than 0	Global, 1km	Tuanmu, M.-N. & Jetz, W. 2015. A global, remote sensing-based characterization of terrestrial habitat heterogeneity for biodiversity and ecosystem modeling. Global Ecology and Biogeography. DOI: 10.1111/geb.12365. http://www.earthenv.org/texture
Habitat heterogeneity: homogeneity	Similarity of EVI between adjacent pixels, between 0 and 1	Global, 1km	Tuanmu, M.-N. & Jetz, W. 2015. A global, remote sensing-based characterization of terrestrial habitat heterogeneity for biodiversity and ecosystem modeling. Global Ecology and Biogeography. DOI: 10.1111/geb.12365. http://www.earthenv.org/texture
Terrain Ruggedness Index (TRI)	Mean of the absolute differences in elevation	Global, 1km	Amatulli, G., et al., 2018. A suite of global, cross-scale topographic variables for environmental and biodiversity modeling. Scientific Data volume 5,

Variable	Description	Extent, resolution	Reference
	between a focal cell and its 8 surrounding cells.		Article number: 180040. DOI: doi:10.1038/sdata.2018.40. http://www.earthenv.org/topography
Cloud Cover: annual mean	Mean annual cloud frequency, as a %	Global, 1km	Wilson, A. M, & Jetz, W. 2016. Remotely Sensed High-Resolution Global Cloud Dynamics for Predicting Ecosystem and Biodiversity Distributions. PLoS Biol 14(3): e1002415. doi:10.1371/journal.pbio.1002415 http://www.earthenv.org/cloud
Cloud cover: seasonality concentration	Seasonal cloud concentration index ranging from 0 (all months equally cloudy) to 100 (all clouds are observed in a single month)	Global, 1km	Wilson, A. M, & Jetz, W. 2016. Remotely Sensed High-Resolution Global Cloud Dynamics for Predicting Ecosystem and Biodiversity Distributions. PLoS Biol 14(3): e1002415. doi:10.1371/journal.pbio.1002415 http://www.earthenv.org/cloud

4.2.3 Modelling

A combination of R-4.1.0 (R Core Team, 2020) and MaxEnt version 3.4.1 (Phillips et al. [undated]) was used to test and develop all models. All maps used were resampled to a resolution of 1 km with nearest-neighbour sampling used if a map was at a higher resolution. To model the predicted habitat suitability, verified occurrence records and the variables (Table 4.2) were fitted using the algorithm of MaxEnt with the following settings: replicated run type = cross-validate, replicates = 5, regularisation multiplier = 0.5, extrapolate = off, maximum number of background points = 10,000. The relatively low regularisation multiplier and the absence of the extrapolate function (which predicts to regions outside of where the model is trained) were used because test runs using the default MaxEnt settings (regularisation multiplier = 1, extrapolate = on), including with the use of a bias file, produced predictions that were far outside the confirmed global range (e.g. Hainan Island, China).

4.2.4 Sampling bias

The majority of modern day (post-2010) records come from the Annamite Mountains which form part of the border between Lao PDR and Vietnam. This is an area of known

importance for biodiversity conservation; it has several endemic and highly threatened plant and animal species (e.g. CEPF 2020). Survey efforts here have mainly targeted Saola *Pseudoryx nghetinhensis* and to a lesser extent Edwards's Pheasant *Lophura edwardsi*, and have also included more systematic, gridded camera-trap survey designs aimed at understanding status and trends in a wider range of ground-dwelling, globally threatened mammals and birds. Many of the Owston's Civet records are by-products of these survey efforts, and the consequences of this uneven survey effort is the false perception that Owston's Civet mainly persists in the Annamite Mountains and, for the purposes of species distribution modelling, a clear sampling bias. Following the recommendations in Kramer-Schadt et al. (2013), spatial filtering was used to minimise the effects of uneven sampling effort within the global range of Owston's Civet. Spatial filtering of occurrence records should ideally be based on the known home-range size (e.g. see Kramer-Schadt et al., 2013), but for Owston's Civet no such data exist. Two arbitrary values were therefore selected for the sampling filter: 10 km and 2 km. The latter was used in a species distribution modelling exercise for a closely related species, Hoses's Civet *Dilpogale hosei* (Mathai et al., 2019). Occurrence records that were within these two distances from an existing record were excluded from the dataset. In addition to this spatial filtering, a bias file was created using the occurrence data points and used in MaxEnt. Target-background correction methods in MaxEnt (see Phillips et al., 2009), such as the use of bias file, can be developed using occurrence data from multiple taxa (e.g. all benthic organisms: Guillaumot et al., 2019), or through assigning values to cells for sampling effort or record density (e.g. Kramer-Schadt et al., 2013). As only the Owston's Civet records were verified and not all of these records were the result of camera-trapping efforts, and publicly available records of other carnivore or hunting-sensitive species, such as on GBFI, were known to have a large number of species misidentifications, only the occurrence data of Owston's Civets were used to generate a bias file (Figure 4.1). It was created using a kernel density estimation (e.g. Guillaumot et al., 2019); the bias file instructs the MaxEnt algorithm to select training points for the model outside of these oversampled cells. The bias file was created using the 'kde2d' function of the MASS R package (Ripley 2015).

4.2.5 Reducing multi-collinearity

To test for multi-collinearity amongst the predictor variables, Variance Inflation Factor (VIF) were calculated. A threshold of 3 was used and any predictor variables that had a VIF value above this were removed from the modelling (see Zuur et al., 2010). This produced a list of 17 variables (Table 4.3).

Table 4.3. Variation Inflation Factor scores for the final set of predictor variables used. VIF threshold set to th = 3, using the function vifstep in the R package USDM.

Variable name	**VIF (Variation Inflation Factor)**
BioClim12	1.952652
BioClim15	2.172008
BioClim18	1.826751
BioClim19	1.658872
BioClim2	2.194229
BioClim8	1.951703
Mean annual cloud cover	2.062697
Ecoregions	1.176309
Habitat evenness	1.590562
Forest type	2.615990
Forest cover	2.876341
Habitat homogeneity	2.388820
Human Footprint Index	1.792507
Euclidian distance to a protected area	1.289781
Land cover classification	2.096917
Terrain Ruggedness Index (TRI)	2.408566
Habitat variance	1.711383

4.2.6 Model evaluation

Models were initially assessed based on the area under the receiver-operator curve (AUC) (Fielding & Bell 1997). In MaxEnt, AUC is a measure of the discriminatory power of the model to distinguish between a randomly chosen presence point and a randomly

chosen background point. AUC values greater than 0.7 are considered to have good discriminatory power (e.g. Marmion et al., 2009). Two thresholds were used to assess the predicted area: 1) the minimum training presence complementary log-log threshold and 2) a 10th percentile training presence complementary log-log threshold. Assessing omission and commission errors were challenging as the present-day distribution in Lao PDR and China is too poorly known, particularly as its preferred habitat (wet evergreen forest) becomes more patchily distributed further west in Lao PDR. Commission errors were assessed based on the relative sizes of predicted areas (in km^2) in two regions where there is no possibility of its occurrence: 1) Hainan Island, China and 2) the Cardamom Mountains (south-western Cambodia) and the Mekong Delta (southern Cambodia and southern Vietnam). Although this could be considered subjective, the species is known to be restricted to wet evergreen forests within Indochina, and its broad global distribution is known. All variables in Table 4.3 were tested first, with a reduced model then tested based on the elimination of predictor variables that had contributions of < 1.5%. All models were given four possible treatments for reducing sampling bias: no treatment, a 2-km radius for occurrence points, a 10-km radius for occurrence points, and the use of the bias file.

4.3 Results

Land-cover classification, forest-type classification, habitat variance, habitat evenness and BioClim 15 were removed on the basis that these five predictor variables contributed <1.5% and none contributed significantly when assessed independently. The four different treatments did not alter the relative contributions of the predictor variables, other than the 10-km treatment which reduced the contribution of the fractional forest layer to <1.5%. However, as there was likely to be some co-linearity (though below the threshold of VIF <=3) between this predictor and the predictor variable used for evergreen forest, this was retained and the two habitat predictors assessed independently in the reduced model.

All reduced models (Tables 4.4 and 4.5), irrespective of which type of treatment was used for the sampling bias, had high AUC values of >0.9 and therefore model selection could not be based on AUC ranking. This is a common problem with species distribution models, particularly those that rely on presence-only data, where there is often strong spatial autocorrelation (Veloz 2009). There were very high commission errors when using the Minimum Training Presence, with predicted areas ranging from approximately 359,000 to 551,000 km^2 (Figures 4.2. through 4.9).

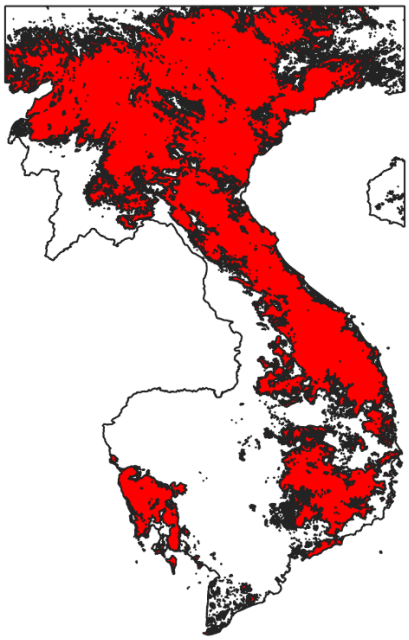


Figure 4.2. EF MPT no spatial filtering

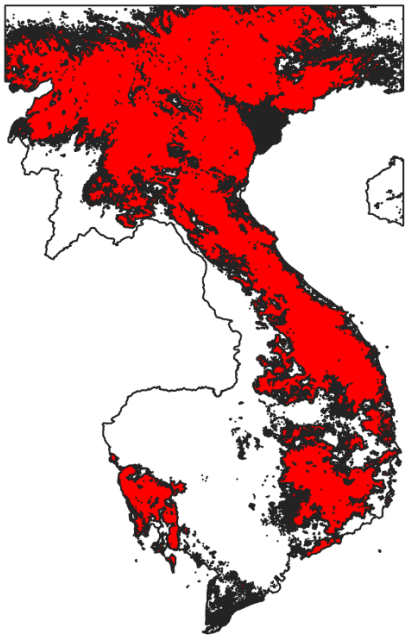


Figure 4.3. FF MPT no spatial filtering

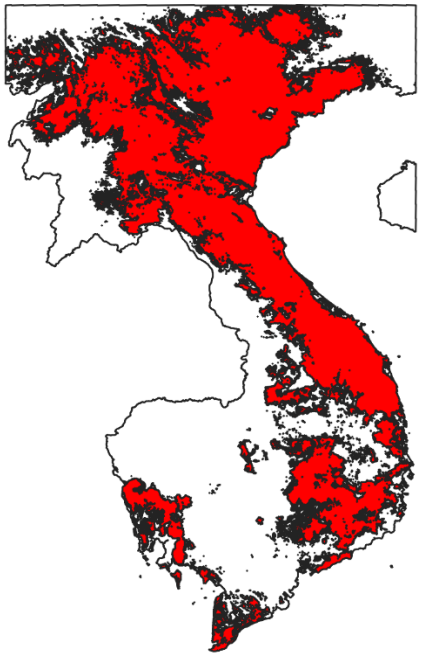


Figure 4.4. EF MPT 10 km radius

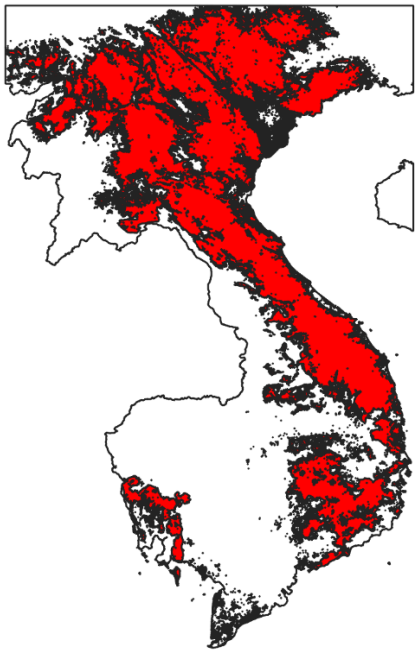


Figure 4.5. FF MPT 10 km radius

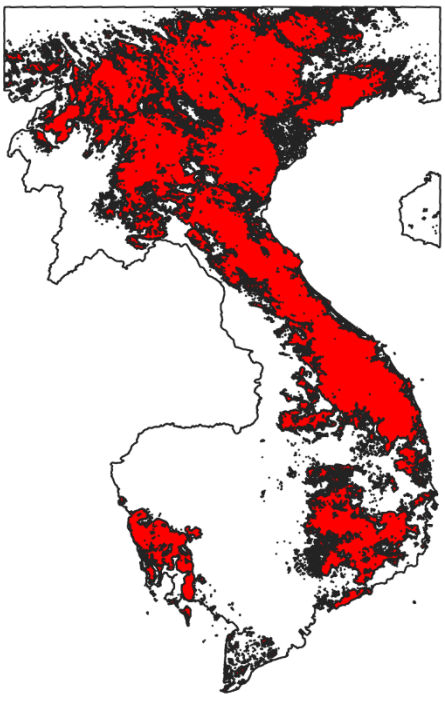


Figure 4.6. EF MPT 2 km radius

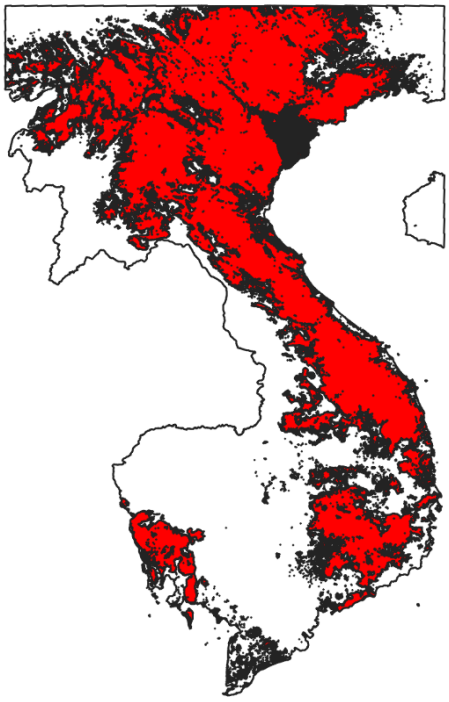


Figure 4.7. FF MPT 2 km radius

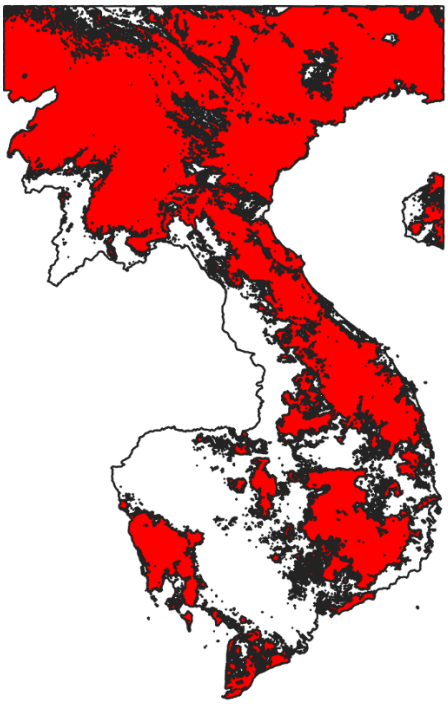


Figure 4.8. EF MPT bias file

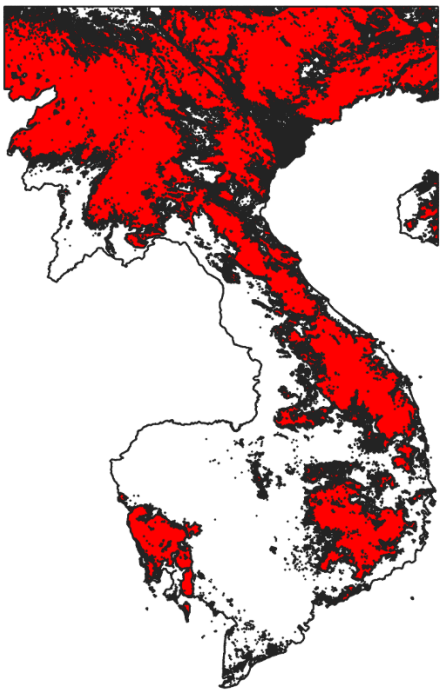


Figure 4.9. FF MPT bias file

Figures 4.2. through to 4.9. EF = Evergreen Forest, FF = Fractional Forest cover, 10PT = 10th Percentile Training Presence, MPT = Minimum Training Presence, 10 km radius = 10 km radius applied for filtering records, 2 km radius = 2 km radius applied for filtering records, bias file = bias file used.

Using the 10th Percentile Training Presence produced more realistic predictions ranging from approximately 36,000 to 79,000 km^2 (Figures 4.10 through 4.17), although all had commission errors, predicting it to be distributed into south-western Cambodia (the Cardamom Mountains) and/or the Mekong Delta. Between the two predictor variables used for forest (evergreen forest and fractional forest cover), fractional forest cover consistently produced fewer commission errors in Hainan Island (China), as well as in the Cardamom Mountains (south-western Cambodia), and the Mekong Delta (southern Vietnam). Final model selection was based on the lowest levels of detectable commission error, which was the use of the 10th Percentile Training Presence with no spatial filtering or bias file (Figure 4.18).

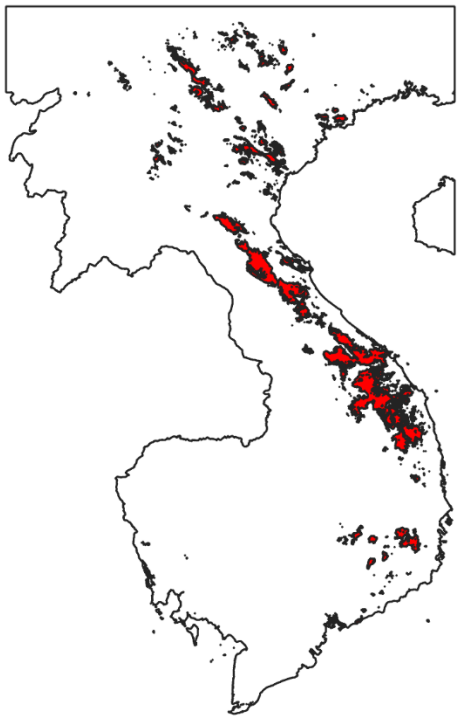


Figure 4.10. EF 10PT no spatial filtering.

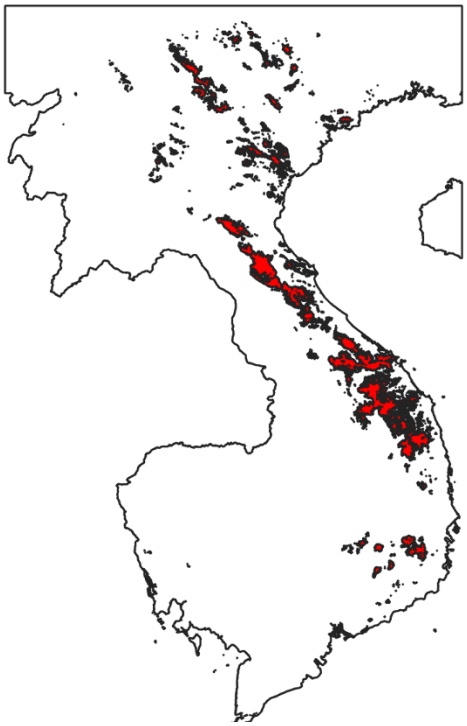


Figure 4.11. FF 10PT no spatial filtering.

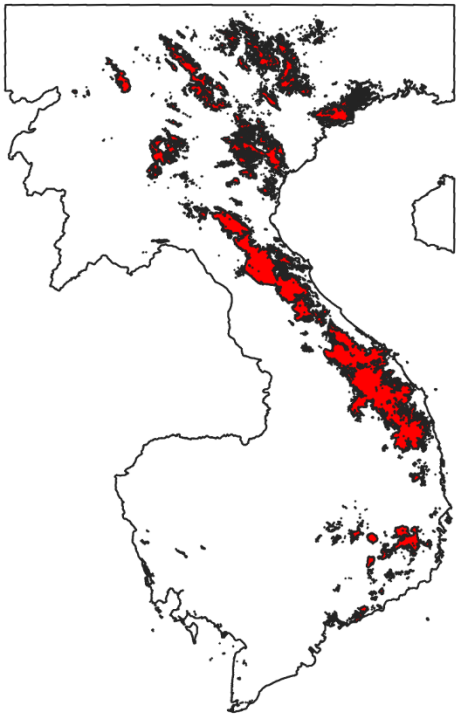


Figure 4.12. EF 10PT 10 km radius.

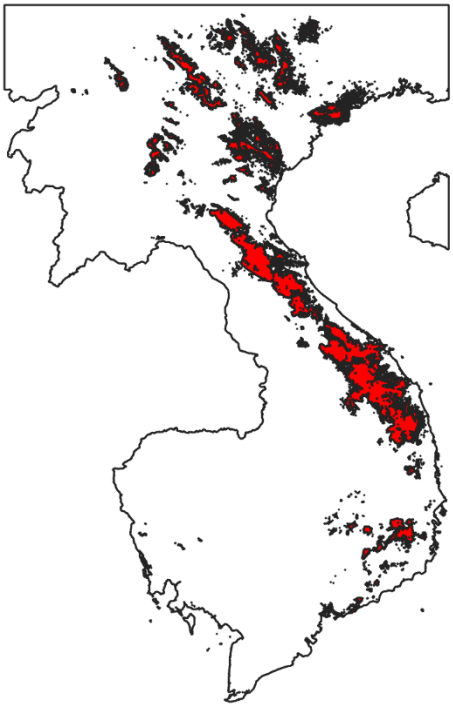


Figure 4.13. FF 10PT 10 km radius.

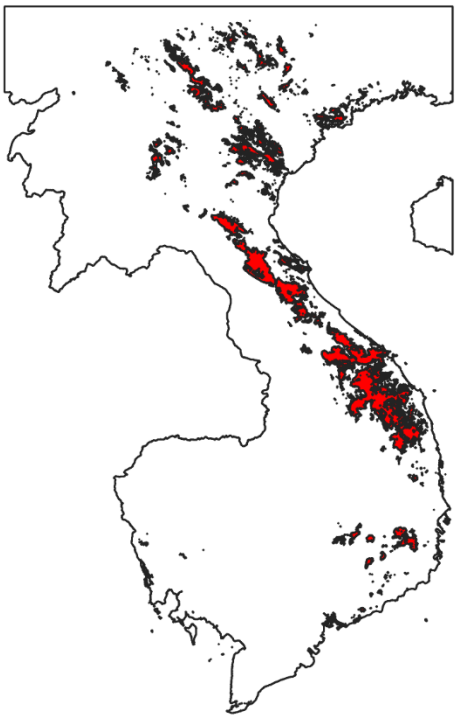


Figure 4.14. EF 10PT 2 km radius

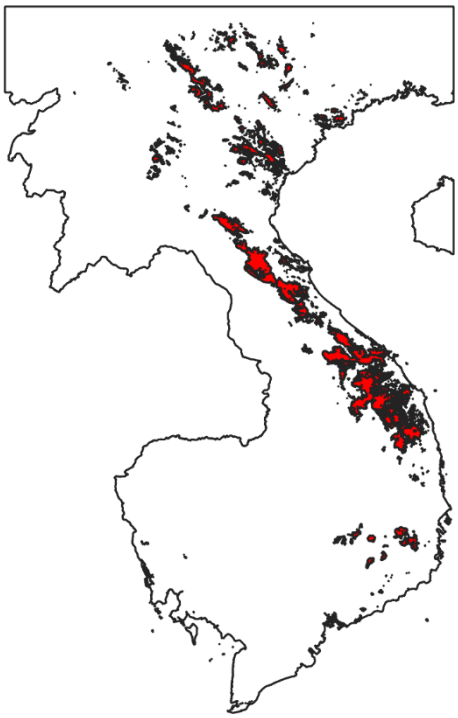


Figure 4.15. FF 10PT 2 km radius

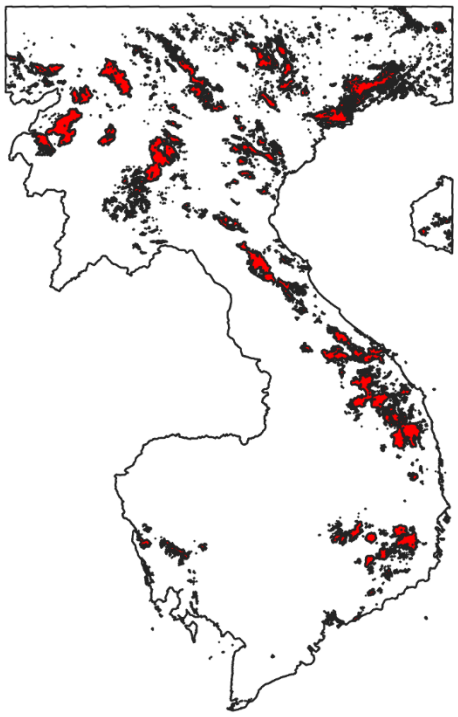


Figure 4.16. EF 10PT bias file

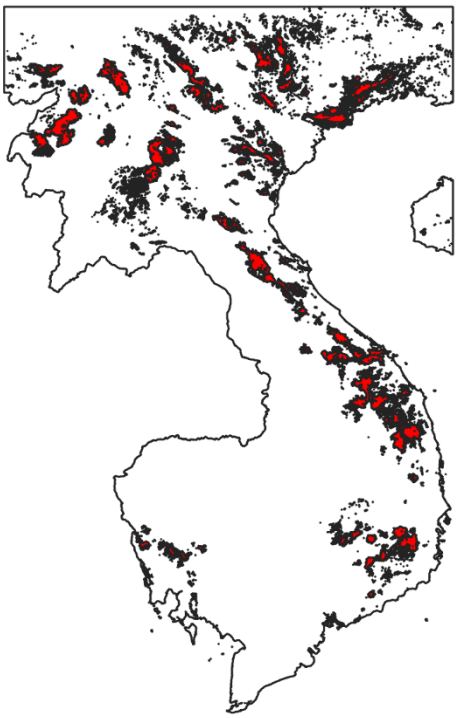


Figure 4.17. FF 10PT bias file

Figures 4.10. through to 4.17. EF = Evergreen Forest, FF = Fractional Forest cover, 10PT = 10th Percentile Training Presence, MPT = Minimum Training Presence, 10 km radius = 10 km radius applied for filtering records, 2 km radius = 2 km radius applied for filtering records, bias file = bias file used.

Predictor variables, ranked highest to lowest in terms of percentage contribution to the final model were as follows: euclidian distance to a protected area (24%), forest cover (18%), terrain ruggedness index (11%), ecoregions (10%), mean annual cloud cover (10%), mean temperature of wettest quarter (7%), mean diurnal range of temperature (5%), human footprint index (5%), annual precipitation (4%), precipitation of warmest quarter (3%) and precipitation of coldest quarter (3%). Although the final three environmental variables contributed relatively little to the final model, their exclusion would increase the relative importance of protected areas and fractional forest cover (which does not distinguish between evergreen forest and other forest types), thereby causing the model to predict to a large range of protected areas, many of which do not contain habitats that can support Owston's Civets. There were clear commission errors in all outputs produced by MaxEnt with predicted occurrence or suitable habitat predicted in Cardamom Mountains (Cambodia), Hainan Island (China), and the Mekong Delta (Cambodia and Vietnam) (Tables 4.4 and 4.5).

Table 4.4. Assessment for the commission error using evergreen forest as the primary habitat variable. MTP = Minimum Training Presence, 10 PTP = 10th Percentile Training Presence.

					Cloglog threshold		Predicted area (km^2)		Commission error – MTP (km^2)		Commission error - 10 PTP (km^2)	
Sampling treatment	No. training samples	No. test samples	Training AUC	Test AUC	MTP	10 PTP	MTP	10 PTP	Cambodia (Cardamom Mountains) and Mekong Delta	Hainan Island (China)	Cambodia (Cardamom Mountains) and Mekong Delta	Hainan Island (China)
none	144	36	0.97	0.96	0.0019	0.214	450,921	36,910	21,693	370	41	0
10 km	51	13	0.96	0.91	0.0121	0.2362	416,152	74,889	23,494	0	181	0
2 km	105	26	0.97	0.95	0.0036	0.2023	376,119	44,378	18,526	82	84	0
bias file	144	36	0.96	0.94	0.0115	0.3509	551,972	67,345	34,130	5,888	1,751	645

Table 4.5. Assessment for the commission error using fractional forest cover as the primary habitat variable. MTP = Minimum Training Presence, 10 PTP = 10th Percentile Training Presence.

					Cloglog threshold		Predicted area (km^2)		Commission error – MTP (km^2)		Commission error - 10 PTP (km^2)	
Sampling treatment	No. training samples	No. test samples	Training AUC	Test AUC	MTP	10 PTP	MTP	10 PTP	Cambodia (Cardamom Mountains) and Mekong Delta	Hainan Island (China)	Cambodia (Cardamom Mountains) and Mekong Delta	Hainan Island (China)
none	144	36	0.97	0.95	0.0013	0.2167	0.5349	0.0562	23,828	137	22	0
10 km	51	13	0.96	0.90	0.0169	0.2610	0.3866	0.0867	13,614	0	101	0
2 km	105	26	0.97	0.95	0.0030	0.2398	0.4548	0.0552	18,828	2	37	0
bias file	144	36	0.96	0.94	0.0197	0.3516	0.5026	0.0896	19,435	3,506	2,003	86

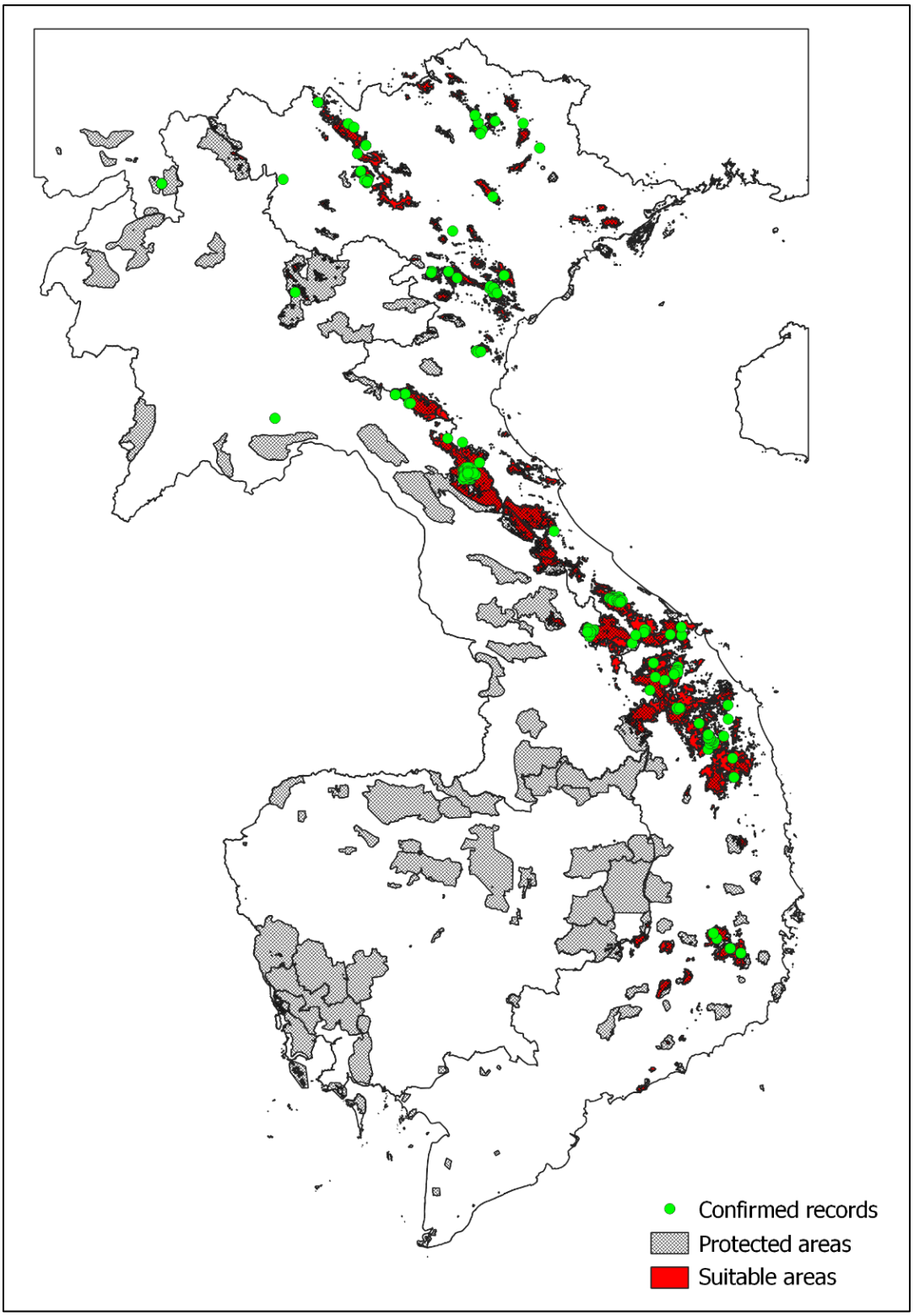


Figure 4.18. Final model using 10th Percentile Training Threshold with no spatial filtering and no bias file.

4.4 Discussion

The input of a relatively large number of accurate (<1km), confirmed occurrence records for Owston's Civet, and the use of three treatments for sampling bias, did not produce very accurate predictions of suitable areas for the species. In comparison to Kramer-Schadt et al. (2013), the predictive performance was highest in the models that did not use any spatial filtering or a bias file (i.e., background manipulation). However, these models also excluded areas, particularly in Lao PDR and southern China, which probably contain suitable habitat but have been under-surveyed for small carnivores. The low number of verifiable records of the species in southern China and in western Lao PDR (i.e., outside of the Annamite Mountains), weakens the predictive power of MaxEnt in these parts of the global range of Owston's Civet, and with so few records there is no accurate way to test for omission and commission errors in these two range countries. Although using the amount of suitable habitat predicted on Hainan Island, the Cardamom Mountains, and the Mekong Delta, as a way to assess commission error, was a very cautious approach, and would have excluded areas that probably contained suitable habitat, the final model still identified areas which are known to not contain Owston's Civets, particularly in the South of Vietnam (e.g. Ta Dung Nature Reserve and Bu Gia Map National Park), where the forest is dominated by semi-evergreen forest types; a habitat type that is known not to support the species. The final model will therefore still require very careful interpretation and ground-truthing before assigning any priority management / survey units or similar for Owston's Civet conservation, particularly any that fall outside what is currently considered to be best knowledge. Additionally, it is likely that any areas that have been excluded outside of the species core range in the Annamites and in the Northern Highlands in Vietnam, are probably peripheral or marginal habitats and therefore of low priority. This is particularly true for western Lao PDR, where the preferred evergreen forest habitat of the species becomes much more patchily distributed.

The 10-km spatial filtering, where all records within a 10-km radius of an occurrence where excluded, produced models that were overfitting to the Annamite Mountains. This

is probably because these parameters reduced the number of occurrence records used to train the model to only 64, the majority of which were located in the relatively over-surveyed Annamite Mountains. Although spatial clumping of occurrence records can sometimes be a true ecological signal, particularly in range-restricted species, in the case of Owston's Civet, this is probably an artefact of survey biases towards the Annamite Mountains, and its local extinction in the Vietnamese lowlands where the species would have probably been widespread within suitable evergreen forest habitat (the majority of historical records, including from the 1990s, were from lowland forests). A modelling approach that used more direct manipulation of the occurrence records, e.g., by only applying any spatial filtering to records from over-surveyed areas (i.e., the Annamite Mountains), and not to areas that have received very little survey effort in comparison (e.g., southern China) may have produced better results.

Although the final model (10% TP with no spatial filtering: Figure 4.18.) is considered to be the most accurate based on the relative absence of predicted areas in three regions that have no biogeographical connection to Owston's Civet (South-west Cambodia, the Mekong Delta and Hainan Island, China), this did restrict the identified areas to regions that have received significant sampling effort: the Annamite Mountains in Lao PDR and Vietnam, and to a lesser extent Northern Vietnam, including the Hoang Lien Mountains. Many of these areas are known priorities for Owston's Civet based on the availability of suitable habitat, the status of other trade-threatened species, and current investment in protected area management. Essentially, the restrictions placed on the model in order to reduce the likelihood of it predicting to regions outside of the distribution of the species (including within its main range countries), meant that it could only be used to re-confirm known areas and that it had very limited predictive power.

Part of the inability of the model to predict accurately to areas outside of known localities was because of the predictor variables used. Although significant effort was made to source accurate spatial information on the extent and quality of the main habitat type of the species (evergreen forest), all MaxEnt outputs contained commission errors. This included the use of recently developed maps that combine information on the extent of

moist broad-leaved forests in South-east Asia, as well an index of human impacts used to assess the condition of these forest types (Hansen et al., 2019). The maps and data developed by Hansen et al. (2019) do not include China, and so were not part of the final model outputs because this was a priority region in which to try to predict. Fractional forest cover (the proportion of a pixel that had forest cover, expressed as percentage between 1 and 100) performed better than maps for evergreen forests, to judge from the commission errors in Cambodia, Mekong Delta and Hainan Island. However, this might simply be because the fractional forest variable was based on more recent satellite imagery from 2019. Two categorical variables were used to try and restrict the predictions to areas of evergreen forest that were within ecoregions that support the species (WWF's Ecoregions: Dinerstein et al., 2017), and where there are relatively low human pressures (Human Footprint Index 2018: Venter et al., 2018). Although there were strong signals in both, and a clear restriction of the data to only several categories, none could fully compensate for false positives because of the four strongest continuous variables: proximity to protected areas, forest cover, terrain ruggedness, and cloud cover. Terrain ruggedness is often a good predictor of human access, and therefore of how intact a mammal population might be, particularly where there is a large and active commercial trade in various taxa. Its importance for predicting suitable habitat areas for Owston's Civet matches similar modelling efforts in the region (Tilker et al., 2019, 2020). The strong influence of distance to protected area in the modelling was to be expected, particularly as the species is part of a taxonomic group (small carnivores) that is deliberately targeted by the commercial wildlife trade and there are likely be few records outside of the protected area network in its three range countries; this is consistent with similar research on other carnivore taxa (e.g. Penjor et al., 2021). Although these patterns are probably influenced by survey biases (the majority of traced records were from within protected areas in mountainous terrain), there are no known records of Owston's Civet from outside of protected areas in the region. This is not thought to be a species that can exist in forest edge habitat or human-dominated peri-urban landscapes, such as Common Palm Civet *Paradoxurus hermaphroditus*, and the model produced supports this.

The absence of continuous predictor variables for hunting pressures and other anthropogenic influences on species distributions meant that the model predicted high (>80%) suitability to areas that formerly retained the species and where there are historical occurrence records, but where hunting pressures are known to have caused significant declines and probable local extinctions. Examples include Cuc Phuong National Park in northern Vietnam, where hunting-driven declines have been documented in a large range of mammal and bird species, including common, adaptable small carnivore species that should, based on detection rates in other protected areas in South-east Asia, be frequently detected (e.g., Common Palm Civet). Three of the six records for Cuc Phuong National Park came from the 1960s and none after 2001 (Table 4.1). Although excluding records such as these may have reduced the number of cells that had high predicted suitability within protected areas but were unlikely to retain populations, it would have also increased the prominence of the Annamite Mountains where 90% of modern-day occurrence records are located. Given the very high likelihood that a presence-only species distribution model was already going to be biased towards the areas that have received significant camera-trapping survey effort in the last 10 years, it was decided that including these older records would support a more robust species distribution model for Owston's Civets. Many of these areas are not priorities for the protection of extant populations, but these areas could, if threats can be controlled, be ideal reintroduction sites. The MaxEnt modelling has therefore helped to identify possible reintroduction sites.

There are inherent limitations in the ability of species distribution modelling to predict accurately the occurrence of rare or difficult-to-detect wildlife species, particularly in locations where the main determinant of presence is human factors such as hunting pressures. Survey (sampling) biases towards areas that retain important wildlife populations and/or are more accessible will always result in a geographically imbalanced set of occurrence data, and therefore an increased chance that a species distribution model is biased to these areas. Although efforts were made to consider sampling biases, none could adequately predict into under-surveyed areas without significant commission errors in regions far outside its global range, including to habitats or areas within Vietnam

that are known not to support the species. Better predictor variables may have compensated for these limitations; the absence of spatial layers that quantify hunting pressures or hunting intensity for South-east Asia, meant that the best model predicted suitable habitat within areas where it is already known, including where it is likely to be locally extinct, such as Cuc Phuong NP, Vietnam. Ecologically, Owston's Civet is a moderate specialist; although only known from wet evergreen forests, it has a quite a broad altitudinal range (100 to 2800 m asl), and prior to declines in the mid-20th Century would have once been found in large areas of Vietnam, Lao PDR and southern China. This probably makes it a difficult species to model its present-day distribution: it is not so specialised that environmental variables are very strong predictors (e.g., it is not a montane species), and because it is not a generalist, the use of spatial filtering may weaken any ecological signals that exist within its occurrence records.

Although some of these issues could be resolved with the use of combined presence - non-detection/absence datasets, there will always be a larger, more accessible presence-only dataset for rare and globally threatened species such as Owston's Civet. For species distribution models that use presence-only data and are focused on regions where there has been known, significant and rapid hunting-driven declines in vertebrate species, such as South-east Asia, the development of spatial predictor layers that can adequately quantify human pressures seems very important to the application of the MaxEnt algorithm in priority setting for species conservation.

Chapter 5: Conclusion

The research undertaken as part of this thesis included collating and reviewing over 600 records of Owston's Civet; once camera-trap station duplicates were removed, this resulted in 217 occurrence records, the majority of which are accurate to <1 km. This process has produced a comprehensive database on the distribution of this Endangered species and has helped to highlight its deteriorating global status, as well as where conservation efforts need to be prioritised, both in terms of sites (e.g., protected areas), as well as the interventions required. As a way of assessing the overall health or status of the carnivore community at these protected areas, presence records for carnivores in the cat (Felidae), dog (Canidae) and bear (Ursidae) families were also collated. This will enable rapid re-assessments of these other carnivore species on the IUCN Red List of Threatened Species and therefore the course-scale tracking of the status of these species over time. Many carnivore species are now confirmed to either be locally extinct or at extremely low populations across Lao PDR and Vietnam; recovery of the region's carnivore populations, including of Owston's Civets, will take significant conservation investment, including in *ex-situ* conservation breeding. Species distribution modelling using MaxEnt helped to re-confirm what the current site priorities are for Owston's Civets but it did not identify potential areas in southern China or northern Lao PDR where suitable habitat may be present. This is probably because of two factors: 1) the large number of confirmed records within the Annamite Mountains that forms the border between Lao PDR and Vietnam and 2) the absence of spatial layers that quantified hunting pressures / protected area management effectiveness. For rare species threatened by the illegal wildlife trade, development of spatial layers or predictor variables for hunting such as snaring intensity, access, local community disposition to hunting wildlife, and/or protected area effectiveness will be important developments if MaxEnt or similar algorithms are to have a greater role within species conservation prioritisation in South-east Asia.

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