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SHORT COMMUNICATION

Diversity and composition of plants, butterflies and odonates in an *Imperata cylindrica* grassland landscape in East Kalimantan, Indonesia

D.F.R. Cleary[1]

Department of Biology, CESAM, Universidade de Aveiro, Campus Universitário de Santiago, 3810-193 Aveiro, Portugal
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Abstract: In Indonesia and elsewhere, *Imperata cylindrica* grassland now covers millions of hectares of land previously covered by rain forest. In the present study, shrubs, trees and climbers were recorded in sixteen 10 × 20-m plots and herb cover (ferns, grasses and herbaceous dicots) estimated in nested 2 × 2-m subplots. Butterflies and odonates were netted along 300-m transects. All plots and transects were randomly allocated to a 450 ha, *I. cylindrica*-dominated landscape. A total of 43 shrub, tree and climber, 16 herb, 67 butterfly and 30 odonate species were recorded. Shrubs, trees and climbers were present throughout the study area, but basal area was very low and mainly consisted of invasive species. *Imperata cylindrica* covered an estimated 65% of the area with other plant species or bare soil covering the remainder. Butterfly and odonate communities mainly consisted of species with large geographic distributions, but some recorded species had more limited distributions. The latter were, however, species known to associate with perturbed forest environments. Variation in the composition of butterflies and odonates was also related to variation in habitat structure (e.g. altitude and slope) and plant composition. Plant composition in particular appeared to structure both butterfly and odonate communities.

Key Words: alang alang, Borneo, Indonesia, Kalimantan, slash-and-burn agriculture

Imperata cylindrica (also known as alang alang or cogon grass) is an aggressive grass species that colonizes land cleared for unsustainable slash-and-burn agriculture or degraded by repeated forest fires (Kinnaird & O'Brien 1998). Once established, subsequent burning increases losses of nitrogen and carbon, thereby eroding agricultural productivity and enhancing regeneration of *I. cylindrica* (Chapin *et al*. 2000, Otsamo *et al*. 1995). *Imperata cylindrica* grassland houses a depauperate and low-stature plant community compared with proximate rain forest (Slik & Eichhorn 2003). In Indonesia, millions of hectares of land, previously covered by lowland dipterocarp forest, are dominated by *I. cylindrica* grasslands due to repeated logging and fire (Estrada & Flory 2015, MacDonald 2004, Otsamo *et al*. 1995). During initial fires, more fuel is produced than destroyed and this acts as a catalyst for future fires, which are more likely to occur and more intense. This positive feedback destroys rain-forest trees and promotes grassland invasion (Laurance 2003).

In the present study, we sampled shrubs, trees and climbers > 1 cm dbh (hereafter called STC), ferns, grasses and herbaceous dicots (hereafter called herbs) and insects (butterflies and odonates) in 16 plots allocated randomly to a 450-ha typical *I. cylindrica*-dominated landscape (Cleary 2003, Cleary *et al*. 2004) in East Kalimantan Indonesia (1°03'S, 116°57'E) from 11 July–12 August 2000. STC were sampled in 10 × 20-m plots and herbs in 2 × 2-m subplots nested within the larger plots. Butterflies and odonates were sampled along 300-m transects crossing the 10 × 20-m plots following previously described methods (Cleary *et al*. 2004). The hypotheses of the present study were that (1) *I. cylindrica* grassland harboured a spatially variable plant community, (2) variation in the plant community structured spatial variation in grassland insect composition and (3) *I. cylindrica* grassland mainly harboured widespread plant and insect species. Despite the prevalence of *I. cylindrica* grasslands, relatively few studies have assessed the biodiversity housed within these

[1] Email: cleary@ua.pt or dfrcleary@gmail.com

degraded environments. Only two studies so far have assessed butterflies (Matsumoto *et al*. 2015, Nakamuta *et al*. 2008) and to the best of our knowledge none assessed odonates.

All analyses were performed in R (https://www.r-project.org/). Abundance and cover matrices of STC, herbs, butterflies and odonates were imported into R and $\log_e(x+1)$ transformed and distance matrices constructed using the Bray–Curtis index with the vegdist() function in VEGAN (https://cran.r-project.org/web/packages/vegan/vegan.pdf). Variation in composition was assessed with Principal Coordinates Analysis (PCO) using the cmdscale() function in R with the Bray–Curtis distance matrix as input. Weighted averages scores were computed for species on the first two PCO axes using the wascores() function in vegan. In each plot, we also measured/estimated a number of habitat variables, namely, altitude, slope/inclination (with a clinometer), number of STC stems, STC basal area and the percentage cover of herbaceous monocots, herbaceous dicots and ferns. Using the envfit() function in vegan, we tested for relationships between these variables, the first two axes of the PCO ordinations of STC and herbs (as proxies for gradients in vegetation composition) and the PCO ordinations of butterflies and odonates. Habitat variables with a $P < 0.10$ were included in the ordinations of butterflies and odonates.

Altitude in the study area varied from 23 to 49 m asl. We recorded a total of 43 STC species including nine morphospecies. The number of stems per plot varied from 5 to 143 and STC basal area from 0.5 to 1336 cm^2. The plot with a basal area of 1336 cm^2 contained two very large *Cocos nucifera* palms. The next largest basal area was only 146 cm^2 (plot Ka09). The most abundant STC species were *Chromolaena odorata* (272 stems; native to North America), the climbing bamboo *Dinochloa scandens* (100 stems), *Melastoma malabathricum* (26 stems), an unidentified Labiatae (13 stems), the climber *Mikania scandens* (eight stems; native to North America), *Vitex pinnata* (six stems), *Ficus* sp. (six stems), *Lygodium microphyllum* (five stems), *Ficus grossularioides* (four stems) and *Dillenia excelsa*, *Manihot esculenta*, *Artocarpus heterophyllus*, *Cocos nucifera*, *Piper aduncum*, *Brucea javanica*, *Callicarpa pentandra* and *Lantana camara* (all three stems). The main gradient in STC composition (Figure 1a) separated plots (Ka03, Ka04, Ka16) with relatively high abundances of *Melastoma malabathricum*, *Ficus grossularioides*, *Mikania scandens*, *Lygodium microphyllum* and the unidentified Labiatae from other plots (Ka06, Ka08, Ka11, Ka14, Ka15). These latter plots were characterized by very low basal areas (< 2.08 cm^2). The second PCO axis separated plots (Ka09 and Ka13) with high abundances of *Dillenia excelsa*, *Stenochlaena palustris* and *Ficus* sp. from plots (Ka02 and Ka10) with high abundances of *Brucea javanica*, *Callicarpa pentandra*, *Piper aduncum*, *Vitex pinnata*, *Cocos nucifera*, *Musa sapientum*, *Manihot esculenta*, *Artocarpus heterophyllus* and *Dinochloa scandens*. *Chromolaena odorata* was present in all but one plot.

A total of 16 herb species were observed, of which eight were morphospecies, including *Imperata cylindrica* (64.8%), *Scleria* sp. (6.3%), *Spermacoce* sp. (5.1%), an unidentified grass (4.6%), *Vernonia cinerea* (0.8%), *Saccharum spontaneum* (0.6%), *Alpinia galanga* (0.3%) and *Pteridium* sp. (0.1%). The main gradient in herb composition (Figure 1b) separated plots with relatively low (Ka02, Ka03, Ka06 and Ka09) versus high (remaining plots) cover of *I. cylindrica*. The second axis separated plots (Ka02 and Ka06) with a relatively high cover of the monocot *Scleria* sp. from plots (Ka03 and Ka09) with a relatively high cover of the herbaceous dicots *Spermacoce* sp. and *Vernonia cinerea*. *Imperata cylindrica* covered > 85% of all plots with the exception of Ka02, Ka03, Ka06 and Ka09 where the cover of the grass varied from 0–1%. *Spermacoce* sp. and *Vernonia cinerea* covered > 80% of Ka06 while *Scleria* sp. covered 95% of Ka09. Plot Ka02 was covered by the climber *Dinochloa scandens*. Ka03 had relatively low herbaceous cover (< 3%) and a relatively high STC basal area (130 cm^2).

A total of 67 butterfly species (3200 individuals) and 30 odonate species (1653 individuals) were recorded in the study area. Dominant butterfly species included *Taractrocera ardonia*, *Orsotriaena medus*, *Spindasis lohita*, *Ypthima pandocus*, *Neptis hylas*, *Zizina otis*, *Mycalesis perseus*, *Potanthus omaha*, *Polytremis lubricans* and *Telicota besta* (Table 1). The most dominant butterfly species (*Taractrocera ardonia*) accounted for 10.9% of all individuals. Dominant odonate species included *Neurothemis fluctuans*, *Orthetrum sabina*, *Diplacodes trivialis*, *Neurothemis terminata* and *Rhyothemis phyllis*. The most dominant odonate species (*Neurothemis fluctuans*) accounted for 36.1% of all individuals.

For butterfly composition, habitat variables selected using the envfit function in R ($P < 0.10$) were fern cover ($R^2 = 0.346$, $P = 0.065$), STC basal area ($R^2 = 0.497$, $P = 0.061$), the first axis of the herb PCO analysis (herb.pc1: $R^2 = 0.689$, $P = 0.002$), grass cover ($R^2 = 0.736$, $P < 0.001$) and herbaceous dicot cover ($R^2 = 0.835$, $P < 0.001$). Butterfly species associated with higher STC basal area and herb.PC1 (Figure 1c) included *Elymnias hypermnestra*, *Ypthima pandocus*, *Mycalesis horsfieldi*, *Eurema hecabe*, *Neptis hylas* and *Jamides celeno*. *Elymnias hypermnestra*, *Eurema hecabe*, *Neptis hylas* and *Jamides celeno* are all widespread species that occur well beyond Borneo and the Sundaland region while *Ypthima pandocus* has a more restricted range and is only found in the Sundaland region. Information on the hostplant use of these butterfly species can be found in Corbet & Pendlebury (1992), Suguru & Haruo (1997, 2000) and http://www.nhm.ac.uk/our-science/data/hostplants/.

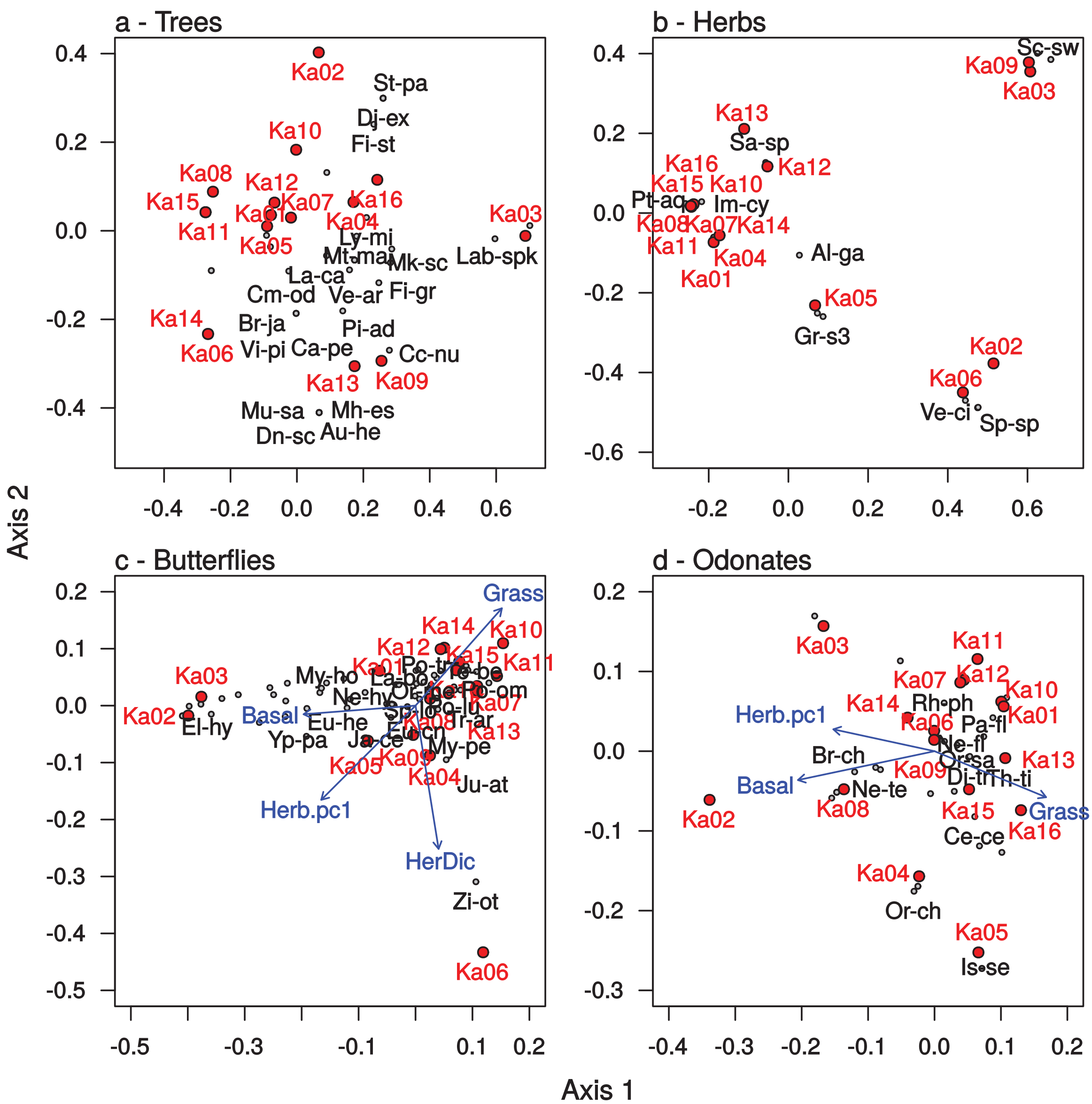

Figure 1. Variation in the composition of shrubs, trees and climbers (a), herbs (b), butterflies (c) and odonates (d) in an *Imperata cylindrica*-dominated grassland habitat in East Kalimantan, Indonesia. Ordinations show the first two axes of the PCO analyses. Red symbols and codes refer to values for plots while black codes refer to loadings for selected species (Table 1). For species codes see Table 1. Abbreviations of habitat variables (indicated by blue arrows) are: Basal: STC basal area, Fern: fern cover, Grass: grass cover, HerDic: herbaceous dicot cover, Herb.pc1: first axis of PCO analysis of herbs.

Elymnias species feed mainly on palms and grasses while *Eurema hecabe* is a generalist that feeds on a wide range of herbs and trees. *Neptis hylas* is another generalist that feeds on herbs, lianas and trees in various plant families. *Jamides celeno* feeds on plants in the families Fabaceae, Meliaceae and Sterculiaceae and was the first species to recover from forest fires following the 1997/98 ENSO event where it fed on resprouts of the tree *Fordia splendidissima* (Cleary & Grill 2004). *Ypthima pandocus* only feeds on grasses.

Species mainly associated with high grass cover included *Potanthus trachala*, *P. omaha*, *Orsotriaena medus* and *Telicota besta*. All of these species are hesperids with a moderate to wide distribution. They also all feed on grass species including *I. cylindrica* and *Oryza sativa*. Butterfly species associated with herbaceous dicot plant cover included *Junonia atlites* and *Zizina otis*, both of which are widely distributed.

For odonate composition, habitat variables selected using the envfit function in R ($P < 0.10$) were herb.pc1 ($R^2 = 0.356$, $P = 0.051$), grass cover ($R^2 = 0.536$, $P = 0.018$) and STC basal area ($R^2 = 0.605$, $P = 0.009$). Odonate species associated with a greater STC basal area (Figure 1d) included *Brachydiplax*

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Table 1. Family, (morpho)species and abundance or percentage cover (herbs) of the most abundant STC, herbs, butterflies and odonates. The 'Code' field refers to loadings for species shown in the ordinations of Figure 1.

Taxon	Code	Family	Species	Abun./Cover
STC	Cm-od	Asteraceae	*Chromolaena odorata* (L.) King & H.E. Robins.	272
	Dn-sc	Gramineae	*Dinochloa scandens* Kuntze	100
	Mt-ma	Melastomataceae	*Melastoma malabathricum* L.	26
	Lab-spk	Labiatae	Unidentified Labiatae	13
	Mk-sc	Asteraceae	*Mikania scandens* (L.) Willd.	8
	Fi-st	Moraceae	*Ficus* sp.	6
	Vi-pi	Labiatae	*Vitex pinnata* L.	6
	Ly-mi	Lygodiaceae	*Lygodium microphyllum* (Cav.) R. Br.	5
	Fi-gr	Moraceae	*Ficus grossularioides* Burm. f.	4
	La-ca	Verbenaceae	*Lantana camara* L.	3
	Au-he	Moraceae	*Artocarpus heterophyllus* Lam.	3
	Cc-nu	Palmae	*Cocos nucifera* L.	3
	Mh-es	Euphorbiaceae	*Manihot esculenta* Crantz	3
	Mu-sa	Musaceae	*Musa sapientum* L.	3
	Pi-ad	Piperaceae	*Piper aduncum* L.	3
	Ve-ar	Asteraceae	*Vernonia arborea* Welw. ex O.Hoffm.	3
	Dj-ex	Dilleniaceae	*Dillenia excelsa* Martelli	3
	St-pa	Blechnaceae	*Stenochlaena palustris* (Burm. f.) Bedd.	3
	Br-ja	Simaroubaceae	*Brucea javanica* (L.) Merr.	3
	Ca-pe	Verbenaceae	*Callicarpa pentandra* Roxb.	3
Herbs	Im-cy	Gramineae	*Imperata cylindrica* (L.) Raeusch.	64.75
	Sc-sw	Cyperaceae	*Scleria* sp.	6.25
	Bo-sp	Rubiaceae	*Spermacoce* sp.	5.06
	Gr-s3	Gramineae	Gram s3	4.63
	Ve-ci	Asteraceae	*Vernonia cinerea* (L.) Less.	0.81
	Sa-sp	Gramineae	*Saccharum spontaneum* L.	0.63
	Al-ga	Zingiberaceae	*Alpinia galanga* (L.) Willd.	0.25
	Pt-aq	Dennstaedtiaceae	*Pteridium* sp.	0.13
Butterflies	Tr-ar	Hesperiidae	*Taractrocera ardonia* Hewitson, 1868	350
	Or-me	Hesperiidae	*Orsotriaena medus* Fabricius, 1775	304
	Sp-lo	Lycaenidae	*Spindasis lohita* Horsfield, 1829	288
	Yp-pa	Nymphalidae	*Ypthima pandocus* Moore, 1857	238
	Ne-hy	Nymphalidae	*Neptis hylas* Linnaeus, 1758	222
	Zi-ot	Lycaenidae	*Zizina otis* Fabricius, 1787	190
	My-pe	Nymphalidae	*Mycalesis perseus* Fabricius, 1775	180
	Po-om	Hesperiidae	*Potanthus omaha* Edwards, 1863	134
	Po-lu	Hesperiidae	*Polytremis lubricans* Herrich-Schäffer, 1869	117
	Te-be	Hesperiidae	*Telicota besta* Evans, 1949	108
	Eu-he	Pieridae	*Eurema hecabe* Linnaeus, 1758	98
	Ja-ce	Lycaenidae	*Jamides celeno* Cramer, 1775	93
	Eu-cn	Lycaenidae	*Euchrysops cnejus* Fabricius, 1798	91
	La-bo	Lycaenidae	*Lampides boeticus* Linnaeus, 1767	81
	My-ho	Nymphalidae	*Mycalesis horsfieldi* Moore, 1892–1894	74
	Po-tr	Hesperiidae	*Potanthus trachala* Mabille, 1878	69
	Ju-at	Nymphalidae	*Junonia atlites* Linnaeus, 1763	68
	El-hy	Nymphalidae	*Elymnias hypermnestra* Linnaeus, 1763	67
Odonates	Ne-fl	Libellulidae	*Neurothemis fluctuans* Fabricius, 1793	597
	Or-sa	Libellulidae	*Orthetrum sabina* Drury, 1770	373
	Di-tr	Libellulidae	*Diplacodes trivialis* Rambur, 1842	267
	Ne-te	Libellulidae	*Neurothemis terminata* Ris, 1911	158
	Ce-ce	Coenagrionidae	*Ceriagrion cerinorubellum* Brauer, 1865	84
	Rh-ph	Libellulidae	*Rhyothemis phyllis* Sulzer, 1776	48
	Or-ch	Libellulidae	*Orthetrum chrysis* Selys, 1891	19
	Th-ti	Libellulidae	*Tholymis tillarga* Fabricius, 1798	16
	Is-se	Coenagrionidae	*Ischnura senegalensis* Rambur, 1842	16
	Br-ch	Libellulidae	*Brachydiplax chalybea* Brauer, 1868	13
	Pa-fl	Libellulidae	*Pantala flavescens* Fabricius, 1798	9

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chalybea and *Neurothemis terminata*. *Brachydiplax chalybea* and *Neurothemis terminata* are both widespread and common dragonfly species that breed in ponds and marshes (http://indiabiodiversity.org/). Odonates associated with higher grass cover included the common and widespread species *Ceriagrion cerinorubellum*, *Tholymis tillarga*, *Orthetrum sabina* and *Pantala flavescens* (http://indiabiodiversity.org/).

Jones *et al*. (2003) previously showed that termite composition, abundance and richness differed strongly in *I. cylindrica* grasslands compared with intact forest with the former housing impoverished faunas. Matsumoto *et al*. (2015) and Cleary *et al*. (2004) also showed that butterfly richness was much lower in *I. cylindrica* grassland than intact forest. Matsumoto *et al*. (2015) recorded 14 butterfly species in *I. cylindrica* grassland areas close to our study area. This is much lower than the 67 species we recorded, but the present study had a much higher sampling effort; they only sampled 72 individuals compared with our 3200. All of the species reported by Matsumoto *et al*. (2015), with the exception of *Appias olferna* and *Pantoporia paraka*, were recorded in the present study.

This study also revealed a prevalence of common, invasive and widespread plant, odonate and butterfly species. The grasslands were not, however, entirely homogeneous. Although some areas were devoid of large woody plants, they still existed in the larger area, particularly around meandering streams. Some areas were also covered by other herbaceous species such as *Scleria* and *Spermacoce* species and the variation in vegetation structure was related to variation in butterfly and odonate composition. Although wide-ranging species dominated the *I. cylindrica* grassland habitat including very wide-ranging species such as *Lampides boeticus* that ranges from Europe to Australia, there were some exceptions. Restricted-range (mainly to Sundaland) species recorded included *Amathusia ochraceofusca*, *Deudorix staudingeri*, *Elymnias harteri*, *Elymnias panthera*, *Pandita sinope* and *Ypthima pandocus*. These species, however, can also be found along edges and in gaps of natural forest in the vicinity of the *I. cylindrica* grassland studied (Cleary *et al*. 2004). The present study shows that *I. cylindrica* grassland harbours a variable vegetation albeit dominated by the grass *I. cylindrica* and that variation in vegetation composition appears to play a role in structuring resident insect communities.

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