

Predicted distribution of the banded civet *Hemigalus derbyanus* (Mammalia: Carnivora: Viverridae) on Borneo

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Wilting et al. (2016: Table 2) list all co-authors' affiliations.

Abstract. The banded civet *Hemigalus derbyanus* is a small, little-known civet with a geographical range comprising Indonesia (Kalimantan, Sumatra and some associated islands), Malaysia, Brunei, peninsular Myanmar and peninsular Thailand. Habitat loss and degradation are the main threats to the species leading to its classification as globally Vulnerable by The IUCN Red List of Threatened Species. The banded civet uses degraded habitat to some extent, but its exact ecological requirements and the extent of its dependence on primary forest are unknown. We analysed 65 (Balanced Model) and 104 (Spatial Filtering Model) location records of the banded civet to predict habitat suitability on Borneo. The resulting model predicted the majority of Borneo to be suitable habitat; although in general, the low-lying coastal areas, swamp forests and high-altitude areas were predicted to be unsuitable. Given this large area of predicted suitable habitat and the high overlap of habitat suitability and protected areas, the results from the distribution modelling do not suggest any urgent special conservation measures for the banded civet beyond maintenance of the current remaining forested habitat and protected areas. However protection and, in some cases, ecological rehabilitation of habitat corridors will also be important to ensure connectivity among populations in increasingly isolated protected areas.

Key words. Borneo Carnivore Symposium, Brunei, conservation priorities, habitat suitability index, Indonesia, Malaysia, species distribution modelling, survey gaps

Abstrak (Bahasa Indonesia). Musang Belang *Hemigalus derbyanus* merupakan kelompok musang kecil yang belum banyak dipahami. Persebaran geografisnya mencakup Indonesia (Kalimantan dan Sumatera), Malaysia, Brunei, Semenanjung Myanmar dan Semenanjung Thailand. Hilangnya habitat dan degradasi merupakan ancaman utama yang menyebabkan jenis ini diklasifikasikan Rentan menurut IUCN global Red List of Threatened Species. Pada tingkat tertentu musang ini akan memanfaatkan habitat yang terdegradasi, namun kebutuhan ekologisnya secara pasti serta tingkat ketergantungan terhadap hutan primer belum diketahui. Kami menganalisa 65 (Model Penyeimbang) dan 104 (Model Spasial Tersaring) catatan lokasi kehadiran Musang Belang guna memperkirakan kesesuaian habitat di Borneo. Hasil perkiraan permodelan menunjukkan mayoritas wilayah Borneo merupakan habitat yang sesuai, walaupun secara umum wilayah pesisir daerah rendah, hutan rawa dan wilayah dengan ketinggian tinggi diperkirakan tidak sesuai. Demikian luasnya wilayah yang diperkirakan sebagai habitat yang sesuai, serta tingginya tingkat tumpang tindih kesesuaian habitat dengan wilayah perlindungan, hasil dari pemodelan persebaran tidak merekomendasikan adanya tolak ukur konservasi yang khusus untuk musang ini, selain dari mempertahankan habitat berhutan yang tersisa dan wilayah perlindungan. Walau demikian, kami memahami bahwa perlindungan, dan dalam hal tertentu, rehabilitasi ekologi dari berbagai koridor habitat juga penting guna memastikan meningkatnya konektivitas diantara berbagai populasi pada wilayah perlindungan yang terisolasi.

Abstrak (Bahasa Malaysia). Musang Belang *Hemigalus derbyanus* adalah musang berbadan kecil yang jarang diketahui, yang mempunyai jangkauan geografi di Indonesia (Kalimantan dan Sumatera), Malaysia, Brunei, Semenanjung Myanmar dan Semenanjung Negara Thai. Kehilangan dan kemusnahan hutan adalah ancaman-ancaman utama spesis ini yang mengakibatkannya diklasifikasikan sebagai Lemah Ancaman (Vulnerable) dalam Senarai Data Merah Spesis Terancam IUCN (IUCN Red List of Threatened Species). Musang Belang mungkin menggunakan habitat yang didegradasi, tetapi keperluan ekologi sebenar dan kebergantungan kepada hutan primer tidak diketahui. Kami menganalisis 65 (model seimbang) dan 104 (Model yang ditapis secara spasial) rekod lokasi Musang Belang untuk membuat ramalan kesesuaian habitat di Borneo. Model yang dihasilkan meramalkan bahawa kebanyakan Borneo adalah habitat yang sesuai, walaupun secara amnya, kawasan tanah rendah persisiran pantai, hutan bencah and kawasan tanah tinggi diramalkan tidak sesuai. Disebabkan oleh ramalan kawasan habitat sesuai yang besar dan pertindihan yang besar dengan kawasan terlindung, keputusan dari model penyebaran ini tidak mengutarakan sebarang tindakan pemuliharaan yang khusus untuk Musang Belang melainkan penyelenggaraan kawasan terlindung dan kawasan hutan yang masih tinggal. Akan tetapi, kami mengenalpasti bahawa perlindungan dan pemuliharaan ekologi kawasan koridor juga penting di kawasan terlindung yang semakin terencil untuk memastikan kesinambungan wujud di antara populasi.

INTRODUCTION

The banded civet *Hemigalus derbyanus* (Gray), is a member of the civet family (Viverridae) which weighs 2.0–2.5 kg (Davis, 1962). Boldly patterned, with dark stripes across its entire body and face, it is one of the more easily identifiable members of this family (Fig. 1). It is native to Indonesia (Sumatra, Kalimantan and some associated islands), Malaysia (peninsular and Borneo), peninsular Thailand, peninsular Myanmar (Hon et al., 2008) and Brunei (Bennett, 2014). The diet of the banded civet is reported to include earthworms, insects and other small animals (Payne et al., 1998). Akin to most other civets, the banded civet is exclusively nocturnal (Ross et al., in press).

Although the banded civet has not been the subject of intensive study, habitat loss and degradation, coupled with the effects of hunting across its range have been inferred to have caused a population decline of 30% over the three generations to 2008 (15 years), leading to its classification as globally Vulnerable by The IUCN Red List of Threatened Species (Hon et al., 2008). The banded civet has been recorded from primary forest and logged forest in Sabah (e.g., Wilting et al., 2010; Brodie & Giodarno, 2011; Ross et al., in press) and Sarawak (Duckworth, 1995; Mathai et al., 2010; Brodie et al., 2015b), from logged forest in East Kalimantan (Rustam et al., 2012; B. Loken et al. unpublished data), and infrequently from oil palm (Ross et al., in press) and acacia (Giman et al., 2007) plantations. Population densities appear to be lower in logged forest than in neighbouring primary forest (Heydon & Bulloh, 1996). Brodie et al. (2015c) found local abundance of banded civet to be lower in selectively logged forest than in unlogged forest, and also negatively associated with road density, but both differences were only marginally statistically significant. The level to which the banded civet is tolerant of habitat modification is therefore not clear. The banded civet is a predominantly ground-dwelling species and, as such, is exposed to the threats of snares on the forest floor. In some parts of Borneo this species may be targeted by hunters for food (Murphy, 2007) and it may also suffer from retribution killings in areas where it takes domestic poultry (Hon et al., 2008).

The banded civet has been listed under CITES Appendix II since 1975. This requires an export permit for trade, but no import permit is needed unless stipulated by national law. Within Borneo, the banded civet is included on Schedule 2 of Sabah's Wildlife Conservation Enactment 1997, meaning that it cannot be hunted or traded without a licence. In Sarawak the species is protected under Part 2 of the First Schedule of the Wildlife Protection Ordinance 1998. In Brunei and Indonesia it is not legally protected. However, in Indonesia



Fig. 1. Banded civet *Hemigalus derbyanus* camera-trapped in Ulu Segama Forest Reserve, Sabah, Malaysia, on 10 April 2007 (Photograph by: Joanna Ross and Andrew Hearn).

no commercial harvest is allowed unless it is specifically mentioned in the harvest and trade quota set by the Ministry of Forestry (Shepherd & Shepherd, 2010).

RESULTS

Species occurrence records. Of 376 records of banded civet, 58% were obtained between 2001 and 2011 (Table 1). The majority of records (192) had a precision of 0.5 km, but 67 records were discounted because of low spatial precision. We used either 65 (Balanced Model) or 104 (Spatial Filtering Model) records to predict habitat suitability (see Kramer-Schadt et al., 2016). Records were obtained from across Borneo, although there was a distinct clustering of records in Sabah and a paucity from the much larger West Kalimantan province (Fig. 2). There were also few records from the high-altitude interior of the island. No spatially precise records were obtained from South Kalimantan or Brunei; the Brunei sighting detailed by Bennett (2014) was sourced too late for inclusion in the models.

Habitat associations. We used 12 respondents' opinions from a questionnaire survey to assess the suitability of different land-cover classes for the species. On the basis of these scorings (Table 2) it is apparent that water and ponds, burnt and bare areas, swamps, mangroves, agricultural areas and upper montane forest are considered unsuitable or poor habitat for banded civets. Lowland and upland forest together with lower montane and forest mosaics were considered to be suitable habitat, with lowland forest scoring the highest. There was, however, little consistency among respondents regarding the suitability ranking for swamp forest and upper montane forests, for which scores ranged from zero (unsuitable) to four (very good).

Habitat suitability index (HSI) model. The predictions from the model are that the majority of Borneo is suitable habitat for the banded civet (Fig. 3). The main exceptions are the low-lying coastal and peat swamp areas and the high-elevation interior. Much of Borneo's lowlands have already been deforested and this might explain why coastal areas were largely not predicted to be suitable habitat. Much of South and West Kalimantan were also predicted to be unsuitable

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Table 1. Summary of the occurrence records for the banded civet *Hemigalus derbyanus* on Borneo.

Spatial Precision	Total No. of Records	No. of Records in M ₁	No. of Records in M ₂	No. of Recent Records 2001–2011
Category 1 below 500 m	192	34	53	188
Category 2 500 m – 2 km	22	5	10	8
Category 3 2–5 km	95	26	41	16
Category 4 above 5 km	42	-	-	3
Category 5 (no coordinates*)	25	-	-	3
Total	376	65	104	218

M₁ = Balanced Model; M₂ = Spatial Filtering Model (10 km); *only coarse location description was available.

Table 2. Land-cover reclassification for the banded civet *Hemigalus derbyanus* based on the questionnaire results of 12 respondents working on carnivores on Borneo.

Land-cover Class	Mean of Reclassification	Range of Reclassifications
Lowland forest	3.75	3–4
Upland forest	3.00	1–4
Lower montane forest	2.30	1–4
Upper montane forest	1.50	0–4
Forest mosaics/lowland forest	2.50	*
Forest mosaics/upland forest	2.24	#
Swamp forest	1.70	0–4
Mangrove	0.70	0–2
Old plantations	1.67	0–3
Young plantations and crops	0.67	0–2
Burnt forest area	0.60	0–2
Mixed crops	0.56	0–3
Bare area	0.00	0–0
Water and fishponds	0.10	0–1
Water	0.00	0–0

*/#Calculated based on the mean of the reclassification of old plantation and *lowland forest or #upland forest, respectively.

Habitat suitability rank ranges from 0 (unsuitable) to 4 (most suitable); further detail, and on land-cover classes, in Kramer-Schadt et al. (2016).

habitat; however these regions have received little survey effort and predictions might reflect the pattern of surveys and search effort rather than true habitat associations. The mapped predictions of the habitat suitability index model in Fig. 3 need to be interpreted with caution (see Kramer-Schadt et al. (2016) for more details). Although search-effort bias has been minimised during the modelling, these areas in South and West Kalimantan might still be underrepresented in the distribution map especially if they are climatically distinct from the rest of Borneo. This is particularly likely for South Kalimantan which has a more pronounced dry season (see Kramer-Schadt et al., 2016: Fig. 3A). Thus, unless there are records sufficiently spatially precise to have been used in the model, the prediction cannot accurately reflect the

potential for occurrence in that region. In general, only further surveys can determine if the lower predictions are because of the minimal survey efforts or reflect a genuine lower suitability of these areas for the species, perhaps because of different climatic conditions or because large areas have been transformed to unsuitable land-cover (see Kramer-Schadt et al., 2016: Fig. 3B).

DISCUSSION

Habitat suitability. The current model suggests testable hypotheses regarding the habitat requirements and distribution of the banded civet. The use of respondent opinion to rank the suitability of habitats has some limitations, as reflected

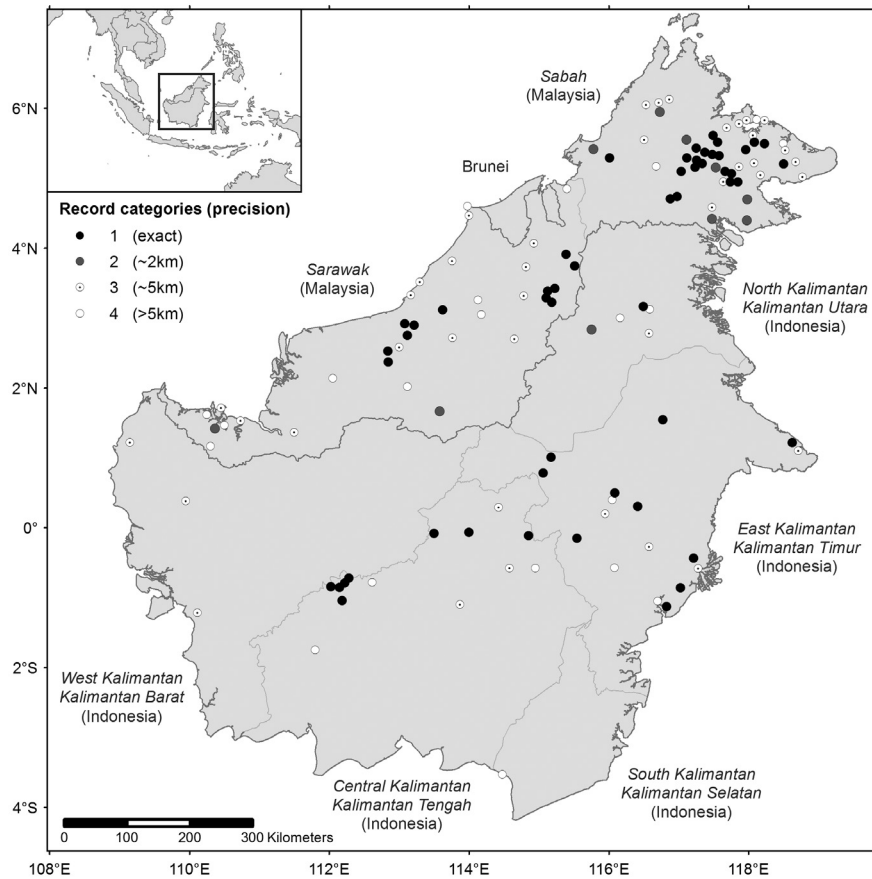


Fig. 2. Location of banded civet *Hemigalus derbyanus* occurrence records across Borneo, showing categories of spatial precision as well as country and state boundaries.

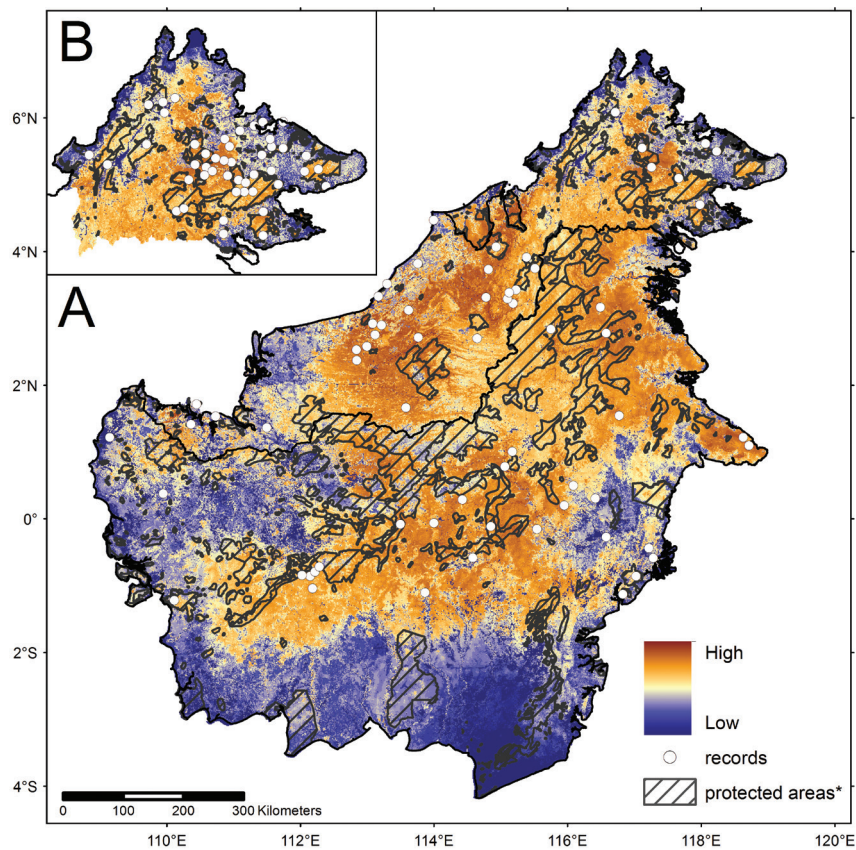


Fig. 3. Predictive Habitat Suitability Index (HSI) models for the banded civet *Hemigalus derbyanus*, including location records used in models. A, Balanced Model for the island of Borneo; B, Spatial Filtering Model for Sabah, Malaysia. Sources for protected area information: see Kramer-Schadt et al. (2016).

by the large range of scores for some of the habitats. This will lead to additional uncertainty in the final estimate of predicted habitat suitability. Nevertheless, the locations of the recent records revealed a similar pattern, in which lowland forest seems to be preferred habitat for banded civet. Jennings et al. (2013) analysed the habitat associations of the banded civet across its global range and considered it to be associated with lowland forest (below 900 m a.s.l.). However on Borneo, at least, this association may be less rigid (Brodie et al., 2015a). Few surveys have been conducted at high elevation and, on Borneo, where surveys have been conducted at higher elevations, the species has been recorded. A camera-trap survey of Crocker Range Park, Sabah, with average elevation of cameras at 1032 m a.s.l. recorded the banded civet at 75% of camera stations, including at the highest survey point at 1452 m a.s.l. (AJ Hearn, J Ross & DW Macdonald, unpublished data). This was the highest camera-trap station of that survey, so it does not necessarily represent the species's upper elevation limit in that area. The species has also been detected at 1500 m in the Kelabit Highlands (Sarawak) and 1600 m in the Ulu Padas region (Sabah; JF Brodie, unpublished data). However, these high-elevation records might result from a relatively localised association because of the presence of certain habitats; this association might not hold throughout its range. Also, few surveys have been conducted in peat swamp forest, but where high search effort has been invested, for example in Sabangau National Park, still over 6000 camera-trap-days did not detect the banded civet (Cheyne et al., 2010). Our model has predicted a large area of Borneo to be suitable habitat for the banded civet. For a fairly widespread species with no apparent strong association with any threatened habitat, at least according to the model results, there are no specific urgent conservation requirements at present above the maintenance of the current protected areas. However, we have identified some areas that seem of particular importance for banded civets.

Sabah, Malaysia. Most of Sabah's remaining forested areas are predicted to be suitable habitat for the banded civet. The central forest complex that includes Danum Valley, Maliau Basin and Imbak Canyon conservation areas is predicted to be highly suitable habitat; the commercial forest reserves that connect these totally protected areas are also predicted to be important. There are recent records of the banded civet from all these areas (Brodie & Giordano, 2011; Matsubayashi et al., 2011; Ross et al., in press). Much of eastern Sabah is now covered with oil palm plantations; a key area for conservation in this region is Tabin Wildlife Reserve (which links to the Lower Kinabatangan through the Segama Conservation Area and Kulamba Wildlife Reserve) and the presence of the banded civet has recently been confirmed by camera-trap in this reserve (AJ Hearn & J Ross, unpublished data).

Sarawak, Malaysia. A large portion of Sarawak is predicted by the model to be suitable habitat for banded civets. High-elevation areas such as Bukit Batu are predicted to be less suitable than is the remainder of the state, as are the coastal areas, although the species has been recorded at sea-level in Similajau National Park, in coastal lowland dipterocarp

forest (Duckworth, 1995). Most records, however, are from non-protected areas. Although this may reflect sampling bias to some degree, these populations might be more vulnerable to anthropogenic change than are others so might warrant further monitoring. Gunung Mulu National Park was also predicted by the models to be good habitat and there are records from this area as well as Pulong Tau National Park and the proposed Hose Mountains National Park (JF Brodie, unpublished data). Interestingly, there are several records from the far south-west of Sarawak, where the model has predicted the habitat to be of low suitability; these records correspond to the Penrissen Range where records have only low spatial precision.

Brunei Darussalam. Although there were no records of the species from Brunei, much of the country was predicted to be suitable habitat, with the exception of the coastal areas. Ulu Temburong National Park is a priority area in Brunei. Indeed, a record from this National Park has now been traced (Bennett, 2014) and there are also unconfirmed records from Tasek Merimbun Heritage Park, which is also predicted to be suitable. Another area likely to be important is the Labi Hills (Sungai Ingei Conservation) Protection Forest, which together with Gunung Mulu National Park, forms a large trans-boundary area. As the banded civet has been recorded from Gunung Mulu, it seems possible that it would also be present in other areas of the same forest block. Increased survey effort in Brunei could test these predictions.

East Kalimantan and North Kalimantan, Indonesia. A high proportion of East Kalimantan was predicted to be suitable habitat for the banded civet. Like other areas of Borneo, most coastal areas were predicted to be of low suitability, although the species has been recorded in the Sungai Wain Protection Forest, consisting of coastal lowland dipterocarp forest (30–140 m a.s.l.). Kayan Mentarang National Park in North Kalimantan was predicted to be particularly suitable, as was Malinau Basin which is currently managed as production forest. An important area of lowland forest that forms a link between North Kalimantan and Sabah is Sebuku–Sembakung National Park. This area covers a range of habitat from mangrove to hill forest, but is currently threatened by proposals for large-scale oil palm plantations.

South Kalimantan, Indonesia. South Kalimantan was predicted to be poor habitat for the banded civet and we received no records from this area. This province is, however, relatively understudied and mammal distribution there is consequently poorly understood. South Kalimantan has a more intense dry season than the rest of Borneo (see above), and given that the northern limit of the banded civet's global range does not include regions with a strong dry season, the species might truly be absent from much of South Kalimantan.

Central Kalimantan, Indonesia. The low elevation extensive peat swamp forests were predicted to be unsuitable habitat for the banded civet. Long-term camera-trap surveys of Sabangau National Park have failed to record this species (Cheyne et al., 2010) and this might have influenced respondents'

classification of swamp forest as low suitability. The higher elevation areas in the north of the province were predicted to be more suitable habitat and there are several records from this area. In particular the area in and around Bukit Baka Bukit Raya National Park and the contiguous Bukit Batikap Nature Reserve is predicted to be relatively good habitat.

West Kalimantan, Indonesia. We received few records for the banded civet from West Kalimantan and our model predicted most of this province to be unsuitable for it (see above). Key protected areas in West Kalimantan include Gunung Palung National Park and Gunung Niut Penrisen Nature Reserve. Both these areas, however, are threatened by the expansion of oil palm plantations. The most suitable areas were predicted by the models to be in the east of this province.

General conclusions. The banded civet appears to inhabit the majority of Borneo, although records were sparse from the south of the island. It does not appear to be a specialist of any particular forest type. Extreme lowlands and uplands, in general, were predicted to be unsuitable. In the case of the lowlands, this might reflect the extensive deforestation of lowland Borneo for agriculture rather than an inherent unsuitability. Camera-trapping too recent for inclusion in this model suggests that forest at around 1000 m and up to at least 1600 m a.s.l. is actually suitable habitat and the prediction of these altitudes as unsuitable reflected a lack of spatially precise records from them rather than an inherent unsuitability. Recent records from fragmented habitats such as the Lower Kinabatangan Wildlife Sanctuary in Sabah and logged forests in several areas of Borneo are encouraging and suggest that the banded civet is able to use or at least cross fragmented, disturbed habitats. However, it is not presently known how far the species will disperse, or how long it will persist in isolated areas. There is, however, a low understanding of the ecological requirements of this species. The data used to build our predictive model were derived primarily from incidental sightings and camera-trap records, often from surveys designed to target other, usually larger species, in which camera-trap placement might not be appropriate for smaller carnivores. The banded civet will benefit from targeted research specifically:

1. To determine its exact habitat requirements, determine:
 - a. The extent to which it will use degraded habitats;
 - b. The extent of its reliance on primary forest;
 - c. The characteristics of unsuitable habitat and size of those patches that constitute a barrier to its movement;
 - d. The characteristics of land that will function as habitat corridors;
 - e. The preferred elevation range and any regional variation in this.
2. Radio-tracking studies to determine range size and therefore the area needed for viable populations.
3. The frequency with which the banded civet is hunted, including how often it is caught as by-catch and regional variation in hunting patterns.

Like all species, it will benefit from the maintenance and restoration of connecting forest corridors between larger, otherwise isolated, forest blocks, and especially those corridors that would allow movement through oil palm and other agricultural plantations.

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