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Original contributions and short notes about wild cats are welcome
Send contributions and observations to ch.breitenmoser@kora.ch.

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Editors: Christine & Urs Breitenmoser
Co-chairs IUCN/SSC
Cat Specialist Group
KORA, Talgut-Centrum 5, 3063 Ittigen
Switzerland
Mobile ++41(79) 789 84 65 (C)
Mobile ++41(79) 410 14 39 (U)
<u.breitenmoser@kora.ch>
<ch.breitenmoser@kora.ch>

Associate Editors: Juan Reppucci
Sugoto Roy
Giridhar Malla
Maximilian Allen
Roland Bürki

Technical Editor: Eline Brouwer

Cover Photo: A manul kitten passes through its mom's legs during a brief moment at their den. Taken by Sebastian Kennerknecht while leading a photo tour through his company Cat Expeditions

JOSEPH K. CHARLES^{1*} AND BEE BIAW ANG¹

Discovery of five felids in Sungai Ingei Conservation Forest in Brunei Darussalam, Borneo

This is the first camera trap discovery of the presence of all five Bornean felids in the pristine, undisturbed Sungai Ingei Conservation Forest of Brunei Darussalam in 2010–2011 – Bornean clouded leopard *Neofelis diardi borneensis*, marbled cat *Pardofelis marmorata*, flat-headed cat *Prionailurus planiceps*, leopard cat *Prionailurus bengalensis* and the endemic Borneo bay cat *Catopuma badia*. Camera trapping during the Sungai Ingei Faunal Biodiversity Survey from 2009–2012 involved the deployment of 82 camera traps with a trapping effort of 51,202 trap-nights. When compared to other sites in Borneo, all the cats in this site showed early detections, bay cat by day 37, flat-headed cat by day 39, clouded leopard by day 43, marbled cat by day 54 and leopard cat by day 92. In term of independent images, the most detected cat was the clouded leopard with 59 images, followed by leopard cat (24), bay cat (18), marbled cat (12) and flat-headed cat (5). The absence of human disturbance in this forest is probably reflected in early detections and number of independent images. This is also the first record of the bay cat in Brunei Darussalam with the images being of the red-brown morph. The flat-headed cat was detected in only 2 of the 6 camera trapping sites that were associated with aquatic habitats while the other felids were recorded in 5–6 sites. This is the only site in Borneo where it is rare and unique to have all 5 felids in a small protected forest underscoring the value of this pristine undisturbed forest with lack of total disturbance for the presence and survival of these felids.

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At a time when forest ecosystems in Borneo are facing massive anthropogenic disturbances such as large-scale commercial logging, conversion of forests into plantations, other agricultural practices, and clearing of forested land for development with consequent biodiversity losses (Kinnaid et al. 2003, Sodhi et al. 2004), our discovery of the presence of all the five Bornean felids in a small protected forest in Brunei Darussalam reveals the importance of small but pristine and undisturbed forested areas for harbouring endangered species.

Borneo is one of the global mega-biodiversity hotspots with a wild land mammal biodiversity of 247 species (including 100 bat species) and 63 endemic species (Phillipps & Phillipps 2016). Brunei Darussalam is the smallest state on the island (Fig. 1), the country being one of the few places in the

world that still has extensive forest cover with 54% of its forested land deemed to be unlogged primary forests (Bryan et al. 2013) while in the Malaysian states of Sabah and Sarawak 18% of forest remain with about 40% of the remaining forest showing degradation (Gaveau et al. 2014). Since scarcity of research data is probably the reason that most of the causes that lead to biodiversity loss are unknown, we decided to explore a hitherto unknown pristine forest for its faunal diversity.

The World Wildlife Fund-sponsored Heart of Borneo initiative in Brunei Darussalam led to a Faunal Biodiversity Survey in the hitherto untouched pristine forest of Sungai Ingei Conservation Forest (2009–2012 Phase 1 with the first author as leader followed by Phase 2, 2012–2015, second author as leader), the aim being to document wildlife inventory on mam-

mals, birds, reptiles, amphibians, freshwater fish, spider and dragon flies. Other than small mammal studies carried out in Ulu Temburong National Park from 1991–1992 (Charles 1994, 1996), in Bang Nalud Belait District (Charles & Ang 2006), and bat surveys (Kofron 2002, Strubbig et al. 2012), there has been no mammal inventory done in any other forest to create a data base on wildlife for the country. The results of the Faunal Biodiversity survey on different taxa have been documented (Charles 2012). We report here the discovery of all 5 Bornean felids in this forest recorded for the first time in 2010–2011 in Phase 1.

Sungai Ingei Conservation Forest is a pristine primary forest situated within the Labi Forest Reserve at the south eastern part of Belait District in the remote border hills along the border abutting with Gunung Mulu National Park, Sarawak (Figs 2a, b). Labi Hills Forest Reserve with a total area of 1,198.8 km² was formally gazetted in 1950 (Charles et al. 1999) and within this Reserve, various patches of primary forests are specially designated as Protection Forests and Conservation Forests. Sungai Ingei was designated as a Conservation Forest consisting of a mosaic of interdigitating lowland dipterocarp forests, riverine, tropical heath (kerangas), wet heath (kerapah) forests with patches of freshwater and peat swamp in the lower valleys and it was specially preserved for scientific, educational and research purposes (Forestry Department Ministry of Industry and Primary Resources 2011).

Materials and methods

We used passive digital infrared motion sensitive incandescent flash type camera traps (Wild-Eye Remote Camera Trap System by Wildtrack Services: trigger speed 0.3 sec, detection angle 60 degrees, detection range 30 ft, interval 10 secs between events) which produced clear, brilliant night and daytime images. 82 camera traps were deployed from 2010–2012 in 6 areas of the forest and were left undisturbed for three to four months. They were positioned on trees about 40–60 cm above the ground for optimal detection of a

Table 1. The 5 felids in the Sungai Ingei Conservation Forest with their respective number of independent images, photographic rate, earliest detection and their IUCN status.

Felid	No. of independent images	Photographic rate	Earliest detection	IUCN status
Bornean clouded leopard	59	0.115	Day 43	Vulnerable
Leopard cat	24	0.047	Day 92	Least Concern
Bornean bay cat	18	0.035	Day 37	Endangered
Marbled cat	12	0.023	Day 54	Near Threatened
Flat-headed cat	5	0.010	Day 39	Endangered

range of mammals of different body sizes. Our records have shown that the cameras were low enough to photograph rats and squirrels and chances of missing a flat-headed cat or a leopard cat were remote unless the small mammal was next to a camera. Cameras were set as single units to operate throughout a 24-hour cycle without any baits or scent lures. Positions of camera traps were recorded by Garmin GPS map 62SC and extreme care was taken that none of the sites were disturbed. There was minimal cutting of vegetation to create paths in flat undulating areas when movement was difficult; Otherwise, movement was along ridges to all the sites using GPS, compass and flagging tapes on trees. Each camera trap location was selected by the team with animal tracking experience employing features like visible wildlife trails, fallen logs, open areas in the forest, salt licks, water sources and other signs of animal use with an average inter-trap distance of 102 meters covering an area of 18.54 km² (Fig. 2c). The trapping effort in terms of trap-nights for each area was as follows: Area A 6,347; Area B 13,271; Area C 4,616; Area D 7,686; Area E 12,694 and Area F 6,588, totalling 51,202 trap-nights (Table 1). The position coordinates of the sites are not given to avoid possibilities of poaching.

Forest types and vegetation in the 6 camera trapping areas

1. Site A: Mixed Dipterocarp Forest MDF with *Shorea* spp. and *Mangifera* spp. was on the ridges and freshwater swamp occurred in the lowland with Eyul palm *Pholidocarpus maiadum*.
2. Site B: This site was a mosaic of wet heath (kerapah) with pitcher plants *Nepenthes ampullaria*, peat swamp with another species of pitcher plants *Nepenthes bicalcarata*, tall dominant *Shorea albida*, while the ridge top had tropical heath (kerangas) dominated by *Agathis borneensis*.
3. Site C: This site had ridges with hill MDF dominated by *Dryobalanops beccarii* and giant *Shorea curtisii*, *Dipterocarpus* spp., a slope with Kerangas terrace dominated by *Agathis borneensis* and *Dipterocarpus* spp. and a wet lowland habitat near Belait river with an aggregation of *Dryobalanops lanceolata* fringed by *Dryobalanops aromatica* and Eyul palm *Pholidocarpus maiadum*.
4. Site D was an extension of Site C with similar vegetation.

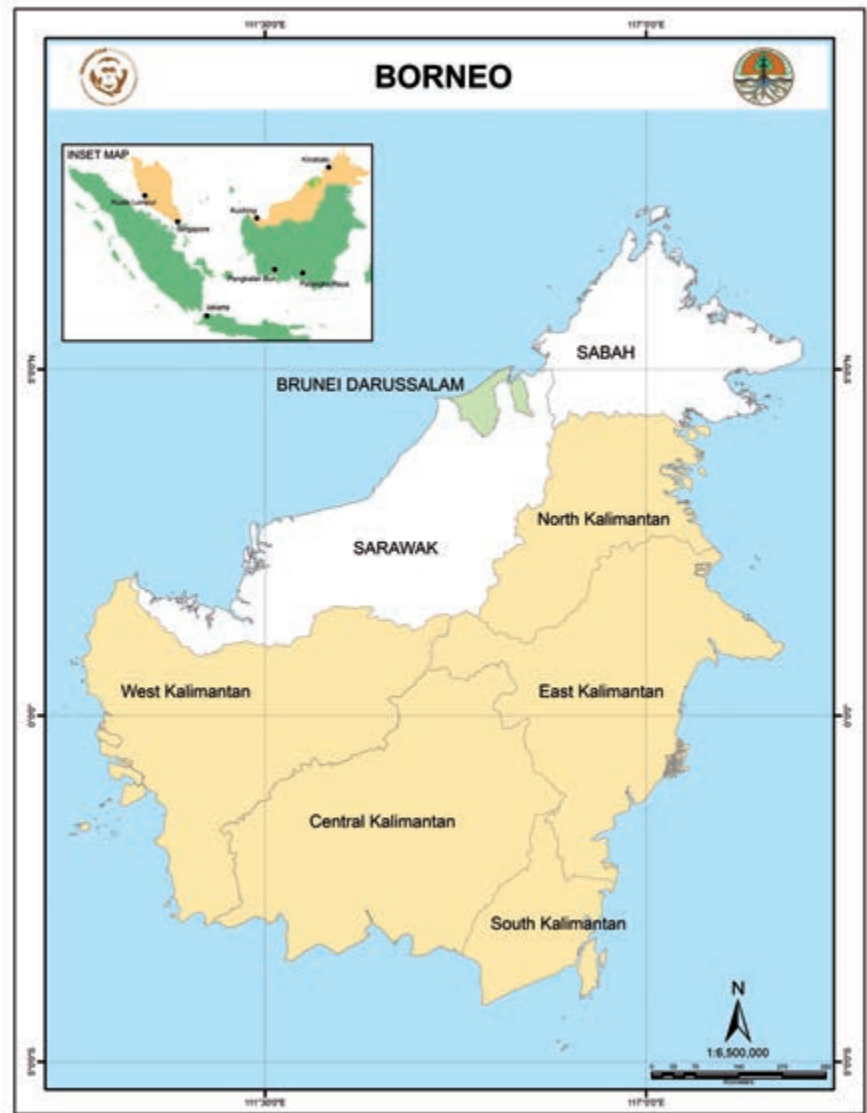


Fig. 1. Map of Borneo showing Brunei Darussalam (Iqbal Tawakkal).

5. Site E: The ridges and slopes were dominated by *Dryobalanops beccarii*, *Shorea curtisii* and *Hopea* spp (Bencaloi) while the slopes have a new *Licuala* sp.
6. Site F was an extension of Site E with similar vegetation.

Results and Discussion

Images from all camera traps were downloaded and sorted using an automatic data organisation program (Sanderson & Harris 2013). Each photograph was individually examined for the presence of mammals which was then identified up to species level. During Phase 1 with a trapping effort of 51,202 trap-nights, 32,553 digital images were obtained of mammals and birds of which there were 9,502 independent samples of mammals and 1,738 independent samples of birds. To be considered an independent sample, at least one hour had to elapse between images of the same species at the same location. Using

photographic rate calculated as the number of independent images of a species captured per 100 trap-nights as a measure of trapping success in a locality, the combined photographic rate of all species in Sg Ingei Conservation Forest was 18.43 independent photographs indicating a high trapping success overall. A species accumulation curve for mammals of Sungai Ingei Conservation Forest based on camera trapping shows an asymptote has been reached (Fig. 3) and 37 species have been recorded (excluding terrestrial small mammals ≤ 1 kg, bats, arboreal mammals). The camera trapping results showed that by day 9, eleven herbivore species have been detected photographically before the carnivores appeared. All the 5 Bornean wild felids showed early detection when compared with other sites in Sabah, Sarawak and Kalimantan (Cheyne et al. 2011, Laneng et al. 2019, Mohd-Azlan et al. 2022) – Borneo bay cat on day 37, flat-headed cat day 39, Bornean

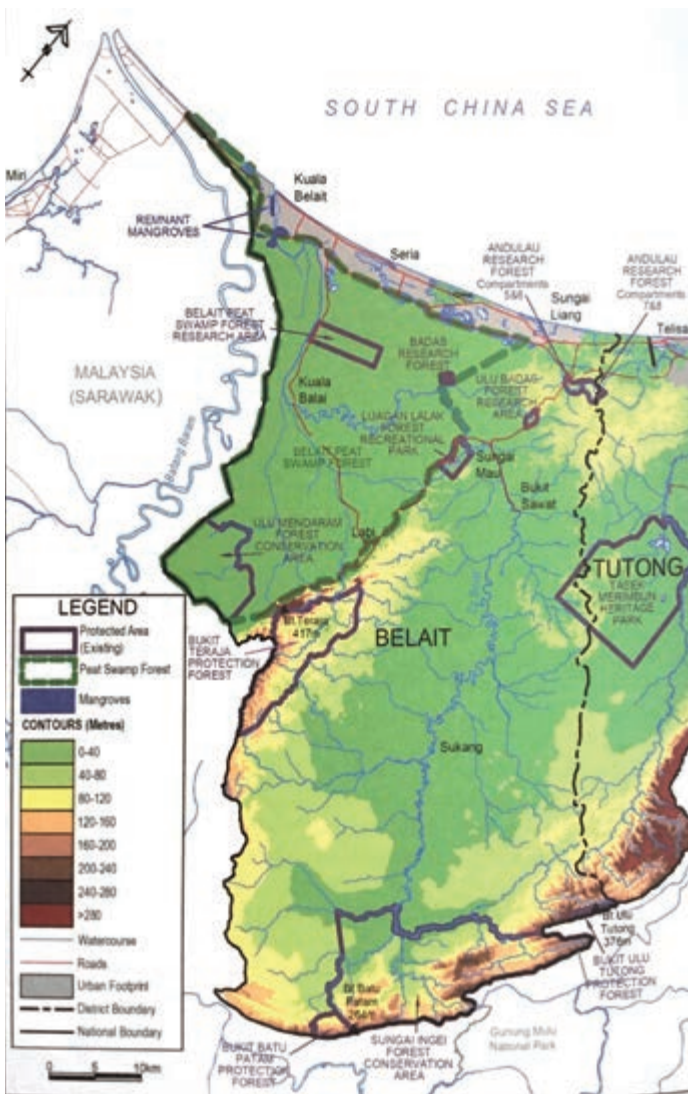


Fig. 2a. Topography of the Belait District, Brunei Darussalam showing Ingei Conservation Forest at the southern corner and other protected areas. (Source: Belait District Plan 2006–2025)



Fig. 2b. Map of Brunei Darussalam showing the Sg Ingei Conservation Forest (shaded) in the Belait District, Brunei Darussalam with the square indicating the 6 camera trap sites (2009–2012; Albert Shim Yun Hin).



Fig. 2c. The six camera trap sites labelled as A–F show the camera trap positions at the core (■) and near the border (x) of the Sg Ingei Conservation Forest in the Belait District, Brunei Darussalam (2009–2012; Albert Shim Yun Hin).

clouded leopard day 43, marbled cat day 54, and leopard cat day 92 (Table 1). The very rare Borneo bay cat was detected earlier than all the other felids. The early detection of these felids is probably influenced by the absence of hunting, logging and little human encroachment and can thus be used as a good indicator of an undisturbed forest in pristine condition. In terms of independent images, the Bornean clouded leopard had the greatest number of 59, leopard cat 24, Bornean bay cat 18, marbled cat 12 and flat-headed cat 5 (Table 1) reflecting the presence of an abundant variety of prey for all these felids especially for the clouded leopard, the apex predator. The presence of multiple forest types in a mosaic pattern in Sungai Ingei Conservation Forest could probably be associated with a rich diversity of mammals. The photographic rate of the felids in the Sg Ingei Conservation Forest also showed the same trend as the number

of independent images, clouded leopard with the highest rate 0.115, leopard cat 0.047, Borneo bay cat 0.035, marbled cat 0.023 and flat-headed cat 0.010. The low number of independent images and photographic rate for the flat-headed cat shows either it occurs in very low numbers or it is restricted to specialised wetland habitats that occur scattered in this mosaic forest or both. A distributional study of the flat-headed cat in Brunei Darussalam (Ang & Charles 2023) has shown its main occurrence in wetland habitats in the country. In contrast to this pristine forest, the number of independent images of these 5 felids in a highly degraded forest of similar size to Sg Ingei Conservation Forest – the rehabilitated INIKEA Forest Rehabilitation Area in Sabah (Laneng et al. 2019) showed that the leopard cat was the most common with 17 images followed by Borneo bay cat 13, marbled cat 7, Bornean clouded leopard 6 and flat-headed

Cat 2 images. In a camera trap survey of 17 years in Sarawak, the leopard cat was also the most often detected with 681 independent images, 94 for marbled cat, 56 for Bornean clouded leopard, 21 for bay cat and 11 for flat-headed cat (Mohd-Azlan et al. 2022) unlike the situation in Brunei Darussalam. The forest types, vegetation and the type of habitat in the camera trapping sites could also influence the presence or absence or detection of the cats (Table 2). Sites A, C, D, E and F were dominated by Mixed Dipterocarp on the ridges except Site B which had kerangas on the ridge, kerapah and peat swamp forest in the lowland. Site A had a freshwater swamp in the lowland. The elevation for the sites varied from 47.1 m to 113.1 m. Though the trapping effort seemed inconsistent between sites, it has not affected the detection of the felids as all 5 were detected in Site A with 6,347 trap-nights while with 13,271 trap-nights in Site B

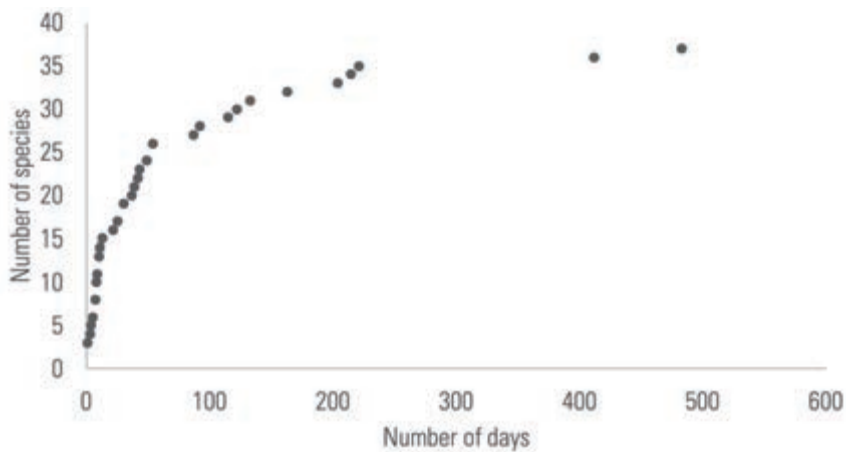


Fig. 3. Species accumulation curve for the mammals of Sungei Ingei Conservation Forest.

and 12,694 trap-nights in Site E, only 4 and 3 felids were detected respectively. The lowest trapping effort of 4,616 for Site C as well as 7,686 for Site D and 6,588 for Site F detected 4 felids. Perhaps the presence of a mixture of forest types as seen in Site A has led to the detection of all 5 felids (Figs 4 A–E).

It is interesting that the Bay Cat was detected in Site B which was a mosaic of kerapah and peat swamp in the lowland and kerangas on the ridge but it was not detected in the peat swamp of Belait (Charles & Ang unpublished data). Cheyne et al. (2011) too did not record the bay cat in the long-term camera-trapping in the Sabangau peat swamp in Kalimantan. Non-detection of a species does not mean absence as a variety of reasons could contribute to it.

It is important to note that the flat-headed cat was detected in only 2 sites (Sites A & B) which had patches of freshwater and peat swamp. Hence its detection near aquatic resources once again confirms our earlier observations in other wetland habitats in Brunei Darussalam (Ang & Charles 2023). A possible reason for its non-detection in the other 4 sites

could be the placement of camera traps to survey mammals for the Sungei Ingei Faunal Biodiversity Survey which did not focus on the aquatic habitats of this felid.

A trapping effort of 13,271 trap-nights in Site B failed to detect the marbled cat though it has been recorded in the Belait peat swamp (Charles & Ang unpubl. data). The non-detection of the leopard cat in Site E may be explained by its presence in Site F which is actually an extension of Site E.

The endemic Borneo bay cat has 3 colour morphs – the red-brown, grey (Sunquist et al. 1994) and black (Ampeng et al. 2015) of which the grey and black morphs are rare. All the 18 independent images of the Borneo bay cat in Sg Ingei Conservation Forest were red-brown in colour. Our record of this cat is the first for Brunei Darussalam as its presence here was stated as uncertain in the IUCN Red List (Hearn et al. 2016).

We are aware of only six sites in Borneo that have confirmed records of the five felid species with Sungai Ingei Conservation Forest (184.91 km²) being the only small, pristine totally undisturbed forest while the

five other forest reserves are all in Sabah ranging from a relatively undisturbed Danum Valley Conservation Area (430 km², Hearn et al. 2018), a sustainable managed Deramakot Forest Reserve (550.83 km², Mohamed et al. 2009), selectively logged Tabin Wildlife Reserve (1,220 km², Gardner et al. 2014), a highly disturbed commercial Kalabakan Forest Reserve (2,240, km², Wearn et al. 2013) and a degraded but rehabilitated INIKEA Forest Rehabilitation Area (185 km², Laneng et al. 2019). A 17-year camera trap survey of 31 study areas in Malaysian Sarawak, Borneo, did not reveal any site with all the five felids (Mohd-Azlan et al. 2022)

The long-term sustainability of these 5 felids in Sungai Ingei Conservation Forest is possible because of the presence of a rich prey base for these carnivores. Camera trapping during this period has recorded the presence of 37 mammal species in this forest (Charles & Ang, unpubl. data), many of which are possible prey for the felids – e.g., bearded pig, deer, pangolin, langurs, otters, pheasants, flying squirrels, rats, porcupines, squirrels, mouse deer, tree shrew, as well as pheasants, partridges, lizards, snakes, frogs (Davis 1962, Phillipps & Phillipps 2016, Rajaretnam et al. 2007).

Other factors that could sustain the survival of these 5 felids in this forest with an area of only 184.91 km² in the long-term, is its location within the Labi Forest Reserve as a buffer, its protection status as a ‘Conservation Forest’ and the strict gun law in Brunei Darussalam that prohibits the use of all types of guns although poaching with other means exists. This discovery shows it is rare and unique to have all five species in a single small area in Borneo which harbours a pristine undisturbed forest with a mixture of forest types and lack of total disturbance for the presence and survival of these felids.

Table 2. The forest types in the camera trapping sites, their elevation, trapping effort and the detection of these felids in each site. (Trapping effort = trap-nights; + detection; - non-detection)

	Site A	Site B	Site C	Site D	Site E	Site F
Forest type	MDF on ridge, Freshwater swamp	Kerapah, Peat swamp, Kerangas on ridge	Hill MDF, Kerangas terraces, lowland MDF	Hill MDF	Hill MDF	Hill MDF
Trapping effort	6,347	13,271	4,616	7,686	12,694	6,588
Elevation range (m)	47.5–52.6	48.1–63.5	65.3–76.3	58.5–133.2	47.1–81.4	113.1–143.3
<i>Detection of felid species</i>						
Clouded leopard	+	+	+	+	+	+
Leopard cat	+	+	+	+	-	+
Borneo bay cat	+	+	+	+	+	+
Marbled cat	+	-	+	+	+	+
Flat-headed cat	+	+	-	-	-	-
Total	5	4	4	4	3	4



Fig. 4. (A) a Bornean Clouded leopard in wet kerangas in site B, (B) the endemic Borneo Bay Cat detected in site B, a mosaic of wet kerangas and peat swamp, (C) a leopard cat on a ridge slope in site D, (D) a flat-headed cat in a swampy area in site B, and (E) a marbled cat on a ridge slope in site C (Photos J. K. Charles & B. B. Ang).

These predators (clouded leopard as apex predator, others as mesopredators) which occupy the highest trophic positions in their respective food webs, play crucial roles in ecological and evolutionary processes in the forest ecosystem and are central to ecosystem functioning, stability, disease regulation and maintenance of biodiversity, thus making their conservation vital. The IUCN Red List of Threatened Species has listed Bornean clouded leopard, Borneo bay cat and flat-headed cat as 'Endangered', marbled cat as 'Near Threatened' and leopard cat as 'Least Concern'. Of the 34 species of mammals, birds and reptiles protected in the First Schedule Part A: Protected Animals of the Wildlife

Protection Law (Laws of Brunei Revised edition 1984) the clouded leopard is the only cat which is included in the Law.

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¹ No.2 Simpang 398, Jalan Subok, Bandar Seri Begawan BD2717, Brunei Darussalam
* <joekcharles@gmail.com>