Tropical Zoology 17: 1-13, 2004

Amphibians of the Kayan Mentarang National Park (East Kalimantan, Indonesia): estimating overall and local species richness

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Received 10 December 2002, accepted 15 April 2004

On the basis of surveys since 1997 and an intensive survey at the World Wildlife Fund field station at Lalut Birai in 2001, we assessed the importance of the Kayan Mentarang National Park in East Kalimantan for the conservation of Borneo's amphibian fauna. Sixty-five frog species and one Caecilian species are currently known to occur in this region. We report their occurrence in 16 subareas. Most of the species were recorded at Upper Bahau (41) and at the Lalut Birai field station (33). Based on the results of opportunistic searches and transect censuses at Lalut Birai, we argue that the amphibian diversity of the national park is still greatly underestimated.

KEY WORDS: Indonesia, Borneo, Kayan Mentarang National Park, amphibian diversity, transect census.

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INTRODUCTION

Protection and wise utilisation of biological resources require an understanding of how ecosystems work (MacKinnon et al. 1997). The description and functional analysis of biological diversity is therefore a core topic in ecology and conservation biology.

Analysis of species diversity falls between assessment of genetic and habitat diversity. It can be measured in terms of species richness or rates of endemism. Indonesia has been identified as one of the most important countries containing the world's "mega-diversity" (Mittermeier 1988). Borneo and New Guinea are the most species-rich areas in Indonesia (MacKinnon et al. 1997). Borneo, the third largest island on earth, harbours an extraordinarily rich herpetofauna. About 145 amphibian (mostly frog) and 250 reptile species are currently known (Inger & Stuebing 1997, Manthey & Grossmann 1997, Inger 1999, Frost 2000, Iskandar & Colijn 2000). Among amphibians, 65% of the species, including two genera, *Ingerana* Dubois 1986 and *Meristogenys* Yang 1991, are endemic to this island (*Leptobrachella* Smith 1925 can also be considered as Bornean endemic, because geographically Natuna Island belongs to Borneo) (Inger & Stuebing 1997, Manthey & Grossmann 1997, Inger 1999, Frost 2000, Iskandar & Colijn 2000).

The high amphibian diversity in Borneo can be explained by several factors: (i) Borneo lies on the equator in the central humid tropics within the species-rich Oriental Region. (ii) During the Quaternary, Borneo was repeatedly connected and disconnected from the mainland and other islands. This favoured faunal exchange with the mainland, thus enlarging the number of species. (iii) High rates of endemism (e.g., 25% in snakes, 45% in lizards, and 65% in frogs) were enhanced by the relatively long and stable history of the Bornean rain forest; the earliest evidence of the occurrence of dipterocarps is from fossil pollen from Sarawak from more than 30 million years ago (MacKinnon et al. 1997). Consequently, many niche specialists could evolve.

Today, Borneo's biodiversity is severely threatened. Logging, burning and conversion into agricultural land have already destroyed large parts of the lowland rainforest (MacKinnon et al. 1997, Slik et al. 2002). Following the 1997-98 El Niño/Southern Oscillation event, the largest fire disaster ever observed in tropical rainforests destroyed 5.2 million hectares of vegetation cover, including 2.6 million hectares of rainforest (Siegert et al. 2001). It did not even spare protected areas such as the Kutai National Park (Slik et al. 2002). The situation appeared to be better in mountain forests; only 5.7% of undisturbed forests were directly affected by the 1997-98 fires (Siegert et al. 2001). In Kayan Mentarang National Park, not a single hectare of undisturbed forest was affected by the 1997-98 fires. Indirect effects, however, may severely affect animal communities in forests spared by the fire. During the forest fires in 1997, one of us (D. Iskandar) happened to be at the head of Embaloh River (a big tributary of Kapuas River in West Borneo). He found that during the thick haze, not a single frog or monkey and essentially no bird was calling during the whole month of the expedition, although the forest fire was about 200 km from the site where he was working. Consequently, the impact of forest fires might be greatly underestimated (see also Stuebing et al. 1999).

The only possible way to avoid the total loss of Bornean rainforests seems to be the establishment of protected areas (Jepson et al. 2001). A major effort in this direction was undertaken by the Indonesian government when it established the

Kayan-Mentarang Nature Reserve in East Kalimantan province in 1980. In 1996, the status of the reserve was changed to national park.

The pronounced elevation profile of the Kayan Mentarang National Park and its variety of geo-morphological formations are probably of major importance for its habitat diversity and species distribution. However, these features make the establishment of floristic and faunistic inventories, the necessary baseline for long-term conservation, difficult and very time consuming. The World Wildlife Fund for Nature (WWF-Indonesia and WWF-International) initiated an inventory of major plant and animal groups of the Kayan Mentarang in 1992 (e.g., FOEAD 1995). However, systematically conducted rapid biodiversity assessments in most parts of the park were only started in 1997 (WULFFRAAT & SAMSU 2000). The selected areas represent all major habitat types of the Kayan Mentarang and these local inventories provide a more representative overview of the park's potential for the conservation of Borneo's biodiversity. Inventories of birds, mammals and major tree species were conducted along transects and plots (e.g., VAN BALEN 1997, WULFFRAAT & SAMSU 2000), but amphibians were not systematically recorded. In contrast, systematic research on amphibian diversity has been conducted for several years in the vicinity of the WWF field station at Lalut Birai.

In the present paper we aim to give an initial overview of the frog community of the Kayan Mentarang National Park. We discuss the park's overall species richness through an extrapolation of local species richness at the Lalut Birai field station.

MATERIAL AND METHODS

The Kayan Mentarang National Park and its sub-areas

Kayan Mentarang is the largest national park in South-East Asia. Its 1.3 million hectares contain the upper parts of the Kayan, Sesayap, and Sembakung watersheds. The area mainly has an ever-wet tropical rainforest climate, with high temperatures and rainfall throughout the year. Rainfall ranges between 2500 and 3700 mm per year (TAD 1983), with the driest months being from July to October. At higher elevations, the climate is more temperate and annual rainfall is probably higher.

The Kayan Mentarang area mainly consists of hilly and mountainous landscapes, and the only flat areas are in the often narrow river valleys and on top of plateaus. The major base substrate of about 3/4 of the park is sandstone. Volcanic mountains, remnants of former volcanic activity in central Borneo, constitute large areas of the southern part of the park (approximately 1/4 of the park's area). Kayan Mentarang is part of the central Bornean upland where many major river systems arise. More than 90% of the area has an elevation higher than 500 m a.s.l., and 40% rises above 1000 m a.s.l.

The present study is based on amphibian records collected since 1997. Several sub-areas of Kayan Mentarang National Park were surveyed in the course of floristic and faunistic transect analyses (Fig. 1): (1) Iwan River. The Iwan River is a tributary of the Kayan River with a length of more than 100 km. The northern and eastern parts of the Iwan watershed have a wide variety of landscapes (volcanic mountains, hills and plateau landscapes). (2) Upper Pujungan plateau. A large irregularly shaped sandstone plateau between the upper reaches of the Pujungan River and the Iwan River. The plateau consists of flat areas with poor white sandy soils, surrounded by small hills and dissected by small valleys. (3) Middle Pujungan limestone ridge. Many elongated limestone ridges are found on both sides along the middle course of the Pujungan River. They are characterised by very steep slopes or cliffs with rather horizontal ridge

crests. The limestone ridges are bordered by sedimentary hills or mountains. (4) Puak highlands. The Puak highlands consist of a large volcanic mountain complex situated between the Pujungan River in the south, the Lurah River in the north, the Bahau River in the east, and a sedimentary hill landscape in the west. Altitude at the foothills starts at 300 m a.s.l. The highest ridges reach 1900 m a.s.l. in the south and 2000 m a.s.l. in the north. (6) Mountains between the Iwan and Lurah Rivers. The Lurah River is a very long western tributary of the Bahau River. The two rivers are separated by a mountain complex of sedimentary origin. The ridges reach 1300 m a.s.l. (7) Upper Enggeng Bio/Lalut Birai. The Enggeng Bio is a tributary of the Bahau River. The western mountains, of volcanic origin, rise to more than 1800 m a.s.l. Near the lower parts of the mountain complex, where the Lalut Birai field station is situated, the base substrate changes from basalt to sandstone. Survey areas are located at the foot of the mountain complex and around the field station. (8) Bahau headwaters and (9) Upper Bahau. The landscape of the Upper Bahau consists mainly of undulating and hilly areas and foothills of the mountains in the far north. This mountain complex divides the Bahau and Sesayap water-

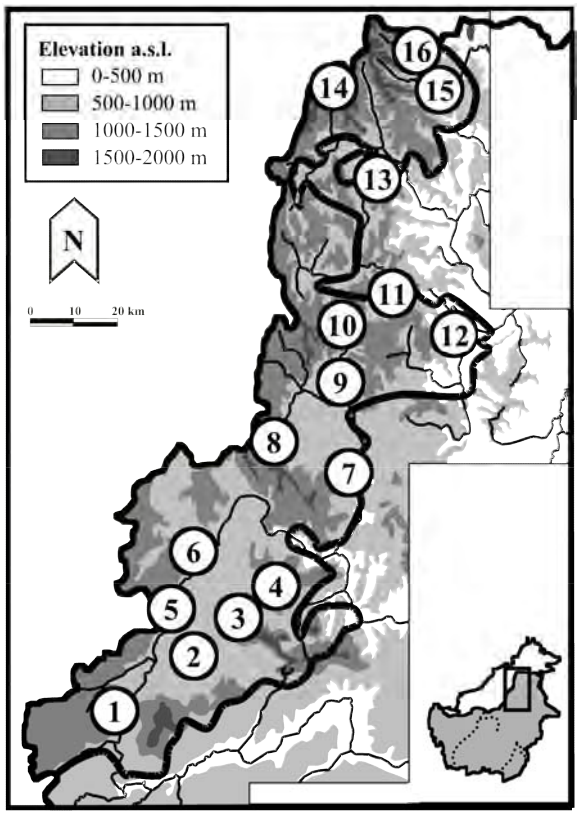

Fig. 1. — Research areas for amphibian inventories in the Kayan Mentarang National Park: (1) Iwan River, (2) Upper Pujungan plateau, (3) Middle Pujungan limestone ridge, (4) Puak Highlands, (5) Upper Iwan hills, (6) mountains between Iwan and Lurah Rivers, (7) Upper Enggeng Bio/Lalut Birai, (8) Bahau headwaters, (9) Upper Bahau, (10) Upper Krayan-Bahau watershed mountains, (11) Paye Rungan heath forest, (12) Tubu area, (13) East Krayan, (14) North Krayan, (15) Lumbis, (16) Upper Sulon. Location of the park within the Indonesian part of Borneo is shown in the insert.

sheds. The base substrate is sandstone. Extensive grasslands are found in certain places, the result of former shifting cultivation and frequent burning. (10) Upper Krayan-Bahau Watershed Mountains. The basins of the Krayan and Bahau Rivers are separated by a wide sedimentary mountain complex which in the surveyed location reaches 1240 m a.s.l. (11) Paye Rungan heath forest. The Paye Rungan area is a wide sandstone plateau surrounded by high mountains. The elevation ranges from 1230 m a.s.l. at the edges to below 1200 m a.s.l. in the core area. The most widespread habitat is the mountain heath forest with a very dense vegetation structure, particularly in the under-storey. (12) Tubu area. The western Tubu area consists almost entirely of sandstone. The main landscape is formed by wide valleys separated by mountain ridges. Lowland river plains in the valleys are sometimes as low as 200 m a.s.l. The mountain ridges are characterised by long slopes with altitudes of up to 1200 m a.s.l. (13) East Krayan. This sedimentary mountain complex separates the Krayan highland plateau from the Tidung and Malinau lowlands. A central mountain ridge with north-south orientation forms a major watershed. (14) North Krayan. The northern Krayan highland consists of alluvial and sandstone plains. They are surrounded and intersected by sedimentary mountains. Northern mountain ridges can reach more than 1900 m a.s.l. (15) Lumbis. The western part of the Lumbis area, bordered by the northern Krayan, consists of high sedimentary mountain ridges while the eastern part is an extremely diverse mountain landscape with both small and large ridges. Slopes are generally quite steep. River valleys extend to the lowest elevations in the Kayan Mentarang National Park (ca 100 m a.s.l.). (16) Upper Sulon area. The upper Sulon area consists of sedimentary mountain ridges dissected by many streams. The highest ridges reach 1600 m a.s.l. and form the boundary between Indonesia and Sabah/Malaysia. Limestone formations exist in the lower parts of this area. The major forest type is old secondary Oak-Myrtle forest, while on lower elevations secondary hill dipterocarp forest exists.

Amphibian survey

In large part and for many areas, our amphibian list (Table 1) is based on the herpetological collection of the Lalut Birai field station. Specimens were collected by members of the field station and foreign scientists. Determination of most specimens was confirmed in the late 1990s by R.B. Stuebing. Additional observations were made during field trips of all the co-authors.

Amphibians were usually recorded at night, primarily by opportunistic sampling. Research in 2001 around Lalut Birai field station also included quantitative transect counts (the methods are described in HEYER et al. 1994).

To assess potential local species diversity, we used two kinds of data collected at the Lalut Birai field station between 12 and 28 September 2001. (i) Analysis of a 500 m forest transect that crossed several small permanent and temporary brooks. Its distance from the main river ranged from 50 to 100 m. Two to four trained scientists searched on 13 non-consecutive days during the course of three weeks and counted all specimens that could be seen within a ca 2 m forest band along both sides of the transect. (ii) Opportunistic search around Lalut Birai during 14 nights in and around all types of flowing and stagnant water bodies. The overall estimate of amphibian diversity around Lalut Birai (transect census plus opportunistic search) is based on 16 days of search effort by five scientists.

RESULTS

Amphibian species of the Kayan Mentarang National Park

Thus far, one caecilian (*Ichthyophis* sp. Fitzinger 1826 at Upper Bahau) and 64 frog species (Table 1) from five families and 23 genera have been recorded from

Table 1

Regional occurrence of frog species in the Kayan Mentarang National Park; we are aware of the problem that an unknown amount of cryptic species diversity is likely to occur in Borneo; we there fore indicate uncertain determinations as "cf"; ? = species occurrence needs to be confirmed.

	Sub-area														
Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Bufonidae																
Ansonia albomaculata Inger 1960							•[3]									
Ansonia hanitschi Inger 1960				•												
Ansonia leptopus (Günther 1872)					•		cf[3]		•							
Ansonia longidigita Inger 1960				•	•											
Ansonia spinulifer (Mocquard 1890)							•[3]									•
Bufo asper Gravenhorst 1829									•							
Bufo divergens Peters 1871									•							
Bufo melanostictus Schneider 1799													•			
Bufo juxtasper Inger 1964		•	•		•		•[3]	•	•					•	•	•
Leptophryne borbonica (Tschudi 1838)								•								
Pedostibes hosii (Boulenger 1892)							•[3]		•			•				
Pelophryne misera (Mocquard 1890)																•
Pelophryne signata Barbour 1938									•							•
Microhylidae																
Chaperina fusca Mocquard 1892							cf[3]		•							
Kalophrynus heterochirus Boulenger 1900										•						
Kalophrynus pleurostigma Tschudi,1838							•		•							
Kalophrynus subterrestris Inger 1966									•							
Metaphrynelle sundana (Peters 1867)									•							
Microhyla berdmorei (Blyth 1856)							•									
Microhyla borneensis Parker 1928									•							•
Microhyla petrigena Inger & Frogner 1979										•						
Megophryidae																
Leptobrachella baluensis Smith 1931				•												
Leptobrachella mjobergii Smith 1925			•				•									•
Leptobrachium abbotti (Cochran 1926)							•[3]									
Leptobrachium montanum Fischer 1885								•								
Leptobrachium nigrops Berry & Hendrickson 1963				?												
Leptolalax dringi Dubois 1987		•								•						•
Leptolalax gracilis (Günther 1872)							•[3]		•							
Megophrys nasuta (Schlegel 1837)							•									
Ranidae																
Fejervarya limnocharis (Gravenhorst 1829)								?		?						
Fejervarya cancrivora (Gravenhorst 1829)							?		?							
Huia cavitympanum (Boulenger 1893)					•		•	•	•							•
Limnonectes asperatus (Inger, Boeadi & Taufik 1996)							cf		•							
Limnonectes finchi (Inger 1966)				cf			•[3]									
Limnonectes ibanorum (Inger 1964)		•					•	•	•	•		•				•
Limnonectes ingeri (Kiew 1978)										•						
Limnonectes kuhlii (Tschudi 1838)				•			•		•			•				

(*continued*)

Table 1. (*continued*)

Species	Sub-area 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Limnonectes laticeps (Boulenger 1882)									•							
Limnonectes leporinus Andersson 1923	•			•			•	•	•	•		•	•			
Limnonectes malesianus (Kiew 1984)									•							
Limnonectes paramacrodon (Inger 1966)									•							
Limnonectes rhacoda (Inger, Boeadi, & Taufik 1996)								cf		•						
Meristogenys jerboa Günther 1872				?												
Meristogenys kinabaluensis (Inger 1966)				•				•	•		•					
Meristogenys phaeomerus (Inger & Gritis 1983)					•			•[3]			•		•			
Meristogenys whiteheadi (Boulenger 1887)					•			•		•						
Meristogenys sp.[1]							•									
Occidozyga baluensis (Boulenger 1896)							cf[3]									
Rana baramica Boettger 1900									•							
Rana chalconota (Schlegel 1837)								•		•						
Rana glandulosa Boulenger 1882									•							
Rana hosii Boulenger 1891	•	•	•				•[3]	•	•			•	•	•	•	•
Rana luctuosa (Peters 1871)						•			•							
Rana nicobariensis Stoliczka 1870					•	•	•									•
Rana picturata Boulenger 1920					•	•	•[3]		•			•	•			•
Rana signata (Günther 1872)									•				•	•		
Staurois latopalmatus (Boulenger 1887)		•		•			•		•			•			•	•
Staurois natator (Günther 1858)[2]							•		•			•		•	•	
Staurois tuberilinguis Boulenger 1918		•		•												
Rhacophoridae																
Philautus sp.				•												
Polypedates colletti (Boulenger 1890)									•							
Polypedates macrotis (Boulenger 1891)									•							
Polypedates otilophus (Boulenger 1893)							•		•							
Rhacophorus appendiculatus (Günther 1858)									•		•					
Rhacophorus nigropalmatus Boulenger 1895											•					
Rhacophorus pardalis Günther 1858							•		•							
Sum of species	2	6	4	13	6	4	33	8	41	5	1	9	5	4	4	12

[1] Found at Kuala Tee.
[2] INGER (1966) considered the Bornean populations of *Staurois natator* to be morphologically different, naming them *S. guttatus*. Its taxonomical status is still to be confirmed.
[3] Observed along the transect.
Sub-areas: (1) Iwan River, (2) Upper Pujungan plateau, (3) Middle Pujungan limestone ridge, (4) Puak Highlands, (5) Upper Iwan hills, (6) mountains between Iwan and Lurah Rivers, (7) Upper Enggeng Bio/Lalut Birai, (8) Bahau headwaters, (9) Upper Bahau, (10) Upper Krayan-Bahau watershed mountains, (11) Paye Rungan heath forest, (12) Tubu area, (13) East Krayan, (14) North Krayan, (15) Lumbis, (16) Upper Sulon.

the Kayan Mentarang National Park. The single records of *Leptobrachium nigrops* Berry & Hendrickson 1963 and *Meristogenys jerboa* Günther 1872 need further confirmation (no vouchers are preserved in the collection of the Lalut Birai field sta-

tion). Six specimens of *Fejervarya limnocharis* Gravenhorst 1829 are preserved in the collection of the field station without number or indication of location. Although this suggests that they originate from around Lalut Birai, confirmation is needed. One specimen of the taxonomically problematic genus *Philautus* Gistel 1848 (Rhacophoridae) from the Puak highlands could not be affiliated to any species.

Local frog communities

With the exception of Upper Bahau (41 species) and Upper Enggeng Bio/Lalut Birai (33 species), the local number of frog species recorded thus far is rather low (Table 1). Thirty species have only been recorded from a single sub-area. An additional 14 frog species recorded from several sites in the vicinity of Kayan Mentarang (Malinau, Sebuku-Sebakung) likely occur also within the National Park: *Ingerana baluensis* (Boulenger 1896), *Leptobrachium hendricksoni* Taylor 1962, *Limnonectes palavanensis* (Boulenger 1894), *Megophrys baluensis* (Boulenger 1899), *Microhyla perparva* Inger & Frogner 1979, *Nyctixalus pictus* (Peters 1871), *Occidozyga laevis* (Günther 1858), *Polypedates leucomystax* (Gravenhorst 1829), *Philautus hosii* Boulenger 1891, *Rana raniceps* (Peters 1871), *Rhacophorus fasciatus* Boulenger 1895, *Rhacophorus gauni* (Inger 1966), *Rhacophorus harrissoni* Inger & Haile 1959, as well as the introduced *Hoplobatrachus rugulosus* (Wiegmann 1834).

River bound frog species are usually recorded from several sub-areas (Fig. 2; up to eleven for *Rana hosii* Boulenger 1891). In contrast, strictly terrestrial and arboreal types are mainly recorded from single sub-areas and never from more than three. This may be due to their rarity or to an observation bias.

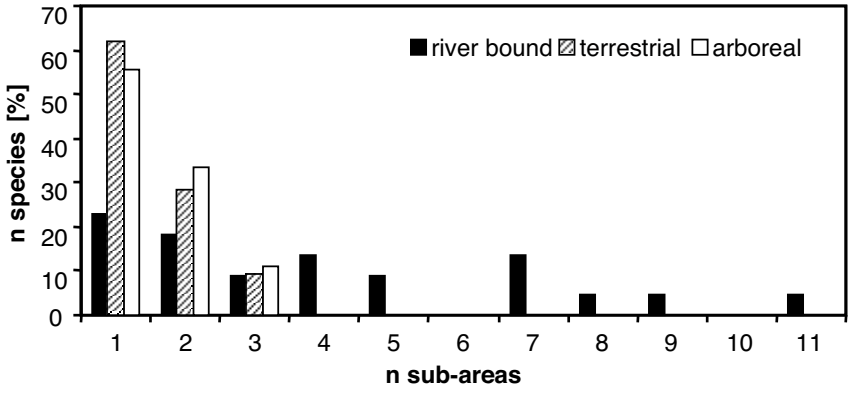

Fig. 2. — Number of Kayan Mentarang National Park sub-areas (n sub-areas) where frog species occur.

Local species diversity

In most parts of the Kayan Mentarang National Park, amphibian monitoring is not performed on a regular basis. We therefore used the results of a period of intensive monitoring at Lalut Birai field station between 12 and 28 September 2001 to estimate the number of species that can be found in a single area.

Twenty-four species were found, with a mean of 9.4 ± 1.9 (range: 7-13) species per day (*Limnonectes* cf. *asperatus* (Inger, Boeadi & Taufik 1996) and *L.* cf. *rhacoda* (Inger, Boeadi & Taufik 1996) could not be distinguished during opportunistic

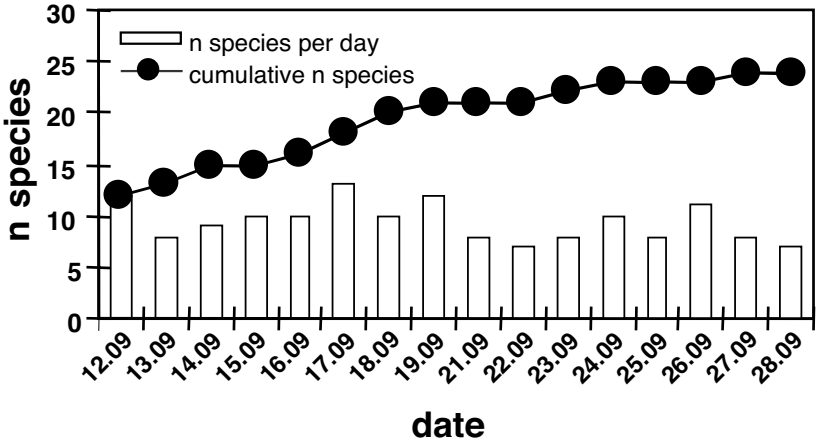

Fig. 3. — Daily and cumulative number of amphibian species recorded at Lalut Birai field station in September 2001.

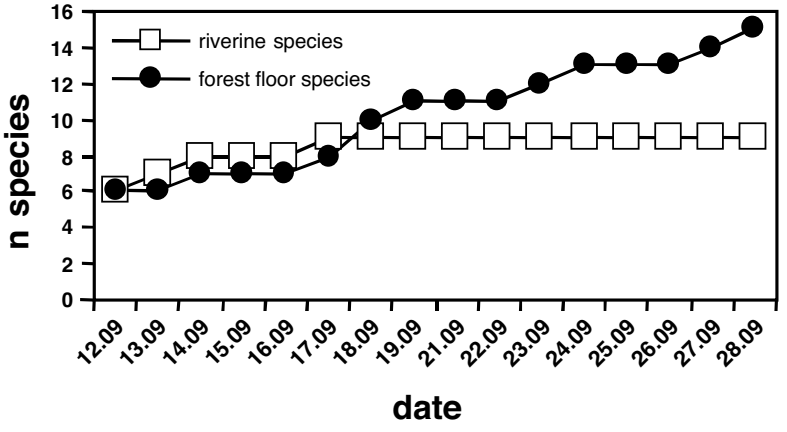

Fig. 4. — Species accumulation curve of riverine and non-riverine/forest floor species at Lalut Birai field station in September 2001.

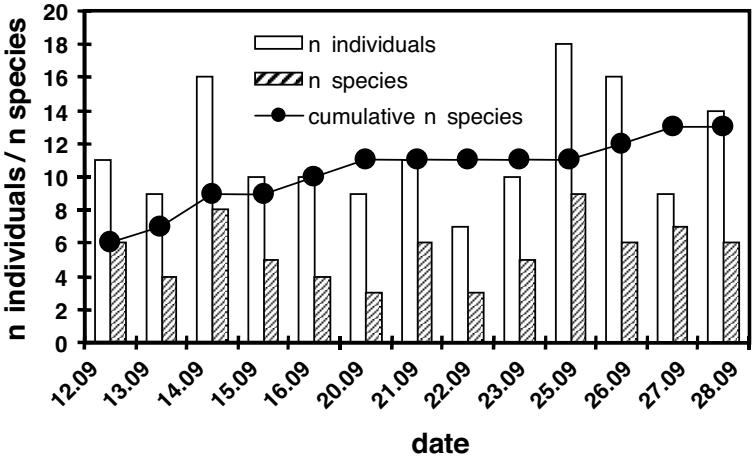

Fig. 5. — Daily number of specimens, daily number of species, and cumulative number of amphibian species recorded along a 500 m forest transect at Lalut Birai field station in September 2001.

searching). More than half of the species were recorded up to five times, but only six species were recorded on 10 or more days: *Pedostibes hosii* (Boulenger 1892), *Meristogenys phaeomerus* (Inger & Gritis 1983) and *Rana picturata* Boulenger 1920 on 11 days, *Ansonia spinulifer* (Mocquard 1890) on 12 days, *Bufo juxtasper* Inger 1964 (status and distribution of members of the *B. asper*/*B. juxtasper*/*B. sumatranus* group are currently under discussion; e.g. ISKANDAR & COLIJN 2000) and *Rana hosii* on 16 days.

Towards the end of the survey the cumulative number of species did not appear to be saturated (Fig. 3). Considering only species that are easy to monitor along streams and brooks, a maximum number of nine species was attained after only six days (Fig. 4). In contrast, the number of species that primarily forage on the forest floor and in low vegetation away from rivers and brooks steadily increased without reaching an obvious plateau.

The overall pattern of species richness at Lalut Birai is strongly affected by the transect census (for species see Table 1). The total number of species recorded along the transect is 13, with 5.5 ± 1.8 (range: 2-8) species and 11.5 ± 3.4 (range: 7-18) specimens per day. The cumulative species number along the transect reached a temporary plateau between days 6 and 10 (Fig. 5). After intensive rainfall between days 9 and 10, two new forest floor species emerged (*Occidozyga baluensis* (Boulenger 1896) and *Chaperina fusca* Mocquard 1892).

DISCUSSION

Thus far, 65 amphibian species have been recorded from the Kayan Mentarang National Park. Considering (a) that ca 145 frog species have been described

for Borneo, (b) the large area of the park, (c) the variety of habitats and microhabitats in the park and (d) that 14 more species are found in the vicinity of the park, this number still seems to be an underestimation of the real frog diversity of the Kayan Mentarang National Park.

Our present knowledge of the Kayan Mentarang amphibian diversity is clearly biased by opportunistic searching along running waters. Species that can be easily recorded at night along river banks [e.g., *Bufo juxtasper, Limnonectes leporinus* Andersson 1923, *Rana hosii*] or on rocks within rivers [*Staurois latopalmatus* (Boulenger 1887)] are usually recorded from multiple sub-areas (Fig. 2). In contrast, species that mainly forage on the forest floor or on low vegetation [e.g., *Ansonia albomaculata* Inger 1960, *A. hanitschi* Inger 1960, *A.* cf. *leptopus* (Günther 1872), *A. longidigita* Inger 1960, *A. spinulifer* (Mocquard 1890), *Chaperina* cf. *fusca, Kalophrynus pleurostigma* Tschudi 1838, *Microhyla berdmorei* (Blyth 1856), *M. borneensis* Parker 1928, *Leptobrachella baluensis* Smith 1931, *L. mjobergi* Smith 1925, *Leptobrachium abbotti* (Cochran 1926), *L. nigrops, Leptolalax dringi* Dubois 1987 "1986", *L. gracilis* (Günther 1872), *Occidozyga* cf. *baluensis*] were recorded infrequently (mainly at the Lalut Birai field station, which is permanently manned, and at Upper Bahau). This latter pattern may be due to the rarity of terrestrial and arboreal species or to a methodological bias. Our data from Lalut Birai field station indicate the latter: terrestrial species steadily increase in numbers, while the cumulative number of river bound species reaches a plateau already after a few days.

Surveys in other potentially species-rich areas such as the Puak highlands were not rigorous and usually lasted only 1 month. Therefore, we can conclude that a thorough survey away from streams and brooks and including highland areas of the Kayan Mentarang National Park will substantially increase the number of recorded species.

The potential diversity of local frog communities is suggested by the data from the Lalut Birai field station. Thirty-three species have been recorded so far from this sub-area (Table 1). Although this number is also biased by searches along riverine habitats, it indicates that more species can be found in a single area if standardised and opportunistic censuses are performed on a regular basis.

A comparison of the frog species recorded in Kayan Mentarang and in Borneo in general tells us which species are likely to be found in the future. River bound species are easy to find, and their cumulative number quickly reaches saturation (Fig. 4). The complete census at Lalut Birai in September 2001 only missed *Staurois natator* (Günther 1858) and *Huia cavitympanum* (Boulenger 1893). These species may be rare around Lalut Birai. In contrast to *Staurois latopalmatus*, a larger species that can be found during the day, *S. natator* is not present in the Lalut Birai collection. Forest floor species are recorded infrequently, and weather may substantially affect their activity patterns. Consequently, their number steadily increased through a 3-week period in September 2001. Many species are probably undetected at Lalut Birai, among them the Bornean dwarf (e.g., *Leptobrachella, Pelophryne* Barbour 1938) or arboreal (e.g., *Philautus, Rhacophorus* Kuhl & van Hasselt 1822) species. This may also account for the lack of species that breed in temporary water bodies, which mainly form at the beginning of the rainy season (e.g., *Kalophrynus* Tschudi 1830).

The richness of local Bornean amphibian communities is illustrated by the data of Inger & Voris (1993). They described local anuran communities that harboured between eleven (Sungau Surinsin, Marak Parak, Sabah, Malaysia) and 23 (Sungau Serbong, Nanga Tekalit, Sarawak, Malaysia) of the 49 possible species.

Mount Kinabalu, a high mountain area at Sabah (Malaysia), is known for its exceptionally rich anuran community (77 species; MALKMUS et al. 2002). However, the Kinabalu massif is not representative of the whole of Borneo, encompassing an exceptionally large altitudinal gradient (up to 4095 m a.s.l.) and many different kinds of habitats. During recent years, several species that were supposed to be endemic to Mount Kinabalu have been recorded in the Kayan Mentarang National Park [e.g., *Ansonia hanitschi, Meristogenys kinabaluensis* (Inger 1966); WULFFRAAT & SAMSU 2000]. This indicates that the present anuran diversity of Kayan Mentarang National Park is still greatly underestimated. Continuous research with standardised methods in different parts of the national park is therefore essential.

ACKNOWLEDGEMENTS

Research at the Kayan Mentarang National Park in 2001 was authorised by the Lembaga Ilmu Pengetahuan Indonesia (LIPI; research permit no. 4969/I.3/KS/2001). The Indonesian Forestry Department allowed us to enter the National Park. Our special thanks go to Mr Ramon Janis, Forestry Department of Kalimantan Timur (Samarinda) and to Mr Susanto Herlembang, Jakarta, for their kind support. Thanks to the staff of Lalut Birai field station for their great assistance during the 2001 field trip. This field trip was partially supported by the Andreas Stihl Stiftung and by Mr Hans Riegel (Haribo Company). We are especially grateful to the people of Long Alango who allowed us to stay and work on their traditional land. Renata Platenberg improved the manuscript linguistically.

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