Biogeography, Diversity and Seasonality of Syrphidae (Diptera) in a Guineo-Congolian Rain Forest in Kenya

Author: De Meyer, Marc

Source: Journal of East African Natural History, 90(1) : 87-101

Published By: Nature Kenya/East African Natural History Society

URL: https://doi.org/10.2982/0012-8317(2001)90[87:BDASOS]2.0.CO;2

Journal of East African Natural History **90**: 87–101 (2001)

BIOGEOGRAPHY, DIVERSITY AND SEASONALITY OF SYRPHIDAE (DIPTERA) IN A GUINEO-CONGOLIAN RAIN FOREST IN KENYA

Marc De Meyer
National Museums of Kenya, Department of Invertebrate Zoology
P.O.Box 40658, Nairobi, Kenya*

ABSTRACT

Syrphidae (Diptera) were collected from different sites in Kakamega Forest, the only dry guineo-congolian rain forest relict in Kenya. In addition, literature records were compiled and old collections specimens were re-identified. In total, 74 species or 43% of the known syrphid fauna in Kenya, were identified. The fauna indicates a biogeographical affinity with the main central and western African rain forest belt, with 12 out of the 74 species being indicator species for such a link. The alpha and beta diversity were compared at four sites, representing the main ecological habitats within the forest complex. Mostly undisturbed forest habitat shows the highest diversity. It also harbours a large proportion of the indicator species (seven out of 12). Natural glades in the forest show a low similarity with the other habitats, indicating the more exceptional fauna of the natural grasslands. The seasonal fluctuations for the more abundant species are briefly discussed. Most species reach highest abundance during the dry season.

INTRODUCTION

Tropical forests are considered to harbour one of the richest faunas and floras of all terrestrial ecosystems. Although they cover only six percent of the earth's land surface, they may contain at least as many species as the rest of the world's terrestrial habitats together (Hammond, 1992). In any diversity estimate of tropical forests, insects constitute the majority of species. Estimates based on the beetle fauna of a tropical tree canopy predict that the number of tropical arthropod species may be 30 times higher than the known number (Erwin, 1982 but see Hammond, 1992 for review of this and other estimates). This richness, together with increased awareness of biodiversity since the Rio Convention in 1992, and rates of rain forest loss worldwide, have prompted several studies on arthropods in tropical forests (e.g. Erwin & Scott, 1980; Stork, 1987; Noyes, 1989; Hodkinson & Casson, 1991; Stork, 1991; Russel-Smith & Stork, 1994; Sanjayan *et al.*, 1995). Many studies have been conducted in the Neotropical or Indo-Australian regions, while few have been done in the Afrotropics. In addition, most of these studies considered the arthropod fauna at family or

*Present address: Koninklijk Museum voor Midden Afrika, Entomology Section, B-3080 Tervuren, Belgium, e-mail: demeyer@africamuseum.be

ordinate level. Only rarely has a study focused on the species level (an exception to this trend is the work on termites by Eggleton *et al.*, 1995). Here, we report on the species composition, diversity, seasonal fluctuations and biogeographical affinities of the hover fly fauna (Syrphidae, Diptera) of Kakamega Forest in the Western Province of Kenya.

About 15,000 yrs ago, due to increased rainfall, Kakamega Forest was part of a large rain forest belt that covered most of Uganda and Kenya, extending to Congo and western Africa (Round-Turner, 1994). Around 10,000 yrs ago, a drier period reduced the extent of the forest belt. In East Africa only a number of isolated patches remained in Kenya and Uganda. During the last few centuries, Kakamega Forest has also been reduced in size due to human activities. It now forms the easternmost relict of the dry guineo-congolian rain forest. It is also the only relict of this type of vegetation in Kenya and most of its fauna and flora is unique.

Syrphidae or hover flies belong to the Aschiza, Brachycera within the order Diptera. They are considered an important group of insects in agriculture, and play a major role as pollinators. The larval life history is varied. Larvae of the subfamily Syrphinae are predators of aphids and have been studied as potential biocontrol agents of agricultural aphid pests (Schmutterer, 1974; Chambers & Adams, 1986; Patro & Behera, 1993). Other syrphid larvae are phytophagous, or live in compost-like materials (e.g. in tree holes). Some are found in association with ant nests or feed on plant tissue in bulbs of Liliaceae and Amaryllidaceae.

MATERIAL AND METHODS

Kakamega Forest (0°10'–0°21'N, 34°47'–34°58'E, altitude 1,500–1,700m) is classified as dry Guineo-Congolian forest. It is closely related to the equatorial rain forests of West Africa, Democratic Republic of Congo and Uganda but has a slightly cooler and less humid climate (Kokwaro, 1988) (Mean monthly min. temperature 14.8–15.2 °C; mean monthly max. temperature 26.4–31.1 °C; average yearly rainfall of just below 2,000 mm (Ojany & Ogendo, 1988)). The forest reserve area, which has been gazetted by the Kenyan Government, covers approximately 29,450 hectares (Wass, 1995) and has a mosaic structure, with disturbed and undisturbed forest patches, and plantations (mainly of exotic timber such as eucalyptus, pine, and cypress, but also fast-growing indigenous trees including *Maesopsis eminii* Engl.). In addition, there are apparently natural open glades, as well as grasslands that used to be under cultivation ('shamba system', see below) but are now abandoned. For a complete vegetation survey and history of use of the forest, see Kokwaro (1988) and Mutangah *et al.* (1992).

The forest was visited six times between 13th November 1994 and 9th December 1995 at approximately two monthly intervals for eight days each time (De Meyer, 1996). At the first visit, suitable sites were selected in the forest that would represent the major vegetation types, but no standardised sampling was conducted. During the last five visits, four sites, that were selected to represent four habitats present, were consistently sampled (figure 1, indicated with solid squares). These sites are denoted by the letters B, I, Y, K and are shortly discussed here with reference to the major plant species found in each (botanical names of the latter as in Beentje, 1994):

B: Buyangu nature reserve: trails near Kenya Wildlife Service headquarters. This part of the forest has been strictly protected, and there has consequently been little disturbance in the last 10 years). All canopy layers are well developed and dominated

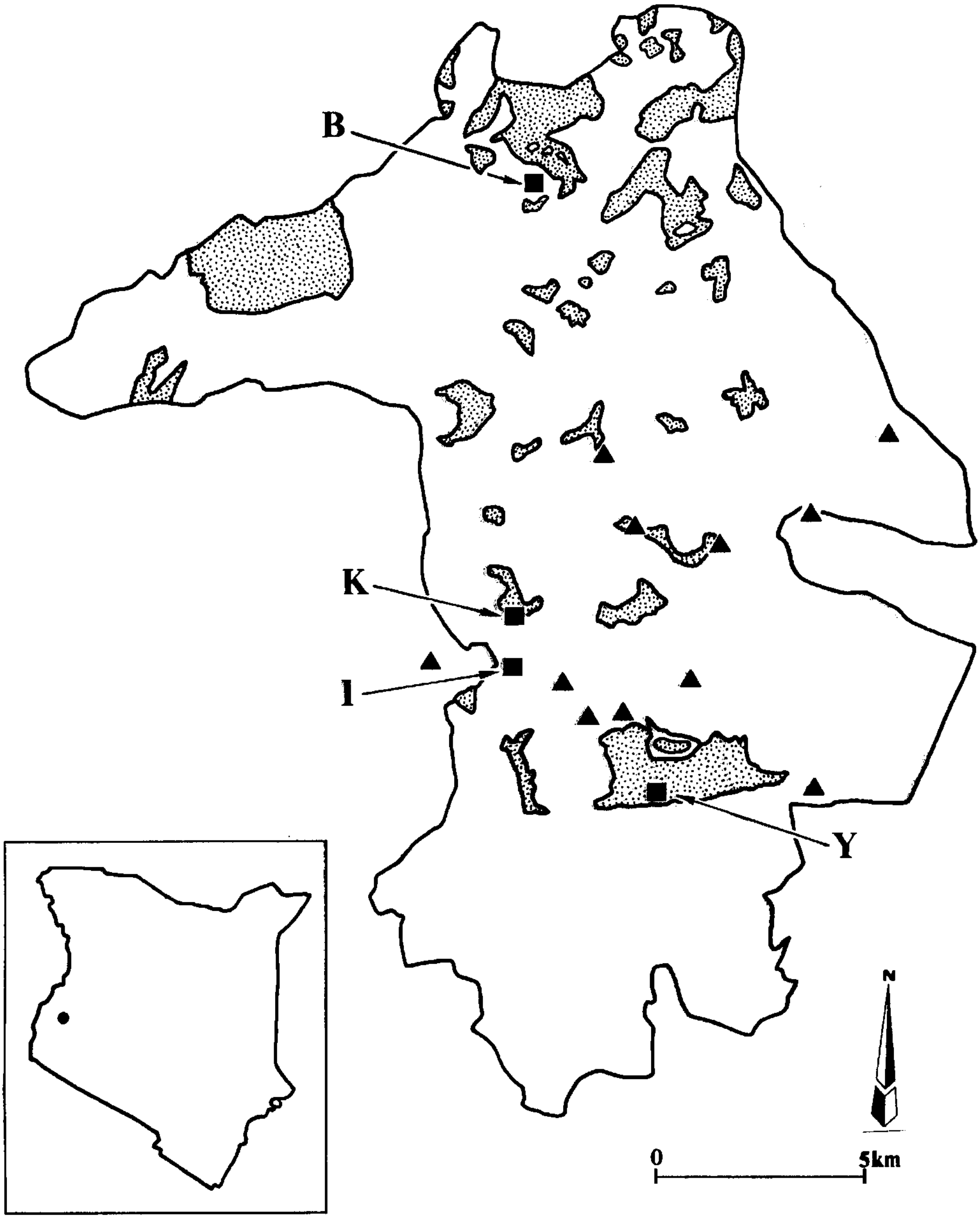

Figure 1: Vegetation map of Kakamega Forest. Solid squares: permanent collecting sites (B=Buyangu, I=Isecheno, Y=Yala, K=Kalunya); solid triangles: other collecting sites; graded areas: grasslands & scrub-cleared areas. (Insert: approximate position of Kakamega Forest in Kenya).

by *Blighia unijugata* Bak., *Trilepsium madagascariense* DC., and *Rinorea brachypetala* (Turcz.) O.Ktze.. The shrub layer is dominated by *Dracaena fragrans* (L.) Ker.-Gaul. and *Mimulopsis solmsii* Schweinf.. The herbaceous layer is not developed except along trail borders.

I: Pump house trail near Isecheno forest station: the forest trail is in heavily-disturbed rain forest. The middle and lower canopy layers have largely disappeared due to illegal clearing of trees with small diameter (less than 20cm) for firewood and construction poles. The tree layer is dominated by *Antiaris toxicaria* (Pers.) Lesch. and *Fagaropsis angolensis* (Engl.) Dale, and the shrub layer by *Dracaena fragrans*. Part of the trail shows regeneration of forest (through plantation) with indigenous trees like *Prunus africana* (Hook.f.) Kalkm., *Maesopsis* sp., *Markhamia* sp. and *Croton megalocarpus* Hutch.. The herbaceous layer is not developed except along trail borders.

Y: Cleared bush- and grassland along the northern bank of the Yala river. The area was an exotic (i.e. non indigenous) plantation, which, after felling, was used as agricultural land by the local population for food crop production in agreement with the Forestry department (the 'shamba system'). This system of dual use was abandoned about ten years ago because of misuse. The vegetation is mainly composed of grasses with limited regeneration of shrubs and trees, mainly *Olea capensis* L., *Acanthus* and *Combretum*.

K: Kalunya glade: apparently natural glade, north of Isecheno forest station. The vegetation is dominated by *Imperata* sp. grass (Kalunya is the vernacular name for this grass, which is used for thatching). The forest edges are bordered with *Acanthus pubescens* (Oliv.) Engl.

Syrphidae were collected with hand nets at each of these four sites with approximately equal collection efforts: a team of 8 collectors collected flies individually along the trails and paths at each site during one day, between 9:00h and 13:00h (giving about 32 hours of collecting effort at each site during each visit). These collection efforts were limited to the morning periods (a comparative test showed that the hover fly activity is higher in the morning than in the afternoon. Also during the rainy season, afternoon showers are more common and syrphid activity is lower during those periods). Records from these four sites were used in the diversity analysis. In addition, material was collected occasionally during the rest of the days at other sites within the forest (figure 1, indicated with solid triangles), to obtain a more complete record of the syrphid fauna. The combined records were used in the biogeographical and seasonal analyses.

The biogeographical analysis is based on a comparison with distribution records in the specimen database of the National Museums of Kenya (NMK, Department of Invertebrate Zoology) for Syrphidae. This database contains records from East Africa based on collections at the NMK, Natural History Museum London, Natal Museum Piertermaritzburg and literature records (for more details see De Meyer, *et al.*, 1995, 1999). The Afrotropical distribution is based on Smith & Vockeroth (1980) and Dirickx (1998).

Methods for assessing species richness and diversity follow Magurran (1988). The following indices were used: for species richness and alpha diversity, Margalef, and Brillouin indices, with the addition of the Berger-Parker index as a dominance measure; for beta diversity, Jaccard and Morisita-Horn indices. The preference for the Brillouin index over the Shannon index is based on the arguments outlined in Magurran (1988) regarding non-random samples, as well as references to above cited individual indices. Size, mobility and conspicuousness affect the hand sampling of insects, hence the 'catchability' of each species is clearly not equal. Also the team of collectors was different at each visit resulting in differences in 'catch efficiency'.

RESULTS

Table 1 comprises all Syrphidae reported from Kakamega Forest including the number of specimens collected during this research at each sampling trip. Also included in this table are those species recorded from Kakamega Forest (either in literature or in other collections) but not found during this survey.

Biogeography

During our visits a total of 2,607 specimens was collected. Most of this material represents 65 species that could be identified, including one *Paragus* species new to science (De Meyer, 1998) (an additional 12 species could only be identified to genus level and were excluded from further analyses). Nine species that were reported from the Kakamega Forest in the literature or were represented in older collections (table 1) were not collected during the course of this research within the forest boundaries (one, however, *Mesembrius cyanipennis* (Bezzi), was found once outside the forest boundaries). This brings the total of identified species from Kakamega Forest to 74. One hundred and seventy-one species are recorded for the country as a whole (De Meyer, *et al.*, 1999). The forest therefore holds 43 percent of the known hover fly fauna of Kenya.

After comparison with other syrphid data for eastern Africa (based on the above mentioned database at NMK), 18 species reported from Kakamega Forest are unique to this locality within Kenya. Of these, 12 are also represented in the Guineo-Congolian forest belt, throughout Central Africa (Democratic Republic of Congo, Gabon, Congo), western African rain forests (Liberia, Ghana), and/or rain forest patches in Uganda. They can therefore be considered as indicator species, reflecting the historical link between Kakamega Forest and other forests of the guineo-congolian belt (De Meyer, *et al.*, 1999). They are indicated with an asterix (*) in table 1.

Some species like *Microdon luteiventris* Bezzi and *Mesembrius cyanipennis* also follow a similar pattern but are found in one or two additional localities in Kenya. No other distribution pattern could be detected although there is an indication that some species might be generally associated with forests in the country (further discussion on distribution patterns found in hover flies in East Africa is found in De Meyer *et al.*, 1999). Fourteen species were also collected outside the forest area during the last three visits. All of these, except *M. cyanipennis* (but see remark above), were also reported from the forest area.

Alpha diversity

Table 2 lists the species recorded at the four permanent sites: Buyangu, Isecheno, Kalunya and Yala, figure 2 shows the rank/abundance plot and table 3 presents all indices for species richness, dominance and diversity for the four sites. The site with the highest number of species (Buyangu, 38 species) contains twice as many species as the one with the lowest number (Kalunya, 19 species). This difference in species richness is also reflected in the Margalef index (D_{Mg}, used as a simple measure for species richness, and based on S: the number of species and N: the total number of individuals summed over all species). The

Table 1: Syrphid species recorded from Kakamega Forest (: species indicating an equatorial rainforest link; °: Indicating species for the first time recorded from Kakamega Forest; lit.: species not recorded within the forest during this survey but mentioned in the literature; col.: species not recorded within the forest during this survey but representatives found in other collections).*

Genus	Species	visit 1	visit 2	visit 3	visit 4	visit 5	visit 6	source
Allobacha	*cuthbertsoni*° (curran)	2	1	8	25	0	12	
	eclara° (curran)	0	0	0	0	0	1	
	ichneumonea° (bezzi)	0	0	1	2	0	0	
	*inversa**° (curran)	1	0	0	0	0	0	
	*marginata** (bezzi)	0	0	0	0	0	1	
	neavei (bezzi)	0	3	0	0	0	5	
	picta° (wiedemann)	5	1	0	1	0	2	
	praeusta° (bezzi)	4	1	0	4	0	0	
Allograpta	*calopoides* (curran)	1	0	0	0	3	0	
	calopus (loew)	3	4	0	1	1	2	
	nasuta (macquart)	2	0	1	58	96	2	
	varipes (curran)	25	2	1	1	3	7	
Asarkina	*africana*° bezzi	2	0	3	4	0	7	
	albifacies° bezzi	4	7	0	0	0	1	
	eremophila loew	0	0	0	0	0	3	
	ericetorum (fabricius)	22	22	10	16	10	23	
	medjensis curran	0	2	0	0	0	0	
	punctifrons° austen	5	0	10	9	1	1	
Betasyrphus	*adligatus* (wiedemann)	5	0	0	5	3	3	
	claripennis (loew)	0	0	0	0	0	0	lit.
	hirticeps° (loew)	5	0	0	0	0	0	
	*inflaticornis** (bezzi)	1	1	0	5	5	4	
	saundersi° (van der goot)	2	0	0	0	2	0	
Chasmomma	*nigrum** curran	0	0	0	0	0	0	col.
Episyrphus	*trisectus* (loew)	74	7	4	42	65	65	
Eristalinus	*dubiosus* (curran)	6	12	7	0	3	3	
	euzonus° (loew)	0	2	0	1	0	6	
	fuscicornis° (karsch)	0	0	1	0	1	0	
	lineifacies (curran)	0	0	0	0	0	0	col.
	*mendax**° (curran)	0	1	0	0	0	1	
	myiatropinus (speiser)	0	1	0	1	0	0	
	quinqeulineatus (fabr.)	42	157	2	17	10	70	
	*surcoufi** hervé-bazin	0	0	0	0	0	0	col.
	taeniops° (wiedemann)	0	7	0	0	0	0	
Eristalis	*apis**° curran	0	0	1	1	0	0	
Eumerus	*maculipennis* bezzi	1	2	1	2	4	0	
	paulae° hervé-bazin	0	1	0	0	5	4	
Graptomyza	*breviscutum*° curran	0	0	0	2	0	0	
	*nigra**° bezzi	1	3	0	3	0	1	
	suavissima karsch	0	1	0	0	0	0	
	triangulifera (bigot)	0	0	0	0	0	0	lit.
Hovaxylota	*perarmata* hippa	0	0	0	0	0	0	lit.

Genus	Species	visit 1	visit 2	visit 3	visit 4	visit 5	visit 6	source
Hovaxylota	*vulcana* hippa	0	0	0	0	0	1	
Ishiodon	*aegyptius*° (wiedemann)	0	18	0	0	0	0	
Mallota	*aperta**° (bezzi)	1	5	0	2	0	1	
Melanostoma	*annulipes* (macquart)	47	12	1	27	67	101	
	bituberculatum° (loew)	0	1	2	0	0	13	
	gymnocera bigot	20	37	41	167	108	249	
	infuscatum becker	11	0	0	4	27	27	
	scalare° (fabricius)	20	24	0	3	2	25	
Mesembrius	*cyanipennis* bezzi	0	0	0	0	0	1	col.
	senegalensis° (macquart)	0	3	0	1	0	7	
	*tarsatus** (bigot)	0	5	0	1	0	0	
Microdon	*luteiventris* bezzi	0	0	0	6	0	0	
	sudanus° curran	0	0	0	0	0	1	
Paragus	*borbonicus* macquart	4	14	0	7	2	2	
	longiventris loew	2	2	6	4	14	1	
	minutus hull	6	4	0	10	5	38	
	stuckenbergi° de meyer	2	1	0	1	1	1	
Phytomia	*bulligera* (austen)	1	18	0	2	0	2	
	incisa (wiedemann)	0	109	0	2	1	1	
	natalensis (macquart)	0	2	0	0	0	0	
Rhingia	*caerulescens*° loew	0	1	0	5	3	1	
	cyanoprora speiser	0	0	0	0	9	4	
	mecyana° speiser	0	0	0	3	1	1	
	trivittata° curran	2	0	0	14	16	3	
Senaspis	*dibapha* (walker)	0	2	0	0	0	3	
	elliotti austen	0	0	0	0	0	0	lit.
	dentipes (macquart)	0	0	0	0	0	0	col.
Simoides	*villipes*° loew	0	1	0	0	0	1	
Syritta	*bulbus* walker	1	7	0	0	3	3	
	fasciata° (wiedemann)	0	1	0	0	0	0	
	nigrifemorata macquart	2	4	0	0	1	0	
Xanthandrus	*congensis**° curran	0	3	0	0	0	1	
Allobacha	sp a	1	0	0	0	0	0	
	sp b	0	1	0	0	0	0	
	sp c	0	0	0	0	2	2	
Asarkina	sp a	1	0	0	0	0	0	
	sp b	0	0	0	1	2	1	
Eristalinus	sp a	2	0	0	0	0	0	
	sp b	0	0	0	0	2	0	
	sp c	0	0	0	0	1	0	
Eumerus	sp a	0	0	0	0	0	1	
Microdon	sp a	1	0	0	0	0	0	
Syritta	sp a	0	0	0	0	1	0	
	sp b	0	0	0	0	1	0	
TOTALS		337	513	100	460	481	716	

Table 2: Syrphid species found at the four permanent sites at Kakamega Forest (abbreviations see text)

Genus	Species	B	I	Y	K
Allobacha	*cuthbertsoni*	18	1	2	0
	ichneumonea	1	0	0	0
	marginata	1	0	0	0
	neavei	1	1	0	0
	picta	1	1	0	0
	praeusta	3	0	0	0
Allograpta	*calopus*	0	6	3	0
	nasuta	12	20	26	14
	varipes	1	0	2	0
Asarkina	*africana*	2	0	0	0
	albifacies	0	4	0	0
	ericetorum	35	9	6	0
	medjensis	1	0	0	0
	punctifrons	19	0	0	0
Betasyrphus	*adligatus*	0	1	0	0
	inflaticornis	3	5	0	0
Episyrphus	*trisectus*	33	25	5	2
Eristalinus	*dubiosus*	3	11	1	5
	euzonus	0	3	1	0
	fuscicornis	0	1	0	0
	mendax	1	0	0	0
	quinqeulineatus	33	135	1	17
	taeniops	0	0	0	7
Eristalis	*apis*	0	0	0	1
Eumerus	*maculipennis*	4	1	1	2
	paulae	7	2	0	0
Graptomyza	*nigra*	0	0	1	0
	suavissima	1	0	0	0
Hovaxylota	*vulcana*	1	0	0	0
Ishiodon	*aegyptius*	0	11	2	0
Mallota	*aperta*	5	0	0	0
Melanostoma	*annulipes*	88	27	15	15
	bituberculatum	0	2	2	9
	gymnocera	62	136	51	13
	infuscatum	2	17	4	0
	scalare	15	4	3	0
Mesembrius	*senegalensis*	0	3	0	5
	tarsatus	0	2	0	0
Microdon	*sudanus*	1	0	0	0
Paragus	*borbonicus*	4	14	0	0
	longiventris	2	0	2	3
	minutus	3	10	4	2
	stuckenbergi	1	0	0	0

Genus	species	B	I	Y	K
Phytomia	*bulligera*	2	7	0	4
	incisa	15	9	0	34
	natalensis	0	0	0	1
Rhingia	*caerulescens*	0	2	0	0
	cyanoprora	0	6	0	0
hingia	*mecyana*	0	0	1	0
	trivittata	0	1	0	0
Senaspis	*dibapha*	0	3	0	0
Simoides	*villipes*	0	1	0	0
Syritta	*bulbus*	2	0	1	0
	nigrifemorata	2	0	0	0
Xanthandrus	*congensis*	2	1	0	0

Brillouin index *HB* is based on the proportional abundance of the species. The values for all four sites vary between 1.93 (lowest, at Yala) and 2.55 (highest, at Buyangu). The Berger-Parker index *d* is a dominance measure weighted towards the abundance of the commonest species. The reciprocal is used here (1/d) so that an increase coincides with higher diversity. The lowest value is found at Yala, reflecting the high abundance of *Melanostoma gymnocera* Bigot. The highest value is found at Buyangu, indicating that the abundance of the commonest species at this site (*Melanostoma annulipes* (Macquart)) has a limited effect on the general diversity.

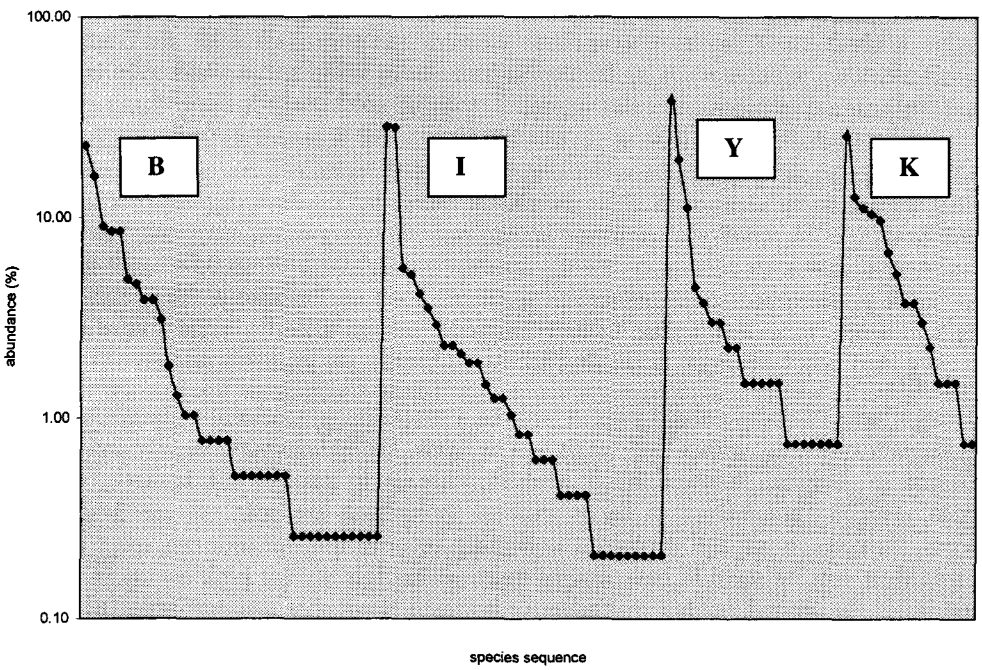

Figure 2: Rank abundance plots for four permanent sites (abbreviations as in figure 1).

Table 3: Diversity indices for four permanent sites at Kakamega Forest (abbreviations see text).

Site	B	I	Y	K
S	38	34	21	19
N	392	482	134	140
D_{Mg}	6.36	5.34	4.08	3.64
HB	2.55	2.27	1.93	2.26
1/*d*	4.45	3.54	2.63	4.12

Beta diversity

Table 4 presents the similarity values among the four sites, used as a measure of beta diversity. Comparing the four sites merely on common presence or absence of species, as with the Jaccard index C_j, the similarity values vary between 0.29 and 0.41. The highest value is found between Isecheno and Yala whereas the lowest is between Yala and Kalunya. The similarity between the two forest patches (Isecheno and Buyangu) is the second highest value (0.40).

Taking into consideration the number of each species, as calculated with the Morisita-Horn index C_{mh}, the differences between the similarity indices vary between 0.44 and 0.69. Most indices show the same tendency as in the Jaccard indices.

Table 4: Similarity indices between four permanent sites at Kakamega Forest (abbreviations see text)

Jaccard index			
Sites	I	Y	K
B	0.39	0.31	0.33
I		0.41	0.33
Y			0.29

Morisita-Horn index			
Sites	I	Y	K
B	0.65	0.65	0.57
I		0.69	0.54
Y			0.44

Seasonality.

Kakamega has a bimodal rainfall pattern without a strict double maximum. Rainfall increases from January onwards, with a first maximum in April, a slight decrease in July and a second maximum in August, followed by a gradual decrease in rainfall till January (Ojany & Ogendo, 1988). Temperature is fairly uniform throughout the year. Figure 3 shows the seasonal fluctuations on the combined collecting records for the fourteen most abundant species. Most species seem to have one or more peaks. Usually the peak occurs in the drier period, after the second rainfall maximum or between November and January. This is most apparent in *Phytomia incisa* (Wiedemann) (distinct peak in the January sampling), *Eristalinus quinquelineatus* (Fabricius) (peak around December–January) and *Melanostoma scalare* (Fabricius) (high abundance from November till January). Some peak earlier, starting from September, like *Episyrphus trisectus* (Loew), *Melanostoma infuscatum* Becker, and

M. annulipes. Others have their peak around June–September, i.e. in or around the rainy season maxima (like *Rhingia trivittata* Curran or *Allograpta nasuta* (Macquart)). Only a few species (like *Asarkina ericetorum* (Fabricius)) were equally abundant throughout the year.

DISCUSSION

The economic importance, biodiversity value of, and existing threats to Kakamega Forest are summarised in the IUCN report reviewing Kenyan forests (Wass, 1995). From the present survey it is shown that it is one of the most valuable but also most threatened forests in the country. Despite its isolation and over exploitation in recent times with consequent changes in habitat, it still harbours unique species representing a historical link with the equatorial rain forest. The importance of rain forest fragments (especially lowland rain forests) for maintaining tropical diversity has been reviewed recently by Turner & Corlett (1996). It is well established for other groups such as birds (Bennun & Waiyaki, 1992), and butterflies (Larsen, 1991), that Kakamega Forest harbours a fauna that is partly a remnant of the guineo-congolian forest belt. The syrphid fauna shows the same trend with 12 out of the 74 identified species possibly being indicator species for this historical link. It is important to notice that all older records for these particular species were reconfirmed, so no apparent extinctions were evident (the occurrence of the two species that could not be confirmed, *Chasmomma nigrum* Curran and *Eristalinus surcoufi* Hervé-Bazin, are both based on recently collected specimens in other collections).

With 74 identified species, or 43% of the total known Kenyan fauna, Kakamega Forest harbours a very rich fauna. Again, no full comparison can be made since no other region has been studied in such detail within the country (a recent study of the hover fly fauna of the Taita Hills fragments has shown a much poorer fauna. These findings require further analysis). For another insect group such as butterflies, for which the available Kenyan records are much more abundant and detailed, a comparable percentage of the national fauna present in the Kakamega Forest is found (350 out of 871, or 40%, see Larsen 1991).

Kakamega is a mosaic of ecosystems and this heterogeneity is the result of natural effects as well as human disturbance (the latter mainly through over-exploitation of the forest resources including commercial logging, and human activities, see Wass, 1995). In addition, the diverse variety of larval development habitats allows occupation of a wide spectrum of forest habitats. This is reflected in the differences in syrphid fauna composition at the four permanent sites. Merely based on the Margalef index, both forest sites show a higher diversity. The highest diversity (expressed by all the indices) is Buyangu forest indicating the richness of the original undisturbed forest. Kalunya glade has a proportional diversity value almost equal to the one for Isecheno (2.26 and 2.27 respectively). This reflects the fact that although the number of species is much lower at Kalunya than at Isecheno, the proportional abundance is more evenly spread in the former. The rank/abundance plot in figure. 2 shows similar trends with Buyangu and Kalunya graphs more evenly spread than Isecheno and Yala.

The highest similarity values (in Jaccard as well as Morisita-Horn indices) are found between apparently different systems (Yala: open bushland and Isecheno: disturbed forest), while the lowest is between somewhat more similar systems (Yala and Kalunya, which are both open areas). This could be due to the major influence of common species that are not typical for the forest, but generalists that are widespread (for example, four out of the five most common species encountered at the four permanent sites, comprising 64% of all specimens

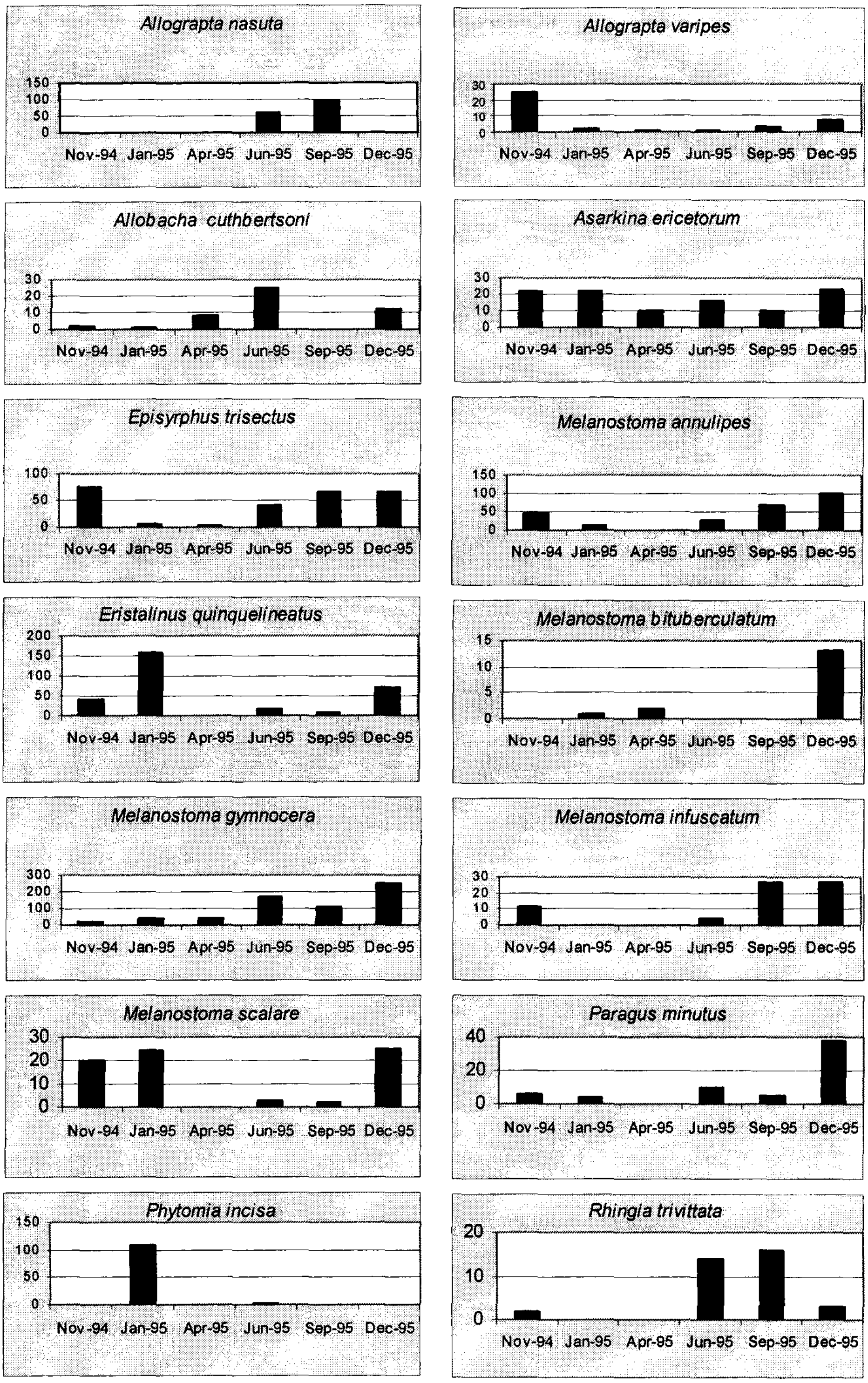

Figure. 3: Seasonal fluctuations in the number of specimens collected, for 14 abundant syrphids in Kakamega Forest.

collected during the last five trips, are also found outside the forest boundaries). The second largest similarity is between the two forest patches perhaps due to a greater input from typical forest species. However the equally large similarity reflected in the Morisita-Horn index between Buyangu and Yala is not directly explicable. Kalunya has fairly low similarity indices (especially in Morisita-Horn index) in comparison to any of the other three sites, indicating the more exceptional faunal composition of the natural grasslands. In addition, taking only into consideration the records of the four permanent sites, of the 12 possible indicator species reflecting the former link with the equatorial rain forest seven are found at Buyangu, three at Isecheno, two at Kalunya and one at Yala. Of the other six species only recorded from Kakamega Forest three are known from Buyangu and one from Kalunya. There seems therefore to be a larger proportion of the unique species richness present in the less disturbed areas, especially in the forested area.

It must be pointed out that 55 of all 65 identified species collected during this study were found in the four permanent sites. The remaining 10 species were found at other localities sampled. Therefore, the four sites do not give a complete picture of the fauna of the forest complex.

Regarding seasonality, it could be argued that because of the collecting method, the catchability will decrease during rainy seasons (because of the inactivity of the flies) without establishing their actual presence or absence. Nevertheless, it was observed that even during sunny intervals in the rainy season, certain species are absent while others are abundant. The catch therefore seems to reflect an actual presence or absence since there is no reason for expecting a difference in behaviour among species. For periods during the heavy rains (e.g. in April) catchability may have well been hampered. Because the graphs are based on combined collecting efforts, there could be bias because of oversampling at a specific site during a single sampling effort. However, if these graphs are compared with the individual sampling records at the four permanent sites a similar seasonality is observed, with the exception of *Paragus minutus* Hull, *Allograpta varipes* (Curran) or *Rhingia trivittata* Curran. This is, however, due to the limited number of specimens of those species collected at any of the four permanent sites.

In tropical forests a large proportion of the arthropod fauna is active in the canopy (Russel-Smith & Stork, 1994). It is possible that a large hover fly fauna could occur there as well. However, no studies with this regard are known. Syrphidae are mainly flower-visiting species. Comparitive study of canopy in Kakamega Forest would be interesting but was beyond the scope of the present study. Equally important would be to obtain data with comparable collecting efforts for other sites in the region.

ACKNOWLEDGEMENTS

This study was largely financed through a research grant from Earthwatch Europe, within the scope of contract B7-5041.93.29 of the European Union DGVIII/D/5 (Biodiversity, conservation and environmental education in African tropical forests). Most of the fieldwork was carried out by Earthcorps volunteers. This work would not have been possible without their help and enthusiasm and all volunteers are thanked for their enormous input and effort. Many thanks to Andy Whittington (National Museums, Edinburgh) for his assistance in the identification of syrphids. Also thanks to Luc Duchateau (ILRI, Nairobi) for his assistance in statistical analysis, to Brian Stuckenberg (Natal Museum, Pietermaritzburg) for his identification of the new *Paragus* species, and to Nadine Van Noppen (Africamuseum, Tervuren) for her assistance in the artwork.

REFERENCES

Beentje, H.J. (1994). *Kenya Trees, Shrubs and Lianas.* National Museums of Kenya, Nairobi.

Bennun, L. & E. Waiyaki (1992). Ornithological report, Kakamega forest. *KIFCON Biodiversity Surveys,* National Museums of Kenya, Nairobi.

Chambers, & Adams (1986). Quantification of the impact of hoverflies (Diptera: Syrphidae) on cereal aphids in winter wheat: analysis of field population. *Journal of Applied Ecology* **23**: 895–904.

De Meyer, M. (1996). Final report on Earthwatch project hoverflies of Kakamega forest. Unpublished report, National Museums of Kenya, Nairobi.

De Meyer, M. (1998). A new *Paragus* species from Kenya (Diptera, Syrphidae). *Annals of the Natal Museum* **39**: 143–147.

De Meyer, M., E. Vanden Berghe & A.E. Whittington (1995). Specimen database: Syrphidae (Diptera) of East Africa. *Centre for Biodiversity Research Reports (National Museums of Kenya), Biodiversity Database* **1**: 1–11.

De Meyer, M., E. Vanden Berghe & A.E. Whittington (1997). Zoogeography and biodiversity of Syrphidae (Diptera) in East Africa. *Journal of East African Natural History* **86**: 43–50.

Dirickx, H.G. (1998). Catalogue synonymique et géographique des Syrphidae (Diptera) de la région afrotropicale. *Instrumenta Biodiversitatis* **2**: 187pp.

Eggleton, P., D.E. Bignell, W.A. Sands, B. Waite, T.G. Wood & J.H. Lawton (1995). The species richness of termites (Isoptera) under differing levels of forest disturbance in the Mbalmayo forest Reserve, southern Cameroon. *Journal of Tropical Ecology* **11**: 85–98.

Erwin, T.L. (1982). Tropical forests: their richness in Coleoptera and other arthropod species. *The Coleopterists' Bulletin* **36**: 74–75.

Erwin, T.L. & J.C. Scott (1980). Seasonal and size patterns, trophic structure and richness of Coleoptera in the tropical arboreal ecosystem: the fauna of the tree *Luehea seemannii* Triana and Planch in the Canal Zone in Panama. *The Coleopterists' Bulletin* **34**: 305–322.

Hammond, P. (1992). Species Inventory. In B. Groombridge, (ed.), *Global Biodiversity, Sstatus of the Earth's Living Resources*. Chapman & Hall. Pp. 17–39.

Hodkinson, I.D. & D. Casson (1991). A lesser predilection for bugs: Hemiptera (Insecta) diversity in tropical rain forests. *Biological Journal of the Linnean Society of London* **43**: 101–109.

Kokwaro, J.O. (1988). Conservation status of the Kakamega forest in Kenya: the easternmost relict of the equatorial rain forests of Africa. *Monographs on Systematics in Botany, Missouri Botanical Garden* **25**: 471–489.

Larsen, T.B. (1991). *The Butterflies of Kenya and their Natural History.* Oxford University Press, Oxford UK.

Magurran, A.E. (1988). *Ecological Diversity and its Measurement.* Croom Helm, London.

Mutangah, J.G., O. Mwangangi, & P.K. Mwaura (1992). Kakamega forest, a vegetation survey report. *KIFCON Biodiversity Surveys, National Museums of Kenya Nairobi.*

Noyes, J.S. (1989). The diversity of Hymenoptera in the tropics with special reference to Parasitica in Sulawesi. *Ecological Entomology* **14**: 197–207.

Ojany, F.F. & R.B. Ogendo (1988). *Kenya, a Study in Physical and Human Geography*. Longman Kenya, Nairobi.

Patro, B. & M.K. Behera (1993). Bionomics of *Paragus* (*Paragus*) *serratus* (Fabricius) (Diptera: Syrphidae), a predator of the bean aphid *Aphis craccivora* Koch. *Tropical Science* **33**: 131–135.

Round-Turner, D. (ed.). (1994). *Kakamega Forest, the Official Guide*. KIFCON, Nairobi.

Russel-Smith, A. & N. Stork (1994). Abundance and diversity of spiders from the canopy of tropical rainforests with particular reference to Sulawesi, Indonesia. *Journal of Tropical Ecology* **10**: 545–558.

Sanjayan, K.P., M.C. Muralirangan, P. Suresh, D. Suresh Chand & S. Albert (1995). Insect diversity in a natural scrub-jungle vegetation of a forest ecosystem in Tamil Nadu. *The Entomologist* **114**: 179–194.

Schmutterer, H. (1974). Oekologische Untersuchungen an entomophager Syrphidae und ihren Parasiten in Hochland von Kenia (Ostafrika). *Zeitschrift für angewandte Zoologie* **75**: 42–67.

Smith, K.G.V. & J.R. Vockeroth (1980). Syrphidae. In Crosskey, R.W. (ed.) *Catalogue of the Diptera of the Afrotropical Region*. British Museum (Natural History), London. Pp 488–510.

Stork, N.E. (1987). Guild structure of arthropods from Bornean rain forest trees. *Ecological Entomology* **12**: 69–80.

Stork, N.E. (1991). The composition of the arthropod fauna of bornean lowland rain forest trees. *Journal of Tropical Ecology* **7**: 161–180.

Turner, I.M. & R.T. Corlett (1996). The conservation value of small, isolated fragments of lowland tropical rain forest. *Trends in Ecology and Evolution* **11**(8): 330–333.

Wass, P. (1995). *Kenya's Indigenous Forests: Status, Management and Conservation*. IUCN, Gland, Switzerland & Cambridge, UK.