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Front cover: Tongkat Ali, *Eurycoma longifolia*, in flower (Photo: Julius Kulip)

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Common medicinal plants of Sabah

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Abstract. Medicinal plants have been used in Sabah for many years, before the advent of modern medicine. There are more than 1,300 species of native and exotic medicinal plants found in Sabah. These plants are used by local villagers as well as the urban communities to alleviate their health problems, especially when modern medicine fails. This paper presents the common medicinal plants found in Sabah.

Keywords: field identification, habitat, medicinal plants, preparation, propagation, Sabah, uses

INTRODUCTION

Sabah is one of the 13 states within the federation of Malaysia and is located in the northernmost part of Borneo island. It is the second largest state in Malaysia with a landmass of approximately 7.4 million hectares. The total forested area is about 4.7 million hectares. It is rich in plant diversity, and abundant in medicinal plants.

Plants that have medicinal value have long been used, cultivated and preserved by the local communities in Sabah. These plants not only serve as medicine, but also as a source of income. Many such medicinal plants are sold in weekly open-air market or *tamu* throughout Sabah. Some have also been commercialized and sold in capsule form. Many people including urbanites use them as an alternative when modern drugs fail. There is a strong demand for traditional medicine, which can be a lucrative business (Kulip 2004).

There are at least 1,300 species of medicinal plants, both native as well as introduced, occurring in Sabah. The more commonly used medicinal plants are presented below. However, readers are advised to consult their doctors when they are sick, and the author is not liable for any direct or indirect damages arising from the use of the medicinal plants mentioned in this paper.

NATIVE (FOUND IN THE FORESTS)

1. Scientific name: *Eurycoma longifolia* (Simaroubaceae).
   Local names: Tongkat Ali/ Munoad Mondou/ Monompuru.

Figure 1. Tongkat Ali plant in flower.

Figure 2. Tongkat Ali fruits.

Field identification: Small to medium-sized tree up to 10 m in height. Usually shrub about 1-2 m. Hemaphrodite.

Habitat: Undisturbed forest under shade. Usually grows on hill slope.

Uses: Aphrodisiac for men. Also used to treat malaria and stomachache.

Preparation: The root is cleaned, chopped or ground into small pieces, and boiled in water. The resulting decoction is consumed after cooling.

Propagation: Seed or cutting.

2. Scientific name: *Labisia pumila* var. *pumila* (Myrsinaceae).
Local name: Kacip Fatimah.

Figure 3. Kacip Fatimah.

Figure 4. The inflorescence of Kacip Fatimah.

Field identification: Small herb with broad leaves. Younger leaves reddish brown in colour.
Habitat: Found in undisturbed or primary forest. Usually grows on land with seasonal water.
Uses: Post-partum treatment for women. General tonic.
Preparation: The whole plant is boiled. Consume about 250 ml of the decoction.
Propagation: Seed or cutting.

3. Scientific name: *Donax cannaeformis* (Marantaceae).
Local name: Lias.

Figure 5. *Donax cannaeformis*.

Field identification: Shrub, to 7 m tall.
Habitat: Lowland mixed dipterocarp forest.
Uses: Sap from new leaves used as an eye pain relief.
Preparation: Sap.
Propagation: Seed.

4. Scientific name: *Fagraea cuspidata* (Loganiaceae).
Local name: Todopon Puok.

Figure 6. *Fagraea cuspidata.*

Field identification: Tree up to 5 m tall.

Habitat: Edge of forest.

Uses: Leaves and roots are used to treat stomachache.

Preparation: Boil the leaves or roots, and drink a cup of the decoction.

Propagation: Seed.

5. Scientific name: *Costus speciosus* (Costaceae).
Local names: Sibu-Sibu/ Insasabu.

Figure 7. *Costus speciosus.*

Field identification: Medium-sized shrub.

Habitat: Common in the forest.

Uses: Sap used to treat asthma/ difficulty in breathing.

Preparation: Cut new stem to get the sap and drink.

Propagation: Rhizome and seed.

6. Scientific name: *Ficus septica* (Moraceae).
Local name: Sintotobou Topurak.

Figure 8. *Ficus septica.*

Field identification: Small tree up to 5 m tall.

Habitat: Open area.

Uses: The root is used for post-partum treatment.

Preparation: Boil the root and after cooling, take it for bath.

Propagation: Seed.

7. Scientific name: *Ficus deltoidea* (Moraceae).
Local name: Daun Perawan.

Figure 9. *Ficus deltoidea.*

Field identification: An epiphyte.

Habitat: On trees.

Uses: Tonic for women.

Preparation: Boil the whole plant and drink about 250 ml of the decoction.

Propagation: Seed.

8. Scientific name: *Poikilospermum suaveolens* (Cecropiaceae).
Local name: Saringkalang.

Figure 10. *Poikilospermum suaveolens.*

Field identification: An epiphyte.

Habitat: On trees.

Uses: To treat wounded skin.

Preparation: Crush shoot and apply on the skin.

Propagation: Seed.

9. Scientific name: *Curculigo latifolia* (Liliaceae).
Local names: Tambaka/ Lamba.

Figure 11. *Curculigo latifolia.*

Field identification: Herb with yellow flowers on the ground.

Habitat: Undisturbed forest, usually near streams.

Uses: Abdominal pain.

Preparation: The rhizome is warmed and applied as poultice.

Propagation: Rhizome and seed.

10. Scientific name: *Etlingera punicea* (Zingiberaceae).
Local name: Tuhau.

Figure 12. Inflorescence of Tuhau, *Etlingera punicea*

Figure 13. The edible piths of Tuhau.

Field identification: Large shrub with very strong smell when leaves are crushed. Inflorescence yellowish red on the ground.

Habitat: Edge of undisturbed forest. Usually cultivated.

Uses: Edible pith. To reduce high blood pressure. Blood cleanser.

Preparation: The pith is eaten raw or cooked.

Propagation: Rhizome.

11. Scientific name: *Gigantochloa levis* (Gramineae).
Local name: Poring.

Figure 14. Poring bamboo, *Gigantochloa levis*.

Field identification: Very large and straight bamboo.

Habitat: Found in primary forest and also much cultivated.

Uses: Water inside the culm is used to cure intestinal bleeding.

Preparation: Drink the water raw.

Propagation: Rhizome.

12. Scientific name: *Tetracera scandens* (Dilleniaceae).
Local names: Pampan/ Mempelas.

Figure 15. *Tetracera scandens.*

Field identification: Climbing herb.
Habitat: Undisturbed lowland forest.
Uses: To treat internal pains.
Preparation: Sap of the plant is taken raw.
Propagation: Seed.

13. Scientific name: *Helminthostachys zeylanica* (Ophioglossaceae).
Local name: Pajerok.

Figure 16. *Helminthostachys zeylanica.*

Field identification: Small herb with erect inflorescence in the middle.

Habitat: Secondary forest.

Uses: To treat wounds.

Preparation: Boil the leaves and drink the decoction.

Propagation: Spore.

14. Scientific name: *Alstonia angustiloba* (Apocynaceae).
Local names: Tombirog/ Pulai.

Figure 17. *Alstonia angustiloba.*

Field identification: Big pagoda-like tree with leaves arranged spirally. White latex appears when bark is cut.

Habitat: Edge of forest and secondary forest.

Uses: To treat malaria.

Preparation: Latex.

Propagation: Seed.

EXOTIC OR NATURALIZED

1. Scientific name: *Melastoma malabathricum* (Melastomataceae).
   Local names: Gata-Gata/ Senduduk.

Figure 18. *Melastoma malabathricum.*

Field identification: Medium-sized shrub with conspicuous purple flowers.
Habitat: Open places.
Uses: Treatment of external wounds.
Preparation: Leaves are pounded and applied as poultice.
Propagation: Seed.

2. Scientific name: *Blumea balsamifera* (Compositae).
   Local name: Tawawo.

Figure 19. *Blumea balsamifera.*

Field identification: Medium-sized herb to 3 m.
Habitat: Disturbed or open places.
Uses: To treat swelling of pancreas.
Preparation: The leaves are pounded and boiled in water for bathing.
Propagation: Seed.

3. Scientific name: *Cymbopogon citratus* (Gramineae).
Local names: Capai Pimping/ Sogumau.

Figure 20. *Cymbopogon citratus.*

Field identification: Bushy with long and narrow leaves. Leaves produce good smell when crushed.
Habitat: Open or mostly cultivated areas.
Uses: Tonic.
Preparation: Roots are boiled for drinking.
Propagation: Rooted stem.

4. Scientific name: *Zingiber officinale* (Zingiberaceae).
Local name: Halia.

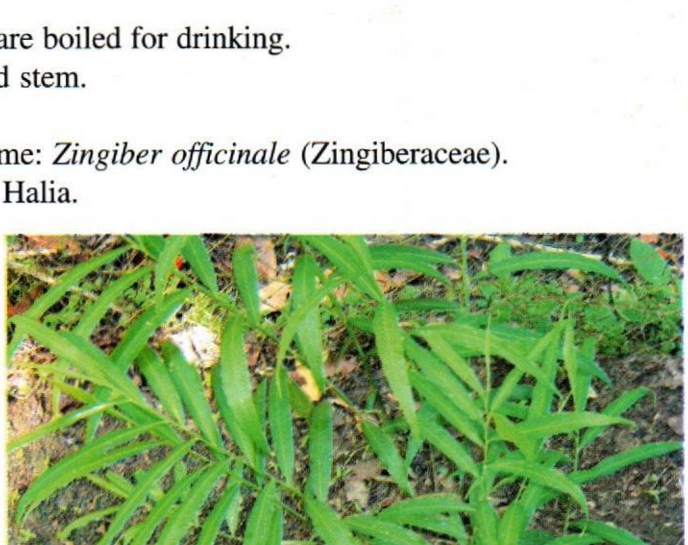

Figure 21. *Zingiber officinale.*

Field identification: Small herb with very strong smell when the leaves are crushed.
Habitat: Open or cultivated areas.
Uses: To remove wind from the body.
Preparation: Rhizome is pounded and boiled for drinking (about 250 ml).
Propagation: Rhizome.

5. Scientific name: *Justicia gendarussa* (Acanthaceae).
Local names: Sikapapar/ Tambiau.

Figure 22. *Justicia gendarussa.*

Field identification: Small shrub with blackish stem.
Habitat: Open places or cultivated as garden plant.
Uses: To treat headache.
Preparation: Leaves are pounded and applied on the forehead.
Propagation: Stem.

6. Scientific name: *Senna alata* (Fabaceae).
Local names: Kayabau/ Manggarut.

Figure 23. *Senna alata.*

Field identification: Medium-sized shrub with leaflets oppositely arranged. Conspicuous yellow flowers.
Habitat: Open and disturbed areas.
Uses: To treat beriberi and ringworm on skin.
Preparation: For beriberi, boil roots in water for drinking; for ringworm, apply pounded leaves on skin.
Propagation: Seed.

7. Scientific name: *Hibiscus rosa-sinensis* (Malvaceae).
Local names: Pangkat/ Bunga Raya.

Figure 24. *Hibiscus rosa-sinensis.*

Field identification: Medium-sized shrub.
Habitat: Planted in open places as ornamental.
Uses: To treat headache.
Preparation: Young leaves are pounded and applied on head.
Propagation: Stem.

8. Scientific name: *Morinda citrifolia* (Rubiaceae).
Local name: Bingkudu.

Figure 25. *Morinda citrifolia.*

Field identification: Medium-sized tree.
Habitat: Open places, seaside, or cultivated.
Uses: To treat gastritis and swollen pancreas.
Preparation: Boil fruits or leaves in water for drinking.
Propagation: Seed.

9. Scientific name: *Coix lachryma-jobi* (Gramineae).
Local name: Dalai.

Figure 26. *Coix lachryma-jobi.*

Field identification: Herb.
Habitat: Cultivated, open places.
Uses: To treat fever.
Preparation: Whole plant is boiled for bathing.
Propagation: Seed.

10. Scientific name: *Solanum torvum* (Solanaceae).
Local name: Terung Pipit.

Figure 27. *Solanum torvum.*

Field identification: Medium-sized shrub.
Habitat: Open places.
Uses: Root is used to treat high blood pressure.
Preparation: Boil the cleaned root for drinking (about 250 ml).
Propagation: Seed.

11. Scientific name: *Curcuma domestica* (Zingiberaceae).
Local name: Kunyit.

Figure 28. *Curcuma domestica.*

Figure 29. Flowers of *Curcuma domestica.*

Field identification: Leafy herb.
Habitat: Open or cultivated areas.
Uses: Rhizome used to treat skin disease.
Preparation: Wash, chop, and apply on skin.
Propagation: Rhizome.

12. Scientific name: *Tinospora crispa* (Menispermaceae).
Local name: Putarwali.

Figure 30. *Tinospora crispa.*

Field identification: Climber with heart-shaped leaves. Leaves bitter when eaten raw.
Habitat: Open places.
Uses: To treat high blood pressure and stomachache.
Preparation: Boil an inch of the stem for drinking (about 250 ml).
Propagation: Stem cutting.

13. Scientific name: *Polygala paniculata* (Polygalaceae).
Local name: Sihou Gamut.

Figure 31. *Polygala paniculata.*

Field identification: Small herb, often with white flowers.
Habitat: Open areas.
Uses: Roots used to cure skin disease.
Preparation: Wash, pound, and apply on skin.
Propagation: Seed.

CONCLUSION

There are 14 native and 13 exotic species of medicinal plants commonly used at present in Sabah, including 4 native and 1 exotic tree species, 3 native and 5 exotic shrub species, 4 native and 7 exotic herb species. This shows that most of the exotic species are shrubs and herbs.

REFERENCE

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Butterfly dispersal and longevity in unlogged and selectively logged forest

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Abstract. This study investigated the butterfly dispersal and longevity in unlogged and selectively logged forest in lowland dipterocarp rainforest of Sabah, Malaysia (Borneo). Fruit-baited traps were used to survey butterflies in unlogged forest and forest that had been selectively logged 10-12 years previously in 1988 and 1989. The study focused on butterflies in the sub-families Satyrinae, Nymphalinae, Morphinae and Charaxinae (Nymphalidae). Traps were set up along four transects on existing paths and trails in unlogged forest (two transects, total length 4 km) and logged forest (two transects, total length 4 km). Traps were hung 1-2 m from the ground at 100 m intervals along transects (total of 80 traps). Traps were operated for 12 days each month (October 1999-September 2000). Dispersal and longevity were investigated in several of the more abundant species. Dispersal and longevity did not differ between habitats or sexes but did differ between species in relation to body size and subfamily. The maximum distance moved by an individual in this study was 4,670 m and the maximum lifespan was 175 days (*Bassarona dunya* in both cases).

Keywords: Borneo, butterflies, dispersal, longevity, rainforest

INTRODUCTION

There are about 20,000 species of butterfly that have been described in the world, of which more than 50% are tropical species (New 1997). In comparison with temperate butterflies, dispersal and longevity of tropical butterflies have received very little attention and are very poorly understood (Corbet & Pendlebury 1992, New 1997). This is probably because few studies in the tropics have used appropriate methods or lasted sufficiently long to address these topics (Didham *et al.* 1996). In temperate areas, adult butterflies that do not enter diapause generally have life spans of less than 20 days (Warren 1992) and the maximum distance moved by non-migrant temperate species is generally less than 2 km (Shreeve 1992, Lewis *et al.* 1997).

One study in tropical rainforest by Beck & Schulze (2000) recorded that some fruit-feeding nymphalids may live up to six weeks but there are few data on this topic.

Destruction of natural habitats is increasing at a rapid rate around the world, and this reduces species diversity and population sizes (Sutton & Collins 1991, Terbough 1992). Habitat isolation in fragmented landscapes (e.g. forest blocks surrounded by agricultural plantations) is likely to affect the distribution of insect species because of their inability to cross non-habitats that separate habitat patches (Diamond 1989). A study in Lago Guri rainforest, Venezuela by Shahabuddin *et al.* (2000) indicated that butterfly species on small islands can disperse to several different islands during their life time but have lower reproduction and higher rates of mortality than species on mainland areas. This and other studies have suggested that higher rates of movement in isolated habitats are probably related to limited availability of resources such as hostplants for larvae and adults (Srygley & Chai 1990, Spitzer *et al.* 1997). In temperate areas, metapopulation biology has been widely used to describe and predict insect population dynamics in fragmented landscape (Hanski & Gilpin 1997). For instance, a study on temperate butterflies by Thomas *et al.* (1992) indicated that a network of habitat patches is important for supporting species, and that dispersal between habitat patches is important for population persistence. So far, there are few data on dispersal and longevity of butterflies in tropical habitats, and very few data to compare survival and longevity in relation to habitat disturbance.

There are approximately 240 species of butterflies on Borneo belonging to the family Nymphalidae (Otsuka 1988) and adults of approximately 75% of these species feed on rotting fruits (Hill *et al.* 2001). In this study, nymphalid butterflies were sampled using fruit-baited traps, although very little is known about how efficient traps are at sampling butterflies, or how butterflies respond to traps. Several studies have investigated butterfly trap addiction and trap aversion in rainforests (Hughes *et al.* 1998, Beck & Schulze 2000). These studies indicated that individuals might recognise traps as a source of food and become 'trap happy'. Thus, Beck & Schulze (2000) and Hill *et al.* (2001) highlighted that it is important to exclude recaptured individuals from some analyses to avoid problems of non-independence of data. In this study, however we analyse data for recaptured individuals to examine dispersal and longevity in different forest habitats.

In previous studies of dispersal, inverse power functions and negative exponential functions have both commonly been used to describe the distribution of distances moved by individuals (Southwood 1978, Begon *et al.* 1996). A study on temperate butterflies by Hill *et al.* (1996) showed that the distribution of distances moved by dispersing butterflies fitted an inverse power function better than a negative exponential. Both of these models may be useful for describing dispersal and longevity of different butterfly species, but this has not previously been examined in the tropics. The aims of this study were to examine trap addiction and aversion in fruit-feeding nymphalid butterflies and to investigate differences in butterfly dispersal and longevity in relation to habitat disturbance.

MATERIALS & METHODS

Study site

The Ulu Segama Forest Reserve contains the Danum Valley Conservation Area (DVCA) which covers an area of 43,800 ha of protected unlogged forest. This area has been shown to be highly diverse for plants (Marsh & Greer 1992, Newbery *et al.* 1992) and animals (Collins *et al.* 1991, Johns 1992, Lambert 1992). DVCA is surrounded by extensive areas of production forest that have been selectively logged using high-lead cable yarding and tractor extraction methods. Danum Valley Field Centre (DVFC) is ideally located for access to both primary forest and logged forest at different stages of forest recovery. The development of DVFC began in 1984 and was completed in August 1986, to provide facilities for scientific research, education and conservation. The study areas include forest which was selectively logged in 1988 and 1989, approximately 10 years prior to this study, and unlogged forest within the largest Protection Forest Reserve (43,800 ha) in Sabah. The logging technique used was conventional logging where trees above 0.6 m diameter at breast height (dbh) were cut in a single operation. Timber trees were removed from up to 25° slopes but buffer zones were left around major rivers and in river catchment areas.

Butterfly data

Butterflies were sampled using fruit-baited traps from October 1999 until September 2000. Butterflies were sampled along four transects, two in primary forest (DVCA, Main West Trail and Rhino Trail) and two in logged-over forest (Coupe 88 and Coupe 89). Each transect was 2 km long with 20 sampling stations placed 100 m apart (80 stations in total). Two of the four transects (one in unlogged forest, the other in logged forest) were sampled for 12 days consecutively each month. Sampling was then rotated to the other two transects the following month (resulting in a total of 5,760 trap-days during the entire study). Butterflies were sampled using traps baited with rotting banana with one trap placed 1-2 m above the ground at each sampling station.

All sampled butterflies were individually marked on the underside of the left hindwing using a permanent-ink pen, identified and released. All identification was based on Otsuka (1988) and Corbet & Pendlebury (1992). Large butterflies (> 30 mm wingspan) were marked with a unique number (24 species in total) and only these larger species are considered in this study. Dispersal was calculated as the total distance moved by each individual between all successive recaptures. Minimum longevity was calculated as the time in days from first capture to the last recapture. For those species that exhibit sexual dimorphism, sexes were identified from a combination of colour patterns, body size and abdomen shape (Corbet & Pendlebury 1992), and differences in dispersal and longevity between males and females were examined.

Statistical analyses

Butterfly trap addiction and aversion, dispersal and longevity were only investigated for the most abundant species with sufficient numbers of recaptures. Trap addiction and aversion were examined for each species by comparing the observed frequency distribution of captures with that expected from a zero-truncated Poisson distribution (see Greenwood 1996 for details of method). In addition, data on distances moved and longevity were linearly transformed using both a semi-ln plot (negative exponential function) and a double-ln plot (inverse power function). Linear regression was then used to test whether the distribution of species dispersal and longevity best fitted a negative exponential or inverse power function. Three-way ANOVA was used to investigate differences in butterfly dispersal and longevity between sexes, species and habitats.

RESULTS

Twenty-four species of fruit-feeding butterfly were individually marked during the study. Of these, individuals of seven species (*Neorina lowii*, *Discophora necho*, *Prothoe franck*, *Melanitis leda*, *Dophla evelina*, *Amathuxidia amythaon* and *Amathusia phidippus*) moved 1-4 km and individuals of two species (*Bassarona dunya* and *Lexias pardalis*) moved > 4 km. Seven species (*L. pardalis, L. dirtea*, *N. lowii*, *P. franck*, *Kallima limborgii*, *B. dunya* and *B. teuta*) had minimum lifespans of 50-175 days. Among all species recorded, *B. dunya* moved the greatest distance (4,670 m) and had the greatest minimum lifespan (175 days) and there was a significant correlation between minimum lifespan and distance moved (Table 1; Spearman correlation; $r_s = 0.56$, $n = 23$, $P < 0.01$, excluding one species, *Dischorragia nesimachus*, which was never recaptured). Four species (*N. lowii*, *B. dunya*, *P. franck* and *L. pardalis*) were captured in large numbers (115-514 individuals; Table 1) and all further analysis is restricted to these four species.

Trap addiction and aversion

The distribution of recaptures differed significantly from a zero-truncated Poisson distribution for *N. lowii* (chi-square = 127.7, df = 4, $P < 0.001$) and *B. dunya* (chi-square = 15.8, df = 4, $P < 0.001$), but there was no significant difference for *P. franck* (chi-square = 4.8, df = 2, $P > 0.05$) or *L. pardalis* (chi-square = 2.75, df = 2, $P > 0.10$). For *N. lowii* and *B. dunya*, there were more individuals than expected caught only once, indicating some trap aversion. However there were also more individuals than expected caught more than four times, suggesting that once an individual was caught twice, it had an increased probability of being recaptured repeatedly. The greatest number of recaptures was an individual *N. lowii* that was caught ten times.

Table 1. Number of individuals recaptured during the study. The maximum distance moved by individuals, and the minimum lifespan are also shown.

Species	No. of individuals	No. of recaptures	Rate of recapture	Max. distance moved (m)	Min. lifespan (days)
Neorina lowii	514	176	0.34	1580	66
Bassarona dunya	412	168	0.40	4670	175
Zeuxidia doubledayi	13	1	0.08	0	1
Kallima limborgii	23	7	0.30	300	127
Discophora necho	103	14	0.14	1300	24
Prothoe franck	238	53	0.22	1190	69
Zeuxidia amethystus	24	1	0.04	540	11
Amnosia decora	31	9	0.29	600	11
Zeuxidia aurelius	33	3	0.09	0	10
Melanitis leda	65	11	0.17	1090	11
Dophla evelina	61	8	0.13	1200	6
Amathuxidia amythaon	11	2	0.18	1000	2
Dischorragia nesimachus	11	0	0.00	0	0
Bassarona teuta	68	15	0.22	854	101
Lexias pardalis	115	29	0.25	4080	56
Agatasa calydonia	12	1	0.08	0	6
Lexias dirtea	44	6	0.14	900	55
Amathusia phidippus	18	2	0.11	1000	2
Lexias canescens	13	1	0.08	100	3
Charaxes bernadus	22	3	0.14	0	3
Cirrochroa emalea	19	2	0.11	0	3
Xanthotaenia busiris	11	4	0.36	0	4
Thaumantis noureddin	4	1	0.25	200	3
Rhinopalpa polynice	13	1	0.08	0	4

Species dispersal

The distribution of dispersal distances of *N. lowii, B. dunya* and *P. franck* all fitted negative exponential functions better than inverse power functions (Table 2). However, there was no difference for *L. pardalis* in the goodness-of-fit between an inverse power function and an exponential function.

Table 2. Goodness-of-fit of species dispersal distributions to negative exponential and inverse power functions.

Negative exponential function		Inverse power function	
(a) *N. lowii*			
Slope	= - 0.002 (SE < 0.01)	Slope	= - 0.48 (SE ± 0.15)
Intercept	= - 0.13 (SE ± 0.10)	Intercept	= 0.92 (SE ± 0.99)
R^2	= 0.98	R^2	= 0.53
$F_{1,9}$	= 520.7, $P < 0.001$	$F_{1,9}$	= 10.2, $P = 0.01$
(b) *B. dunya*			
Slope	= - 0.001 (SE < 0.001)	Slope	= - 0.60 (SE ± 0.15)
Intercept	= - 0.48 (SE ± 0.20)	Intercept	= 1.63 (SE ± 1.07)
R^2	= 0.92	R^2	= 0.54
$F_{1,13}$	= 149.1, $P < 0.001$	$F_{1,13}$	= 15.30, $P < 0.002$
(c) *P. franck*			
Slope	= - 0.003 (SE < 0.001)	Slope	= - 0.43 (SE ± 0.17)
Intercept	= 0.114 (SE ± 0.120)	Intercept	= 0.48 (SE ± 0.17)
R^2	= 0.99	R^2	= 0.55
$F_{1,5}$	= 390.1, $P < 0.001$	$F_{1,5}$	= 6.23, $P = 0.06$
(d) *L. pardalis*			
Slope	= - 0.0007 (SE < 0.001)	Slope	= - 0.37 (SE ± 0.12)
Intercept	= - 0.89 (SE ± 0.39)	Intercept	= 0.52 (SE ± 0.74)
R^2	= 0.31	R^2	= 0.66
$F_{1,5}$	= 8.77 , $P = 0.031$	$F_{1,5}$	= 9.58, $P = 0.03$

Species longevity

Longevity of *N. lowii*, *B. dunya*, *P. franck*, and *L. pardalis* all fitted negative exponential functions better than inverse power functions (Table 3).

Table 3. Goodness-of-fit of species longevity distributions to negative exponential and inverse power functions.

Negative exponential function		Inverse power function	
(a) ***N. lowii***			
Slope	= - 0.05 (SE ± 0.01)	Slope	= - 0.98 (SE ± 0.26)
Intercept	= - 0.12 (SE ± 0.44)	Intercept	= 0.75 (SE ± 0.94)
R^2	= 0.89	R^2	= 0.74
$F_{1,5}$	= 40.8, P = 0.001	$F_{1,5}$	= 14.2, P = 0.01
(b) ***B. dunya***			
Slope	= -0.027 (SE ± 0.001)	Slope	= - 0.91 (SE ± 0.21)
Intercept	= -0.069 (SE ± 0. 12)	Intercept	= 1.32 (SE ± 0.89)
R^2	= 0.98	R^2	= 0.65
$F_{1,10}$	= 591.9, P < 0.001	$F_{1,10}$	= 18.7, P = 0.002
(c) ***P. franck***			
Slope	= - 0.04 (SE ± 0.01)	Slope	= - 0.62 (SE ± 0. 20)
Intercept	= - 0.02 (SE ± 0.32)	Intercept	= 0.43 (SE ± 0.67)
R^2	= 0.89	R^2	= 0.71
$F_{1,4}$	= 31.99, P = 0.005	$F_{1,4}$	= 9.98, P = 0.03
(d) ***L. pardalis***			
Slope	= - 0.05 (SE ± 0.01)	Slope	= - 0.63 (SE ± 0.25)
Intercept	= 0.2 (SE ± 0.40)	Intercept	= 0.38 (SE ± 0.79)
R^2	= 0.88	R^2	= 0.69
$F_{1,3}$	= 21.9, P = 0.02	$F_{1,3}$	= 6.53, P = 0.08

A three-way ANOVA by ranks (Zar 1999) was used to investigate differences in dispersal between sexes, species (*N. lowii*, *B. dunya*, *P. franck*) and habitat. *L. pardalis* was excluded from this analysis because there were too few recaptures. There was a significant difference in dispersal between species (Figure 1; Kruskal-Wallis H' = 13.56, df = 2, P < 0.001), and *B. dunya* moved further than either of the other two species. However, there was no significant difference in dispersal between sexes (H' = 0.45, df = 1, P = 0.50) or habitats (H' = 0.46, df = 1, P = 0.50), or any significant interactions between any of these variables (P > 0.20).

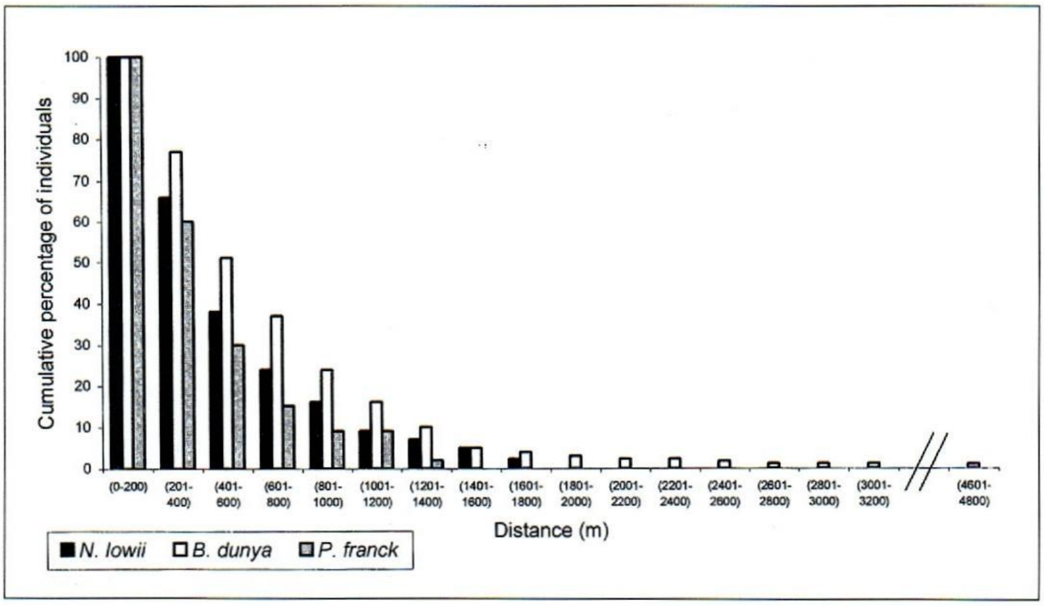

Figure 1. Dispersal of butterfly species based on marked individuals moving between traps over one year.

There was a significant difference in longevity between species (Figure 2; three-way ANOVA by ranks; Kruskal-Wallis H' = 27.96, df = 2, $P < 0.001$) and *B. dunya* lived longer than other two species. However there was no significant difference in longevity between sexes (H' = 1.02, df = 1, $P > 0.25$) or habitats (H' = 1.86, df = 1, $P > 0.10$). There was a significant sex*species interaction (H' = 7.31, df = 2, $P < 0.05$) and sex*habitat interaction (H' = 7.65, df = 1, $P < 0.01$), showing that lifespans of males and females were related to those species of larger thoraxes and body sizes, and suitable breeding and feeding habitats for butterflies.

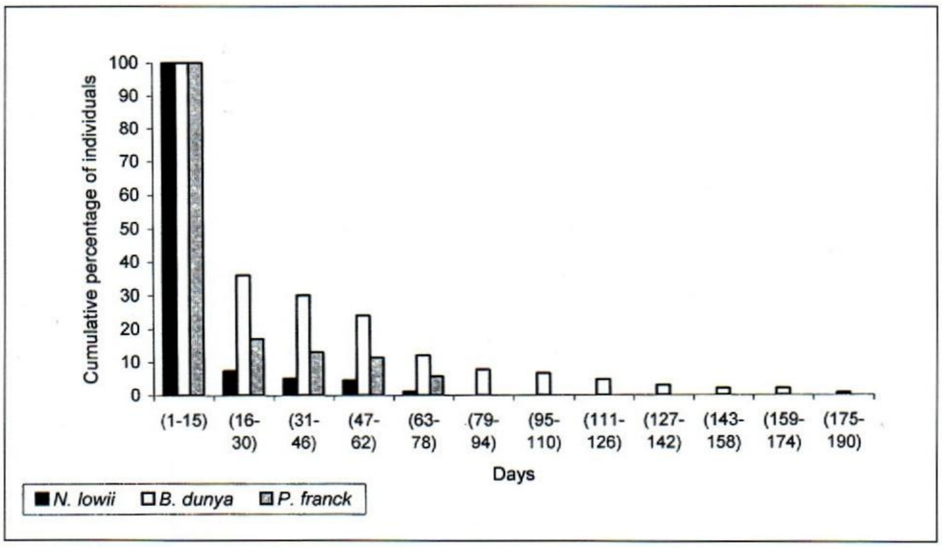

Figure 2. Longevity of butterfly species based on recaptures of marked individuals.

DISCUSSION

The results of this study show that *B. dunya* moved the greatest distance (4,670 m), followed by *L. pardalis* and *N. lowii*. *B. dunya* also had the longest minimum lifespan (175 days), followed by *K. limborgii* and *B. teuta*. It should be stressed that individuals were not necessarily newly emerged when they were first caught, and so these data indicate minimum lifespan and dispersal. It is also possible that by providing food in traps, the lifespans and dispersal of some individuals were increased. These data are therefore only an approximate indication of minimum lifespan and dispersal under natural conditions. A previous study on fruit-feeding nymphalids recorded adult lifespans of up to 45 days (Beck & Schulze 2000) but the study lasted for less than three months. Thus the longer lifespans recorded in our study may reflect the longer sampling period. Our study demonstrates that some adults may live for considerable periods, in some cases for much longer than previously recognized.

Trap addiction and aversion

Species differed in their recapture rates (Table 1). This may reflect differences in relative abundance and/or dispersal among species, but may also indicate that different species responded differently to traps. For two species, *N. lowii* and *B. dunya*, the frequency of recaptures differed significantly from random showing evidence of both trap addiction and trap aversion. Trap addiction can occur when individuals recognize traps as a source of food (Hughes *et al.* 1998, Hill *et al.* 2001) and in this study, some individuals of both *N. lowii* and *B. dunya* were observed to return repeatedly to the same traps every day for more than 7 days. Trap aversion may be an effect of marking and handling individuals, which can then affect the subsequent behaviour of marked specimens (Morton 1984).

Frequency distributions of dispersal and longevity

Dispersal of *N. lowii*, *B. dunya* and *P. franck* all fitted negative exponential functions better than inverse power functions, whilst dispersal of *L. pardalis* fitted both functions equally well, indicating that all four species were dispersing randomly within the forest. Non-random dispersal can result from individuals having territories or home ranges, from competition for resources and from resources having a patchy distribution (Andrewartha 1961, Southwood 1978, Hill *et al.* 1996). The results indicate that these were not important factors influencing the dispersal of the four species in this study.

Data for longevity also fitted a negative exponential function better than an inverse power function for all four species, indicating a constant rate of survival in each case (Southwood 1978). Longevity may be influenced by many factors including predation, pathogens, parasites, food resources and weather conditions in the forest (Yong 1983, Speight *et al.* 1999). Extreme weather such as high temperatures or very dry or wet conditions may also affect butterfly mortality (Smart 1975). Further data are needed for adults of known time since emergence, to study changes in survival over an adult's lifespan.

Butterfly dispersal and longevity

B. dunya moved longer distances than *P. franck*, with *N. lowii* having intermediate values. Differences in dispersal among butterfly species have been related to body size (Chai & Srygley 1990, Srygley & Chai 1990), and *B. dunya* and *N. lowii* (wing length 43-50 mm and 45-52 mm respectively) are larger than *P. franck* (wing length 37-43 mm) (Otsuka 1988). In butterflies, the thorax contains mainly flight muscles and, in addition to body size, larger thoraxes have been associated with increased flight ability in butterflies (e.g. Berwaerts *et al.* 2002). Nymphalinae and Charaxinae are generally reported to have relatively larger thoraxes and body sizes than Satyrinae (Hill *et al.* 2001), which is likely to affect their capability to disperse in the forest. *B. dunya* is a member of the Nymphalinae and this may explain why it had greater dispersal than *N. lowii*, which is in the Satyrinae, although they have similar wing lengths.

There was no significant difference in dispersal between sexes or between unlogged and logged forest. This study took place in forest that was selectively logged 10 years before the study, and habitat regeneration over that time might have resulted in selectively logged forest providing plenty of suitable breeding and feeding sites for butterflies (Willott *et al.* 2000). It should be pointed out, however, that the three species studied are all relatively mobile, and habitat disturbance may affect dispersal of more sedentary species (New 1997, Shahabuddin *et al.* 2000) and this deserves more research.

This study found that species that lived longer moved greater distances. Beck *et al.* (1999) indicated that minerals, proteins and carbohydrates are all essential for adults of some species to increase their longevity and flight capacity. Those species which are more dispersive may have more opportunities to select and utilize more widespread resources (Andrewartha 1961), thus increasing their longevity. Alternatively, greater distances moved by long-lived species may result from both lifespan and dispersal being related to body size, or simply from more time available to disperse in longer-lived species. Compared with temperate species, adults of tropical species appear to have much longer lifespans. This may explain why such a high proportion of tropical species are dependent as adults on nutrients such as those available in rotting fruit and carrion (Beck *et al.* 1999, Hall & Willmott 2000).

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Conservation of aquatic and semi-aquatic mosses in a Mediterranean area in Spain and a tropical area in Malaysia

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Abstract. Aquatic and semi-aquatic mosses are useful in balancing and regulating moisture in the environment. It is important to conserve and manage these mosses for the benefit of all. Aquatic and semi-aquatic mosses were checklisted, identified for a Mediterranean area in Región de Murcia in Spain and a tropical area on Mount Kinabalu in Sabah, Malaysia. Water-dependent mosses were found to be more abundant and diverse in a tropical country like Malaysia. The ecological functions of aquatic and semi-aquatic mosses such as in mitigating floods and soil erosion are highlighted. Bryoflora conservation in Malaysia as well as Spain is discussed.

Keywords: aquatic mosses, conservation, ecological functions, Mediterranean area, semi-aquatic mosses, systematics, tropical area

INTRODUCTION

Mosses are lower plants which belong to the division Bryophyta (Weier *et al.* 1974). Basically, aquatic mosses are submerged in the freshwater ecosystems all year round and are very few in number relatively. Mosses are abundant in habitats like rocky beds and boulders in fast-flowing mountain streams. As for semi-aquatic mosses, they are not tolerant of prolonged submergence in the aquatic ecosystems (Rhind 2006). The gametophytes of the semi-aquatic mosses are not fully submerged.

Based on Watson (1919), 4 communities of aquatic mosses can be divided:

(*a*) A constantly submerged and stream bed community, dependent on the acidity of the water;

(*b*) A frequently submerged and constantly moist community, through splashes or sprays;

(*c*) An occasionally submerged and frequently wet community; and

(*d*) A community of plants growing in or near waterfalls.

Generally, aquatic and semi-aquatic mosses are sensitive bioindicators in monitoring the occurrence of water pollutants, particularly heavy metals (Ando & Matsuo 1984). Frahm *et al.*

(1996) stated that bryophytes have narrow ecological ranges, and leaves which are not protected by waxy cuticle as compared to the higher plants. These factors make mosses more vulnerable to absorbing and accumulating more metal elements as compared to the other divisions in the plant kingdom. In Europe, Japan and Northern America, bryophytes are widely used as bioindicators for water quality.

According to Moore *et al.* (1998), bryophytes can absorb most of the water from the atmosphere and the surface of the substrate. They can contain from 50% to 2500% of water as compared to their dry weight. Most mosses are tolerant of desiccation. In a nutshell, mosses act like 'sponges' which absorb, conserve and regulate the water sources in an ecosystem. As a result, they can naturally control floods and are potentially crucial in disaster management.

Bryophytes are also useful for controlling erosion. The delicate green webs of protonemata as well as turfs of bryophytes occurring along the banks of the freshwater systems are vital and effective in preventing soil erosion (Welch 1948). This was proven by Conrad (1935), Whitehouse & McAllister (1954), and Ando (1957). Communities of mosses that are occurring along the banks and beds of a riverine system are densely packed with sand and soil (Grout 1912). In short, mosses aid in forming and retaining the substrate particles efficiently.

Bryophytes are also beneficial in treating industrial waste water, e.g. *Sphagnum* in the peatlands. The chemical characteristics of *Sphagnum* allow effective adsorption and filtration of waste water containing heavy metals, organic substances like oils, detergents and dyes, and also microorganisms. Physically it is highly cellular and permeable. This is a rather cheap, simple and convenient method to eliminate a broad spectrum of pollutants (Coupal & Lalancette 1976).

The importance of bryophytes is undeniably vast in serving the environment. Aquatic and semi-aquatic mosses specifically have to be conserved and managed for their continual occurrence, and they should not be allowed to go extinct, at a time when their habitats particularly forests are being transformed by humans into concrete buildings.

STUDY AREAS & METHODS

Study areas

Scholarly literature research/review was done on a Mediterranean area in Región de Murcia in Spain (Figure 1) and a tropical area on Mount Kinabalu in Sabah, Malaysia (Figure 2).

Figure 1. Map showing the location of the study area (highlighted in rectangle) in Spain in the Mediterranean (Wikipedia Foundation 2006).

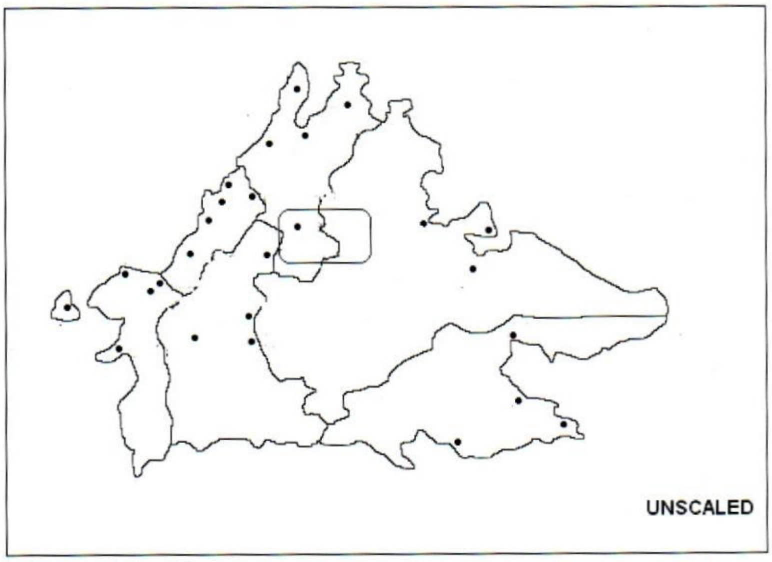

Figure 2. Map showing the study area (highlighted in rectangle) in Sabah, Malaysia (Signet Information Technology 2004).

Methodology

Checklisted mosses from the herbaria of MUB, BCB, C, MA and PC (unique codes used for herbaria) were researched and referred according to Cano *et al.* (2004). Aquatic and semi-aquatic mosses found in the Región de Murcia (Mediterranean area of Spain) were sorted out. Collections of aquatic and semi-aquatic mosses were also referred to from the bibliographic materials (Sergio *et al.* 1994, Sergio *et al.* 1995). For identifications and characterizations we followed Vitt *et al.* (1992) and van der Wijk (1958). For nomenclature, we referred to Jeffrey & Heywood (1973). A list of bryophytes from the study area on Mount Kinabalu, Malaysia is included in this paper. The rationale is to provide a preliminary idea on the bryodiversity in a tropical zone.

RESULTS & DISCUSSION

Diversity

This review found 23 species of aquatic and semi-aquatic mosses belonging to 17 genera and 9 families in the Mediterranean area of Spain. Family Pottiaceae was the most dominant with 6 species. The least represented were Cratoneuraceae, Helodiaceae and Bartramiaceae, each with 1 species (Appendix 1).

As for the study area in Sabah, 46 species of hydrophilous and hygrophilous (water-dependent) species were checklisted, belonging to 37 genera and 23 families (Akiyama *et al.* 2001). Sematophyllaceae was the most dominant with 6 species. On the other hand, 10 families Hypnaceae, Brachytheciaceae, Thamnobryaceae, Racopilaceae, Mniaceae, Grimmiaceae, Ditrichaceae, Diphysciaceae, Sphagnaceae, Takakiaceae, were having 1 species each (Appendix 2).

The diversity and abundance of bryophytes are dependent on the precipitation in a particular area. Moore *et al.* (1998) stated that mosses are water-borne or moist plants. In the Mediterranean area of Spain, the precipitation recorded (for the period between October 2004 and September 2005) was only 200 mm (Wikipedia Foundation 2006). On the other hand, more than 3000 mm of precipitation annually was recorded on Mount Kinabalu (Frahm *et al.* 1996). Water-dependent mosses are therefore more abundant and diverse in a tropical country like Malaysia. Management of aquatic and semi-aquatic mosses in a drier country like Spain is hence critical. The bryoflora in the wetter tropics should also be soundly managed and not be blindly exploited.

Biosystematics, conservation and environmental management

Aquatic and semi-aquatic bryophytes are natural biological agents in mitigating disasters like floods and soil erosion. To ensure the continual functions of this 'mitigator', conservation management has to be implemented. Conservation management plan means identifying 'who they are' and preservation before allowing any development projects to take place that might damage the species forever (extinction).

For this to happen, systematics has to be incorporated into the plan. Systematics plays a crucial role in biodiversity conservation and disaster management (Jeffrey & Heywood 1973, Ando & Matsuo 1984). In this case, it refers to the processes of checklisting, examining, identifying, characterizing and documenting the existing moss species. Without systematics, managers will never know the status of the particular species, which can be common, rare or endemic. Systematics helps us to appreciate the bryoflora and also to manage the environment. If we never know the existence of a particular moss, we will never conserve it. And if we do not conserve and manage the environment as a whole, degradation and even desertification may ensue.

Morphological and anatomical characters of bryophytes are also important, apart from just knowing the number of species, genera and families. There is more in-depth research at the cytological or molecular level (Stuessy 1990) but for environmental and disaster management purposes, morphological and anatomical characters will suffice. The ecological functions and services provided by the aquatic and semi-aquatic mosses are mostly significant at the obvious morphological and anatomical levels. This is a good example of how taxonomy can be applied in management.

In a nutshell, realizing the existence and functions of bryophytes will lead to conservation and environmental management.

Tropical bryodiversity management

In Sabah, Malaysia, bryodiversity is managed normally in the natural parks. As bryophytes are part of the tropical rainforest ecosystem, managing bryophytes in the tropical rainforest also means managing the whole ecosystem.

Mosses rely on branches, leaves and water resources (like creeks, streams and rivers) as their habitats. In return, mosses provide a 'water reservoir' for the plants in the forest and regulate precipitation in an environment-friendly manner.

Managing the diverse and abundant bryoflora in the protected natural parks of Malaysia does not actually require much effort. All mosses are protected along with the angiosperms, gymnosperms, as well as other flora and fauna in the gazetted areas. The main problem is in the unprotected areas. Malaysia is one of the mega-biodiversity centres in the world, and Sabah in Borneo island has high endemism and possibly many species new to science. But Malaysia is also a developing country which needs money for her developments, and deforestation is unavoidable.

Unfortunately, the awareness on the importance of 'lumut' (Malay word for bryophytes) is still low among Malaysians. Nonetheless, scientific bodies in Malaysia, e.g. the Institute for Tropical Biology and Conservation (ITBC) of Universiti Malaysia Sabah, are working with the mass media in awareness campaigns. Talks are also given by bryologists to the industrial people on the importance of conserving mosses. However, the survival of mosses depends very much on forest conservation, where bryophytes are often overlooked. It would be good if a small management unit solely for the conservation of bryophytes could be formed under the Forestry Department.

Is there a bryoflora management group in Malaysia? There is no local permanent bryodiversity management team, but scientists, research institutes and government departments are working towards the goal of conserving and preserving the existing mosses in Sabah. The

Japan International Cooperation Agency (JICA) has been working closely with the scientific community in Sabah on conservation issues and environmental problems. The BRYOTROP project from Germany also worked with local bryologists and documented the existing bryophytes of Mount Kinabalu. It is hoped that a bryodiversity management group can be formed to intensify research on bryophytes, and to provide grants for their research and conservation.

Mediterranean bryodiversity management

Mediterranean mosses are less diverse in comparison with tropical mosses in Sabah. Generally, Mediterranean forest is less thick, without obvious canopies, dry and vulnerable to fire. All these features are in contrast with tropical rainforest. According to World Wildlife Fund (2006), the Mediterranean area of Spain is under pressure from forest fire, urbanization, coastal and mountain tourism, competition for agricultural lands, firewood collection, overgrazing by livestock, and wildlife hunting. All these factors lead to bad soil quality and low quality of ground water. As a result, the Mediterranean forest in Spain could be in danger of desertification.

Bryophytes are minute plants in the forest. Normally people are unaware of their existence. If the Mediterranean forest is neglected and not conserved, the various communities will face extinction, including the aquatic and semi-aquatic mosses. However, Spain is a developed country and conservation is an important matter. Bryologists in Spain are continually updating their database from time to time. For instance, University of Murcia is working in bryological conservation in the southeastern part of Spain. The checklisting will act as a biomonitoring programme. It works by comparing the diversity and abundance of each species in every fieldtrip made.

Furthermore, there is a bryological society in Spain named the "Spanish Society of Bryology". The society encourages the public to join in to know more about the importance of mosses. Knowledge about functions of mosses should not just be kept within the circle of scientists, as the ultimate goal of science is to spread knowledge and to improve lives.

In Spain, quite a number of research groups are working towards the conservation of bryophytes. Nevertheless, a long-term management plan for the bryophytes is needed. Conservation of bryophytes is especially crucial and critical in a drier country like Spain.

In general, scientists are more interested in tropical bryophytes which are not well studied yet. For instance, the British Bryological Society had set up a Tropical Bryology Group in 1989. Mediterranean mosses were mainly studied in Europe by the European bryologists themselves. Both Mediterranean and tropical groups are vital for the environment. In fact, without tropical mosses, flooding and soil erosion would cause severe disasters to tropical rainforests and their people. Meanwhile, without mosses in Spain, the country would become drier (mosses store and regulate precipitation), and significant soil erosion and flooding could happen.

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Appendix 1. List of mosses from a Mediterranean area in Región de Murcia, Spain.

FAMILY: POTTIACEAE

Barbula bolleana (Müll. Hal.) Broth.
Didymodon tophaceus (Brid.) Lisa
Eucladium verticillatum (Brid.) Bruch & Schimp.
Gymnostomum calcareum Nees & Hornsch.
Hymenostylium recurvirostrum (Hedw.) Dixon
Tortula marginata (Bruch & Schimp.) Spruce

FAMILY: BRYACEAE

Bryum caespiticium Hedw.
Bryum pseudotriquetrum (Hedw.) P. Gaertn., B. Mey & Scherb.
Pohlia melanodon (Brid.) A.J. Shaw
Pohlia wahlenbergii (F. Weber & D. Mohr) A.L. Andrews

FAMILY: CRATONEURACEAE

Cratoneuron filicinum (Hedw.) Spruce

FAMILY: BRACHYTECIACEAE

Eurhynchium hians (Hedw.) Sande Lac.
Eurhynchium speciosum (Brid.) Jur.
Platyhypnidium riparioides (Hedw.) Dixon

FAMILY: FISSIDENTACEAE

Fissidens grandifrons Brid.
Fissidens warnstorfii M. Fl.

FAMILY: FONTINALACEAE

Fontinalis antipyretica Hedw.
Fontinalis duriaei Schimp.

FAMILY: AMBLYSTEGIACEAE

Hygroamblystegium tenax (Hedw.) Jenn.
Leptodictyum humile (P. Beauv.) Ochyra
Leptodictyum riparium (Hedw.) Warnst.

FAMILY: HELODIACEAE

Palustriella commutata (Hedw.) Ochyra

FAMILY: BARTRAMIACEAE

Philonotis fontana (Hedw.) Brid.

Appendix 2. List of mosses from a tropical area on Mount Kinabalu, Sabah, Malaysia.

FAMILY: TAKAKIACEAE
Takakia lepidozioides Hatt. & Inoue

FAMILY: ANDREAEACEAE
Andreaea rupestris Hedw. var. *rubicunda* (Bartr.) Iwats.
Andreaea subulata Harv.

FAMILY: DIPHYSCIACEAE
Diphyscium involutum Mitt.

FAMILY: POLYTRICHACEAE
Pogonatum flexicaule Mitt.
Pogonatum iwatsukii Touw

FAMILY: FISSIDENTACEAE
Fissidens nobilis Griff.
Fissidens zippelianus Dozy & Molk.

FAMILY: GRIMMIACEAE
Racomitrium subsecundum (Hook. & Grev.) Mitt. & Wils.

FAMILY: BRYACEAE
Bryum billardierii Schwaegr.
Orthodontium infractum Dozy & Molk.
Rhodobryum giganteum (Schwaegr.) Par.

FAMILY: MNIACEAE
Plagiomnium rhynchophorum (Hook.) Kop.

FAMILY: FUNARIACEAE
Entosthodon buseanus Dozy & Molk.
Entosthodon mittenii Dozy & Molk.

FAMILY: RACOPILACEAE
Racopilum spectabile Reinw. & Hornsch.

FAMILY: HYPNODENDRACEAE
Hypnodendron fusco-mucronatum (C. Muell.) Jaeg.
Hypnodendron milnei Mitt. subsp. *korthalsii* (Par.) Touw
Hypnodendron vitiense Mitt.

FAMILY: THAMNOBRYACEAE
Thamnobryum ellipticum (Bosch & Sande Lac.) Nog. & Iwats.

FAMILY: DALTONIACEAE

Distichophyllum mittenii Bosch. & Sande Lac.
Distichophyllum osterwardii Fl.

FAMILY: HYPOPTERYGIACEAE

Hypopterygium tenellum C. Muell.
Hypopterygium vriesei Bosch. & Sande Lac.

FAMILY: HOOKERIACEAE

Achrophyllum javense (Dix. ex Froehl.) Iwats., Tan & Touw
Callicostella papillata (Mont.) Mitt.
Calyptrochaeta rotundifolia (Nog. & Iwats.) Touw
Chaetomitrium leptopoma (Schwaegr.) Bosch & Sande Lac.
Hookeria acutifolia Hook. & Grev.

FAMILY: BRACHYTHECIACEAE

Brachythecium plumosum (Hedw.) B.S.G.

FAMILY: SEMATOPHYLLACEAE

Acroporium lamprophyllum Mitt.
Brotherella falcata (Dozy & Molk.) Fl.
Mastopoma uncinifolium (Broth.) Broth.
Taxithelium alare Broth.
Trichosteleum boschii (Dozy & Molk.) Jaeg.
Trismegistia gracilicaulis Dix. & Herz.

FAMILY: SPHAGNACEAE

Sphagnum cuspidatum Ehrh. ex Hoffm.

FAMILY: DITRICHACEAE

Ditrichum difficile (Duby) Fl.

FAMILY: SCHISTOMITRIACEAE

Oxystegus cuspidatus (Dozy & Molk.) Chen
Schistomitrium mucronifolium (C. Muell.) Fl.

FAMILY: PTEROBRYACEA *sens. lat.*

Garovaglia elegans (Dozy & Molk.) Bosch & Sande Lac.
Neolindbergia rigida (Bosch & Sande Lac.) Fl.

FAMILY: NECKERACEAE

Himantocladium plumula (Nees) Fl.
Pinnatella kuehliana (Bosch & Sande Lac.) Fl.
Pinnatella mucronata (Bosch & Sande Lac.) Fl.

FAMILY: HYPNACEAE

Isopterygium sp.

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An evaluation of the optimal number of chainsaws required for felling in a peat swamp forest

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Abstract. The use of chainsaws for felling in forest concessions has been going on since 1970. However, information about the number of chainsaws required under certain forest conditions has never been studied. This paper presents findings on the optimal number of chainsaws used for felling in a peat swamp forest in Jambi, Indonesia. The results of the study reveal that for efficient use, the number of chainsaws for felling trees was dependent on production target. The number of chainsaws used in the company's operations was found to be more than what would be considered optimal. This inefficiency suggests unnecessary costs were being incurred.

Keywords: chainsaw, Indonesia, peat swamp forest

INTRODUCTION

Indonesian peat swamp forests have an important socio-economic as well as environmental function. Indonesia has about half of the total area of peat swamp forests in the world, and the highest biodiversity of any peat swamp forest (Bellamy 1997 in Lazuardi 2000). Important commercial timber species found in Indonesian peat swamps are Ramin (*Gonystylus bancanus*), Meranti (*Shorea* spp.), Jelutung (*Dyera lowii*), Nyatoh (*Palaquium cochlearia*), Bintangur (*Calophyllum* spp.) and Rengas (*Gluta renghas*) (Dulsalam *et al*. 1999, Anonymous 2000, Daryono 2000).

Logging at peat swamp forest in Indonesia has been done intensively until now. Since the Law No. 1: 1967 and Law No. 6: 1968 about foreign and domestic investments were declared, and following the government decision to allow forest exploitation (logging) by private companies, forest activities especially outside Java increased significantly. The forestry sector plays an important role in supporting national development (Soebiato 1990).

Forest concession holders are given the right for logging at natural forests and selling the logs to domestic or international market. There are several stages in the process of timber extraction before logs are sold, i.e. felling, skidding, loading-unloading and transportation. Felling is an important part of logging activities because log quality and utilization are determined by the felling technique and tools. There is a standard diameter for felling. Felling is also aimed at the manufacture industry with the right number and quality (Anonymous 1990). Felling can be done by full mechanization, semi-mechanization or manually by using chainsaw, axe, handsaw (Staaf & Wiksten 1984).

Forest companies use chainsaws of different brands, sizes and numbers. Good and efficient planning on the number of chainsaws needed is therefore required. It needs to conform to production target, as well as production cost. The use of chainsaw may improve efficiency for a forest concession holder. However, it can cause problems because of the misuse of chainsaw, i.e. felling with more chainsaws than required. This results in over-cutting and endangers the sustainability of the forest.

This paper presents the results of a study on the optimal number of chainsaws required for felling in a peat swamp forest.

METHODOLOGY

Study site

This research was conducted in October 2005 in the work area of PT. Putra Duta Indah wood logging concession. This logging concession was located in the forest district of Muaro Jambi, Forest Service of Jambi Province, Indonesia.

The topography was mainly slopes between 0-3%, with elevation of 5-10 m above sea level. Based on Schmidt and Ferguson's classification, the type of climate in the research area was categorized as "A" with monthly rainfall of 172.6 mm. The soil type was organosol and alluvial. The vegetation was dominated by Rengas trees (80%) and swamp Meranti trees, mostly buttressed. Tree density was about 213 trees/ha (for diameter 10 cm and up). The brushwood in average had intermediate density. The logging operation used chainsaw for felling. The brand of chainsaw was Stihl, type 070 with 15 HP. The number of chainsaws in field was 6 units.

In the company's Annual Work Plan 2005, log production target was 49,110.8 m^3/year, production realization was 48,889.12 m^3/year taken from 1,600 ha, and maximum AAC (annual allowable cut) was 84,000 m^3/year. The material and tools used in this research were chainsaw, stopwatch, measuring meter and phi-band.

Research procedure

The research was done by collecting primary and secondary data. Primary data were taken from field observations like the number of chainsaws, working time and productivity. Secondary data, including annual allowable cut, forest area (ha), forest potential (m^3/ha) and logging concession production data, were taken from the company's profile and interview with employees.

Data analyses

1. Felling productivity:

$$FP = \frac{TV}{FT} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

where

FP = felling productivity (m^3/hour)

TV = felled trees volume (m^3)

FT = felling time (hour)

2. Chainsaws required:

(*a*) Based on maximum AAC

$$NCAAC = \frac{\text{Maximum AAC}}{\text{Work productivity per day} \times \text{Working time per year}} \quad \ldots\ (2)$$

(*b*) Based on production target

$$NCT = \frac{\text{Production target}}{\text{Work productivity per day} \times \text{Working time per year}} \quad \ldots\ldots\ (3)$$

(*c*) Based on production realization

$$NCR = \frac{\text{Production realization}}{\text{Work productivity per day} \times \text{Working time per year}} \quad \ldots\ldots\ (4)$$

where

NCAAC = the number of chainsaws based on maximum AAC (unit)

NCT = the number of chainsaws based on production target (unit)

NCR = the number of chainsaws based on production realization (unit)

3. Felling cost (Anonymous 1992):

$$FC = \frac{Ed + Eis + Eit + Et + Ef + Eo + Em + Ew}{FP}$$

$$Ed = \frac{P \times 0.9}{1{,}000 \text{ hours}} \qquad Eis = \frac{P \times 0.6 \times 3\%}{1{,}000 \text{ hours}} \qquad Eit = \frac{P \times 0.6 \times 18\%}{1{,}000 \text{ hours}}$$

$$Et = \frac{P \times 0.6 \times 2\%}{1{,}000 \text{ hours}} \qquad Ef = 0.20 \times P \times 0.54 \times FPr$$

$$Eo = 0.1\ Ef \qquad Em = 1.0 \times Ed$$

where

FC = felling cost (Rp/m^3)
Ed = depreciation expenses (Rp/m^3)
Eis = insurance expenses (Rp/hour)
Eit = interest expenses (Rp/hour)
Et = tax expenses (Rp/hour)
Ef = fuel expenses (Rp/hour)
Eo = oil expenses (Rp/hour)
Em = maintenance expenses (Rp/hour)
Ew = wages expenses (Rp/hour)
FP = felling productivity (m^3/hour)
P = tool price (Rp)
FPr = fuel price (Rp/litre)

RESULTS & DISCUSSION

Felling productivity

The number of chainsaws required can be calculated from the work productivity based on a common felling technique adopted by the local company. The results of felling productivity are shown in Table 1. After the work productivity is known, the number of chainsaws required can be calculated (Table 2). The details are shown in Appendix 1.

Table 1. Felling productivity, N = 20.

Aspect	Log volume (m^3)	Felling time (hour)	Productivity (m^3/hour)
Range	2.001-3.275	0.057-0.159	18.625-35.175
Mean	2.540	0.107	24.973

N = Number of replications
Diameter range = 44-59 cm

Table 2 shows that the number of chainsaws required is smaller than the number of chainsaws in the field. The difference based on production target, production realization and maximum AAC are 5 units (6 - 1 = 5), 5 units (6 - 1 = 5), and 4 units (6 - 2 = 4). It indicates that the company was using more chainsaws than was actually required.

Table 2. Number of chainsaws required.

Aspect (based on)	Number (unit)
Production target	1
Production realization	1
Maximum AAC	2

No. of chainsaws in field = 6 units

From the analysis of the number of chainsaws, the average log production can be calculated as shown in Table 3. This table shows that log production from the number of chainsaws in the field (6 units) is 314,659.8 m^3/year. It indicates that the log production is more than the production target (49,110.8 m^3/year), production realization (48,889.12 m^3/year) and maximum AAC (84,000 m^3/year).

Table 3. The average timber production based on the number of chainsaws.

Aspect	Number of chainsaws (unit)	Timber production (m^3/year)
Production target	1	52,443.3
Production realization	1	52,443.3
Maximum AAC	2	104,886.6
Chainsaw in field	6	314,659.8

Finishing time on felling based on the number of chainsaws is presented in Table 4 and the details are shown in Appendix 2. Based on the number of chainsaws in the analysis and in the field, the finishing time on felling can be calculated. One unit can finish felling in 11.2 months, while by using 6 units it can be finished in 1.9 months. This could be a disadvantage to the company for the cost and maintenance of the extra chainsaws.

Table 4. Finishing time on felling based on the number of chainsaws.

Aspect	Number of chainsaws (unit)	Finishing time (month)
Production target	1	11.2
Production realization	1	11.2
Maximum AAC	2	5.6
Chainsaw in field	6	1.9

The evaluation of the number of chainsaws required

Appendix 1 shows the number of chainsaws required for that company based on production realization is one unit. For reaching production realization at 48,889.12 m^3/year, the company did not need to use 6 units of chainsaw. That number of logs produced, about 314,659.8 m^3/year, was much more than the production realization and it indicates over-production. By using 6 units of chainsaw, there was a waste from chainsaw investment cost and other operational costs like maintenance and operator wages. Also, using 6 units of chainsaw and producing 314,659.8 m^3/year, far exceeded the maximum AAC (84,000 m^3/year), resulting in over-cutting.

Analysis of felling cost

By measuring the productivity, purchasing and operational costs of the Stihl chainsaw (type 070) for tree felling, the felling cost per m^3 can be calculated (Table 5).

Table 5. Felling cost component (Rp/hour).

Cost component	Cost of 1 unit	Cost of 2 units	Cost of 6 units
Depreciation expenses	5,850	11,700	35,100
Insurance expenses	117	234	702
Interest expenses	702	1,404	4,212
Tax expenses	78	156	468
Fuel expenses	7,290	14,580	43,740
Oil expenses	729	1,458	4,374
Maintenance expenses	5,850	11,700	35,100
Wages	28,571	57,142	171,426
Total expenses	**49,187**	**98,374**	**295,122**

US $1 = Rp 9,200
Price per unit = Rp 6,500,000
Fuel price = Rp 4,500/litre
Expected life of tool = 1 year = 1,000 hours
Insurance = 3%/year
Interest = 18%/year
Tax = 2%/year
Operator and helper wages = Rp 200,000/day
Work hours per day = 7 hours
Machine power = 15 HP

CONCLUSION

Based on the production target, actual production and maximum AAC, the optimal number of chainsaws required for felling by the company in the swamp forest was: 1 unit, 1 unit and 2 units respectively. The number of chainsaws used in the field was greater than the number necessary to achieve production target, production realization and maximum AAC. Using more than the number of chainsaws required would accelerate the rate of felling and jeopardize the sustainability of the forest. It would also add unnecessary cost to the company.

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Appendix 1. Analysis of the number of chainsaws required.

By using formula (1)
Productivity = 24.973 m^3/hour
Effective working time = 7 hours/day, 25 days/month, 300 days/year
Work productivity = 24.973 m^3/hour x 7 hours/day = 174.811 m^3/day
Based on:
Production target = 49,110.8 m^3/year
Production realization = 48,889.12 m^3/year
Maximum AAC = 84,000 m^3/year
By using formulae (2), (3) and (4), the number of chainsaws required:

$$\text{NCAAC} = \frac{\text{Maximum AAC}}{\text{Work productivity/day} \times \text{Working time/year}}$$

$$= \frac{84{,}000 \text{ m}^3\text{/year}}{174.811 \text{ m}^3\text{/day} \times 300 \text{ days/year}}$$

$$= \frac{84{,}000 \text{ m}^3\text{/year}}{52{,}443.3 \text{ m}^3\text{/year}} = 2 \text{ units}$$

$$\text{NCT} = \frac{\text{Production target}}{\text{Work productivity/day} \times \text{Working time/year}}$$

$$= \frac{49{,}110.8 \text{ m}^3\text{/year}}{52{,}443.3 \text{ m}^3\text{/year}} = 1 \text{ unit}$$

$$\text{NCR} = \frac{\text{Production realization}}{\text{Work productivity/day} \times \text{Working time/year}}$$

$$= \frac{48{,}889.12 \text{ m}^3\text{/year}}{52{,}443.3 \text{ m}^3\text{/year}} = 1 \text{ unit}$$

Appendix 2. Finishing time on felling.

Effective working time = 7 hours/day, 25 days/month, 300 days/year

Productivity = 24.973 m^3/hour x 7 hours/day x 300 days/year = 52,443.3 m^3/year

Based on production target about 49,110.8 m^3/year, using:

$$1 \text{ chainsaw} = \frac{49{,}110.8 \text{ m}^3\text{/year}}{52{,}443.3 \text{ m}^3\text{/year x 1 unit}} \text{ x 12 months} = 11.2 \text{ months}$$

$$2 \text{ chainsaws} = \frac{49{,}110.8 \text{ m}^3\text{/year}}{52{,}443.3 \text{ m}^3\text{/year x 2 units}} \text{ x 12 months} = 5.6 \text{ months}$$

$$6 \text{ chainsaws} = \frac{49{,}110.8 \text{ m}^3\text{/year}}{52{,}443.3 \text{ m}^3\text{/year x 6 units}} \text{ x 12 months} = 1.9 \text{ months}$$

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NOTE

Magas fruit-borer

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Fruits of Magas (*Duabanga moluccana* Blume, family Sonneratiaceae), collected at Pinangah Forest Reserve in the lowlands, as well as Tenompok Forest Reserve in the highlands near Kinabalu Park headquarters, were found to be infested with brownish caterpillars. The caterpillars were voracious eaters, which could reduce the fruits to dust within a few days, and hence lower the germination rate of Magas.

Round boreholes were seen on infested, rotting fruits. Each fruit could house several similar caterpillars. The caterpillar, about 1-2 cm long, had a round chocolate-brown head, with dark longitudinal lines running down the length of its body (Figure 1). Each body segment had diffuse brown patches with numerous dark dots. Its dull colours made it camouflage well with the Magas fruit it was feeding on.

The adults, when emerged, were medium-sized light brown moths of Herminiinae (family Noctuidae). Most herminiine moths are drably coloured in shades of brown or black (Barlow 1982), and many herminiine caterpillars are detritivores (Holloway *et al*. 2001), feeding on dead organic matter such as leaf litter and fruits.

The species is in a problematic *Simplicia* group which consists of many similar-looking moths. It was later identified as *Simplicia caeneusalis* Walker (Figure 2) upon examination of its male genitalia, which had the characteristic valve shape as well as the diagnostic thornlike process at the apex of the aedeagus. The male can be easily distinguished from the female by its antennae. Each of the male antennae has a long node in the basal half while the antennae of the female are simple.

The wingspan of the moth was around 2.5 cm. A pale submarginal line could be seen on both of its fore- and hindwings. The forewing also had two longer dark fasciae in the middle with a shorter one in between.

The species is widely distributed in the Indo-Australian tropics (Holloway 1976). Based on the moth collection in the Forest Insect Museum in Sepilok, the moth was also seemingly attracted to ripe banana placed in fruit-baited traps for butterflies.

Previous records for its caterpillar (Robinson *et al*. 2001) include commercial crops such as *Sorghum* (Gramineae); *Albizia* (Leguminosae); also attap leaves, oil palm *Elaeis guineensis*, *Nypa* (all Palmae); cocoa *Theobroma cacao* (Sterculiaceae); and tea *Camellia sinensis* (Theaceae). Magas (*Duabanga moluccana*) represents a new hostplant record for the caterpillar.

ACKNOWLEDGEMENTS

Dr Jeremy Holloway at the Natural History Museum in London kindly identified the moth. The fruits were collected by my colleague Mr Petrus Butin. Another colleague Mr Richard Ansis helped in the rearing of the caterpillars.

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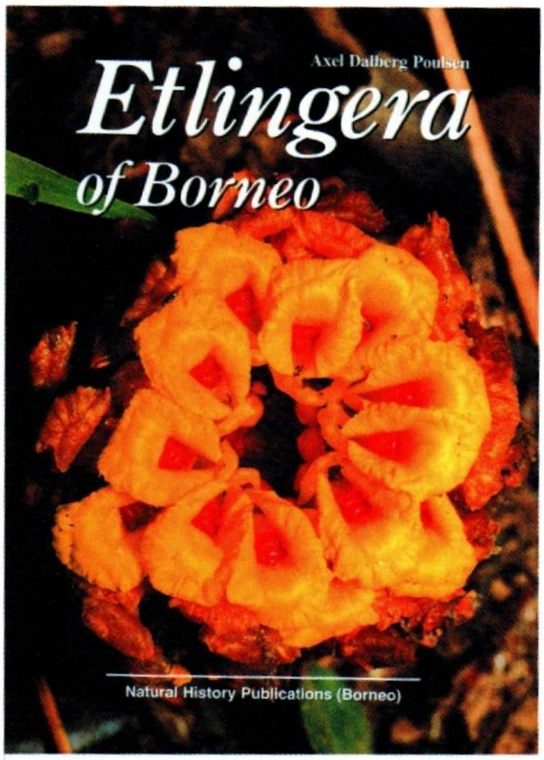
Figure 1. *Duabanga moluccana* fruit (2 cm diameter) with a caterpillar of *Simplicia caeneusalis* (1.5 cm long), showing borehole.

Figure 2. *Simplicia caeneusalis*, male, with nodes in the antennae. Wingspan 2.5 cm. Empty pupal case on the right.

BOOK REVIEW



***Etlingera* of Borneo** by Axel Dalberg Poulsen. Published by Natural History Publications (Borneo), Kota Kinabalu, 2006. Pp. 263. ISBN 983-812-117-7.

Reviewed by M. Ajik

Borneo is home to over 300 ginger species. Among the most diverse and attractive of the genera is *Etlingera*, the species of which are used as food, spice, medicine, ornamentals or for other purposes. The unique character diagnostic of all the species of *Etlingera* is a tube formed above the insertion of the corolla lobes.

This beautiful book presents current revision of 42 taxa, including 16 new species, one new subspecies, one new variety, and one new combination.

The book certainly demonstrates that Borneo is exceptionally rich with *Etlingera*. The chapters comprehensively cover taxonomic history, morphology, ecology, uses and conservation of the genus concerned. The future potential for food, drugs or as ornamentals is also documented in this book, making it an important ethnobotanical reference.

The book also offers a key to identification of species; most are described in detail coupled with beautiful colour photographs and line drawings. The quality of the photographs is superb. One is simply mesmerized by looking at those well-taken photographs. All photographs are accompanied with scientific names. However, some of the scientific names in the index are not italicized.

Etlingera was previously revised by Rosemary M. Smith in 1986. The author, Dr Axel Dalber Poulsen, a tropical forest botanist with vast experience in Borneo, has done a fantastic job where *Etlingera* is concerned. This book is not only useful and beneficial to botanists, horticulturists and ethnobotanists, but is also a must-have guide book for anyone who loves gardening.

GUIDE TO CONTRIBUTORS

Sepilok Bulletin is a biannual peer-reviewed journal published by the Forest Research Centre of the Sabah Forestry Department. The Bulletin publishes manuscripts addressing subjects related to tropical forestry, in Borneo and elsewhere. Manuscripts may be in the form of original research papers, short communications, review articles, monographs, book reviews, and announcements.

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Burgess, P.F. (1966). Timbers of Sabah. *Sabah Forest Record No. 6.* Sabah Forest Department, Sandakan. 501 pp.

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Front cover: Tongkat Ali, *Eurycoma longifolia*, in flower (Photo: Julius Kulip)