Oxford University Expedition to

Comoé National Park, Ivory Coast 1999

REPORT

Temporal dynamics and community composition of aerial insects in a West African Bush Savannah

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COMPILED BY WALTER JETZ, WITH CONTRIBUTIONS FROM EMILY SHEPPARD (ES), JONATHAN TURNEY (JT) AND JOHANNA JUNBACK (JJ). 2002.

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Selected outcomes of the expedition are also documented in the following research theses and papers:

Junback, J. (2001) The abundance of aerial insects changes over height and time from dusk to dawn with changing moon phase. Master Thesis, University of Oxford, Oxford.

Müller, B. (2000) Patterns and Determinants of Insect Flight Activity in a West African Bush Savannah. Master Thesis, University of Oxford, Oxford.

Shepard, E. (2001) An investigation into diurnal patterns of abundance, biomass and richness of three insect orders in a West African bush savannah. Honours Thesis, University of Oxford, Oxford.

Turney, J. (2000) A methodological comparison of four different insect trapping devices in a West African bush savannah. Honours Thesis, University of Oxford, Oxford.

Jetz, W., Steffen, J., & Linsenmair, K.E. (2002) Constraints of visual life at night - nocturnal, lunar and seasonal activity of tropical nightjars and their insect prey. manuscript.

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Contents

1. Introduction

Tropical insect communities are as yet poorly documented. Communities in highly diverse rainforests have received increased research attention over the last decades (Erwin, 1982, 1983; Morse et al., 1988; Stork, 1987, 1988), but insects in savannah habitats are as yet little studied (but see Chown et al., 1995; Kruger & McGavin, 1998; Roberts & Irving Bell, 1985). Many questions in behavioural -, evolutionary -, species -, population -, community - and ecosystem ecology in relation to tropical insects have never been addressed (or even asked):

- What is the taxonomic and ecological composition of aerial insect communities and how does it differ from communities sampled from substrate?
- What are the temporal patterns of flight activity of insects, and what are their physiological, ecological and environmental correlates and constraints?
- How do patterns and determinants differ with height? What are the resulting spatio-temporal patterns of insect biomass in the air and thus the potential prey availability to aerial insectivores?
- How do these patterns relate to ecology and behaviour of aerial predators and contribute to ecosystem energy flow?

Most studies have focused on communities living on particular plants with insects usually being knocked down with insecticides (Paarmann & Stork, 1987), or sampled with sweep nets (Siemann et al., 1996). Obviously, such techniques are limited to specific substrates and neglect individuals in flight. Furthermore, while the spatial resolution of these methods is good, their validity in terms of temporal resolution is very limited as they are very elaborate and repeated samples of the same substrate cannot be compared in a simple way. Sampling of aerial insects not only gives an estimate of the communities in the particular habitat, but also allows quantification of overall extent and interspecific differences in dispersal (Taylor, 1986).

A plethora of factors have been invoked to explain variation in patterns of insect flight activity, such as feeding habit (Springate & Basset, 1996), age, size, and sex (Turner, 1987). However, it is recognised that aerial activity in many arthropod groups is strongly influenced and often determined by abiotic factors (Gilbert, 1985; Gupta et al., 1990; McGeachie, 1989; Yela Jose & Holyoak, 1997). These include time of day or night and natural light cycle, moon brightness and phase, and local weather conditions - particularly air temperature, precipitation and wind (Kunz, 1988).

Aerial insects can be sampled in many ways (McGavin, 1997; Southwood & Henderson, 2000). One method for collecting insects is light trapping, most extensively used in the tropics due to its simplicity (e.g. Sparks et al., 1986). However, light traps are attractant (also to non-flying insects), highly selective and fail to deliver neutral estimates (Julliet, 1963; McGeachie, 1989; Muirhead-Thomson, 1989; Yela Jose & Holyoak, 1997). Alternative techniques to accurately quantify aerial number like suction traps (Macaulay et al., 1988), rotary traps (Nicholls, 1960; Topping et al., 1992) and car traps (Bidlingmayer, 1974; Rautenbach et al., 1988) have been used in some studies, but only limited to certain heights and not at all in the tropics (see Muirhead-Thomson, 1989, for overview).

The aims of the expedition were manifold and included both short and long-term goals. In overview, they were to:

1. Sample insects using a variety of trap designs in a comparative manner
2. At a coarse taxonomic level describe the composition of the “community” of airborne insects
3. Perform analyses on the temporal pattern of aerial insect abundance and its (e.g. environmental) determinants
4. Compare different trap designs in their selectivity and efficiency in relation to environmental conditions
5. Examine the performance of a novel trap design, the height-selective rotary trap which samples insects simultaneously at 2m, 4m and 6m and evaluates the determinants of aerial insect abundance at different height layers
6. Cover the final three months of a 9-month study into the seasonality of aerial insect abundances as sampled by car trapping
7. Collect insect samples that would allow experts much-needed taxonomic and biogeographic work including the description of many new species

This report documents the mid-term outcomes of the expedition. Data analysis is heavily reliant on taxonomic classification of samples and its degree of sophistication depends on the taxonomic resolution attained. At this point, many samples have been sorted at least to the level of order and some to the level of family. Only few samples have been size-classed to allow estimation of biomass. So far several first analyses were possible, some of which are first-of-their kind and already provide some very interesting insights. Short summaries are presented in this report. However, further work is under way or planned. Accordingly, the report documents work in progress and part of its aim is to present a reference overview for subsequent analyses. Emphasis was thus put on adequate documentation of site, traps, sampling procedure and state of sample classification.

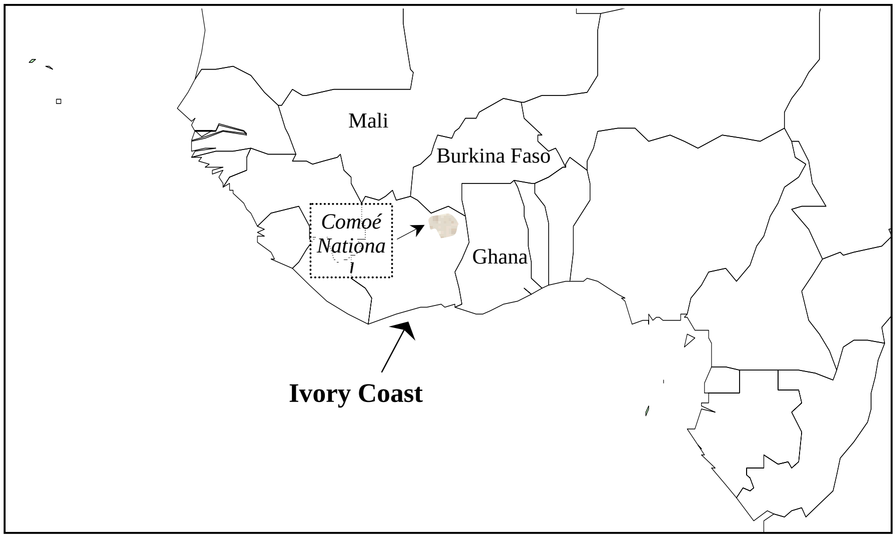
2. The Study Site: Comoé National Park

2.1. Overview

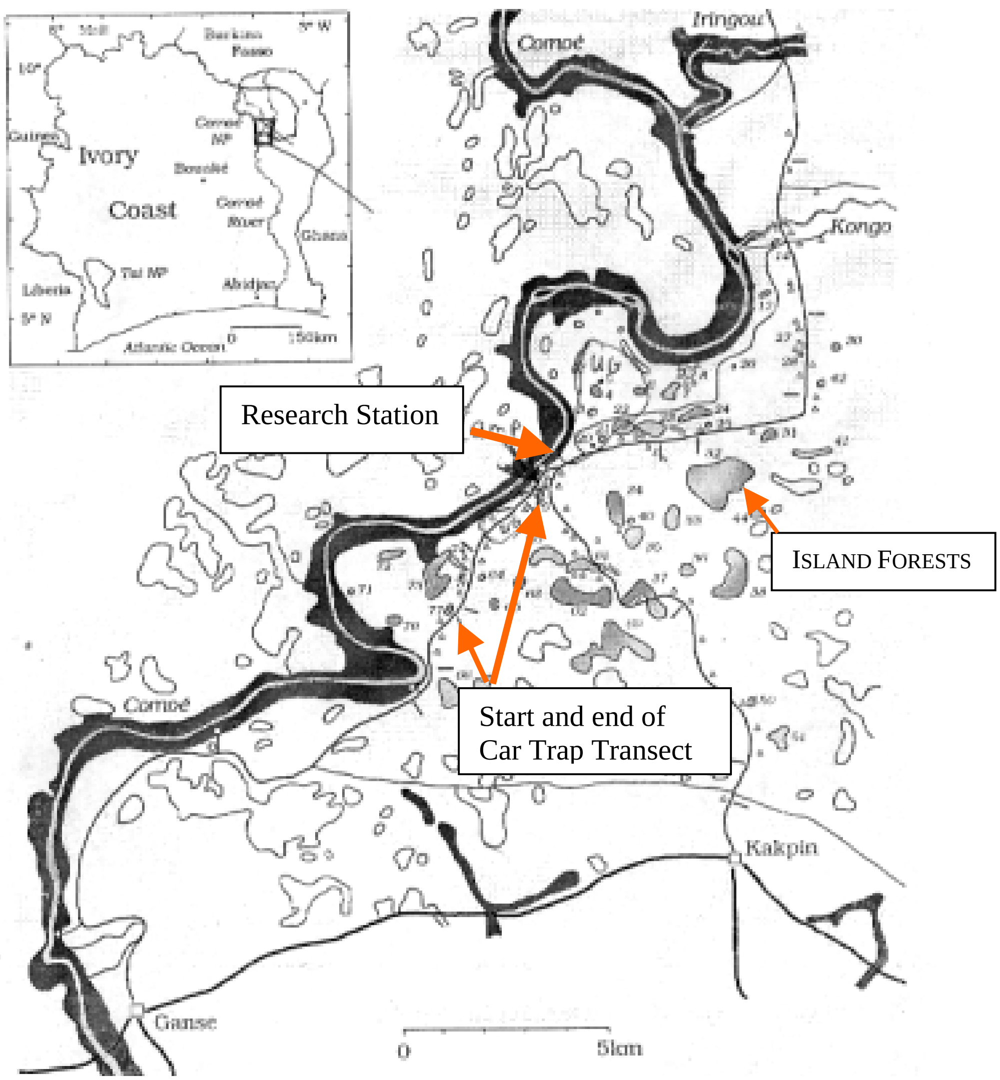
The study was carried out in one of the largest areas of as yet undisturbed bush savannah habitat in Northern Ivory Coast, Comoé National Park (11500km^2). The park is situated between 8.5° and 9.6° North and 3.1° and 4.4 ° West, mainly between 250-300m altitude (maximum 635m). The park comprises an interfluvial peneplain of schist and granite between the Comoé and Volta rivers, with mean altitude of 250m to 300m and a series of ridges and granite inselbergs rising to 600m. The River Comoé and its tributaries form the principal drainage and the Comoé runs through the park for 230km. Watercourses also drain to the Volta in the east. Permanent and semi-permanent water occurs in many places. The soils are infertile and unsuitable for cultivation in some areas.

With an annual rainfall of 1100mm in the South and 900mm in the North it holds a mosaic of fringing gallery forests, forest islands, savannah woodland, inselbergs and open plains. More than 300 species of woody plants and over 400 bird species have been recorded in the park, which is assumed to be of international significance for conservation. Yet the park as well as the whole region is still understudied with only little research having been conducted on arthropods, frogs, larger mammals and migratory birds.

VIEW N FROM AN INSELBERG SOME 12KM NW OF THE RESEARCH STATION.



LOCATION OF COMOÉ NATIONAL PARK



LOCATION OF RESEARCH STATION AND STUDY AREA

2.2. Vegetation

The park contains a remarkable variety of habitats and plant associations found, more often, further south, including savannah, forests and riparian grasslands. It provides an outstanding example of an area of transitional habitat from forest to savanna. Open forest and savanna woodland characteristic of the Sudano-Guinean zone, occupies about 90% of the area, and gallery forest and dense dry forest, about 10%. All types of savanna occur. The forest is composed of many leguminous trees including *Burkea africana*, *Detarium microcarpum*, *Afzelia africana*, *Daniellia oliveri*, and *Isoberlinia doka*. The savanna grasslands consist mainly of *Panicum*, *Ctenium*, *Andropogon*, *Elionurus* and *Cymbopogon* species varied by some *Bauhinia* spp., *Combretum* spp. and *Gardenia* spp. thicket. The gallery forests are dominated by *Cynometra vogelii*; the patches of dense dry forest by *Isoberlinia doka*, *Anogeissus leiocarpus*, *Cola cordifolia*, *Antiaris africana*, nationally threatened *Chlorophora excelsa* , and the edible 'akee' *Blighia unijugata*; and the flood plains by *Hyparrhenia rufa*. Other forest species recorded include: *Parkia biglobosa*, *Pterocarpus erinaceus*, *Combretum*, *Terminalia*, including *T. avicennioides*, shea nut *Butyrospermum parkii* and *Uapaca somon*, *Lophira lanceolata*, *Protea elliotii*, *Burkea africana*, nationally threatened *Borassus aethiopum*, *Mitragyna inermis* and *Entada abyssinica*, a grassy ground cover of *Andropogon* spp.. Areas of specialised vegetation occur on the rocky inselbergs and in aquatic habitats (UNEP-WCMC, 1982).

VIEW ACROSS THE STUDY SITE FROM NE TO SW. THE DIRT ROAD IN FRONT IS THE ACCESS ROAD TO THE CAMP WHICH LIES 200M TO THE NORTH ON THIS PICTURE.

2.3. Fauna

Comoé forms the northerly limit for some species including yellow-backed duiker *Cephalophus sylvicultor* and bongo *Tragelaphus euryceros*. There are a large number of mammal species with 11 species of monkey including: anubis baboon *Papio anubis*, green monkey *Cercopithecus aethiops*, diana monkey *Cercopithecus diana*, mona monkey *C. mona*, lesser white-nosed monkey *C. petaurista*, white collared mangabey *Cercocebus torquatus lunulatus*, black and white colobus *Colobus polykomos* and chimpanzee *Pan troglodytes*; 17 species of carnivore including lion *Panthera leo* and leopard *P. pardus*; giant pangolin *Manis gigantea*, aardvark *Orycteropus afer*, and rock hyrax *Procavia capensis*; and 21 species of artiodactyl including bushpig *Potamochoerus porcus*, warthog *Phacochoerus aethiopicus*, hippopotamus *Hippopotamus amphibius*, elephant *Loxodonta africana*, bushbuck *Tragelaphus scriptus*, sitatunga *T. spekei*, buffalo *Syncerus caffer aequinoctialis*, red-flanked duiker *Cephalophus rufilatus*, waterbuck *Kobus ellipsiprymnus*, kob *K. kob*, roan antelope *Hippotragus equinus* and oribi *Ourebia ourebi*. Birds include 10 species of herons such as grey heron *Ardea cinerea*, goliath heron *A. goliath*, yellow-billed egret *Egretta intermedia*, ducks (Anatidae), raptors (Accipitridae), plovers and francolins (Phasianidae), hammerkop *Scopus umbretta*, black-winged stilt *Himantopus himantopus*, four of the six West African stork species, and five of the six West African vulture species. Reptiles include all three species of African crocodile, slender-snouted *Crocodylus cataphractus*, Nile *C. niloticus*, and dwarf *Osteolaemus tetraspis* (UNEP-WCMC, 1982).

PUFF ADDER (*BITIS ARIETANS)* – CAN ADD EXCITEMENT TO OTHERWISE DULL SAMPLING PROCEDURES

Aerial insectivores are diverse and abundant. Eight species of swifts and spinetails (*Apodidae*) have been recorded in the park as well as 18 swallows and forktails (*Hirundinidae*) (Salewski, 2000). Nocturnal aerial insectivores at the core study area include five nightjar species (see table) and several dozens of bats (as yet no published species list available).

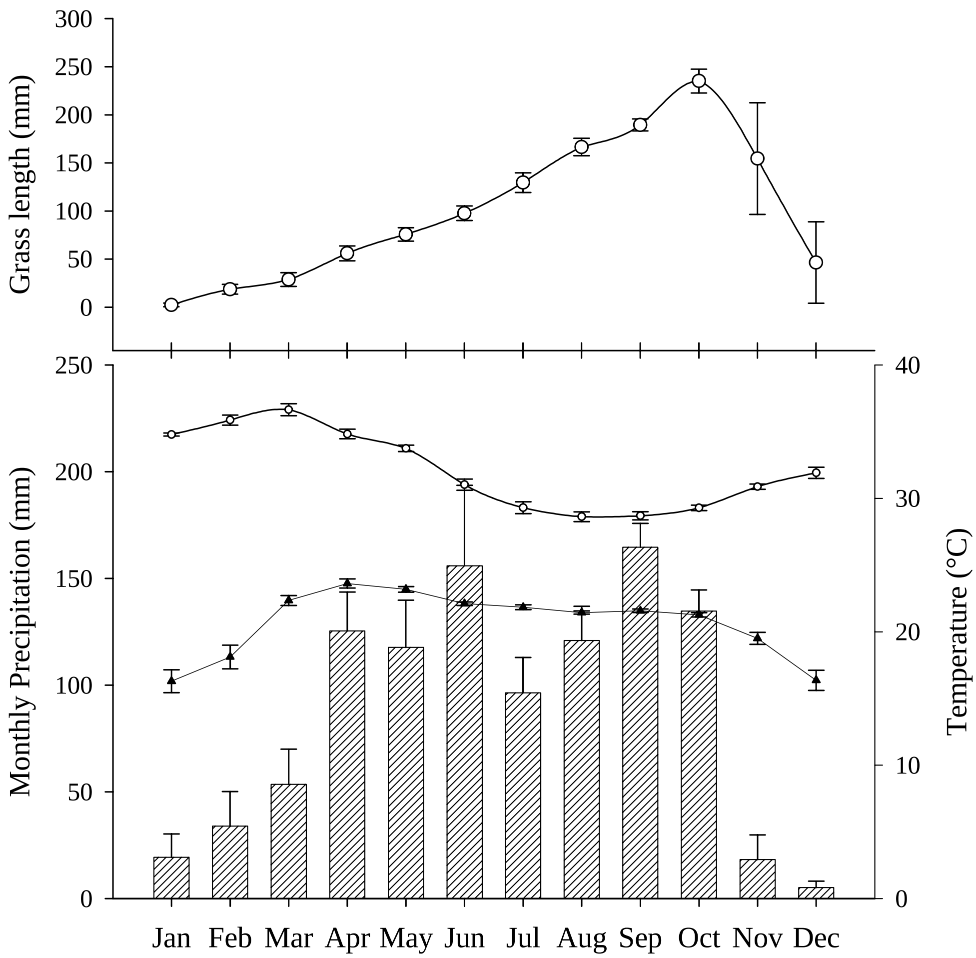
NAMES AND SEASONALITY OF NIGHTJAR SPECIES OCCURRING IN THE STUDY AREA. FROM (JETZ ET AL., 2002)

Species		Presence	Breeding	Breeding Season	Outside Breeding
Long-tailed Nightjar	*Caprimulgus climacurus*	Resident	Comoé	March to June	Comoé
Standard-winged Nightjar	*Macrodypterix longipennis*	Intra-African migrant	Comoé	January to March	Sahelian savannah
Plain Nightjar	*Caprimulgus inornatus*	Intra-African migrant	Sahelian savannha	April to June	Comoé
Red-necked Nightjar	*Caprimulgus ruficollis*	Palearctic migrant	SW Europe, NNW Africa	May to August	Comoé
Black-shouldered Nightjar	*Caprimulgus nigriscapularis*	Resident	Comoé	April to May	Comoé

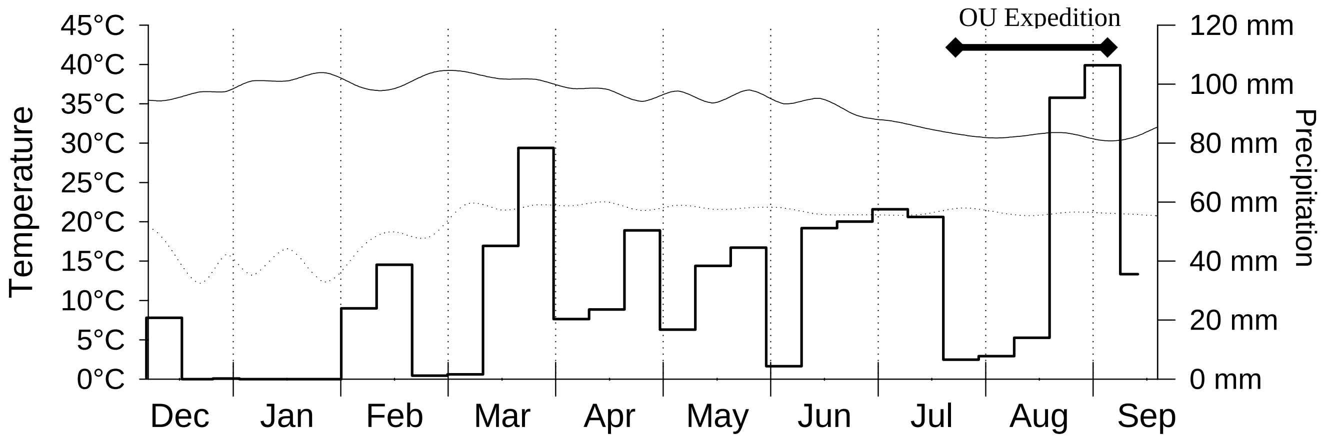
PLAIN NIGHTJAR (CAPRIMULGUS INORNATUS) – ONE OF THE FIVE COMMON NIGHTJAR SPECIES IN THE STUDY AREA

2.4. Weather and Light Conditions

The park has a Sudan-type humid tropical transitional, highly seasonal climate with a fairly distinct dry season from December to around March when there is little rainfall and the daily variation in temperature is high (figure). Annual rainfall varies between 1100 and 1300 mm. Towards the end of the wet season the herbaceous cover can be up to 2m high and grass stems well over 2m long (figure), but fires at the onset of the dry season annually reduce it to few centimetres in most places. Approximate dates for start of the wet season were 30 March in 1998 and 14 March in 1999.

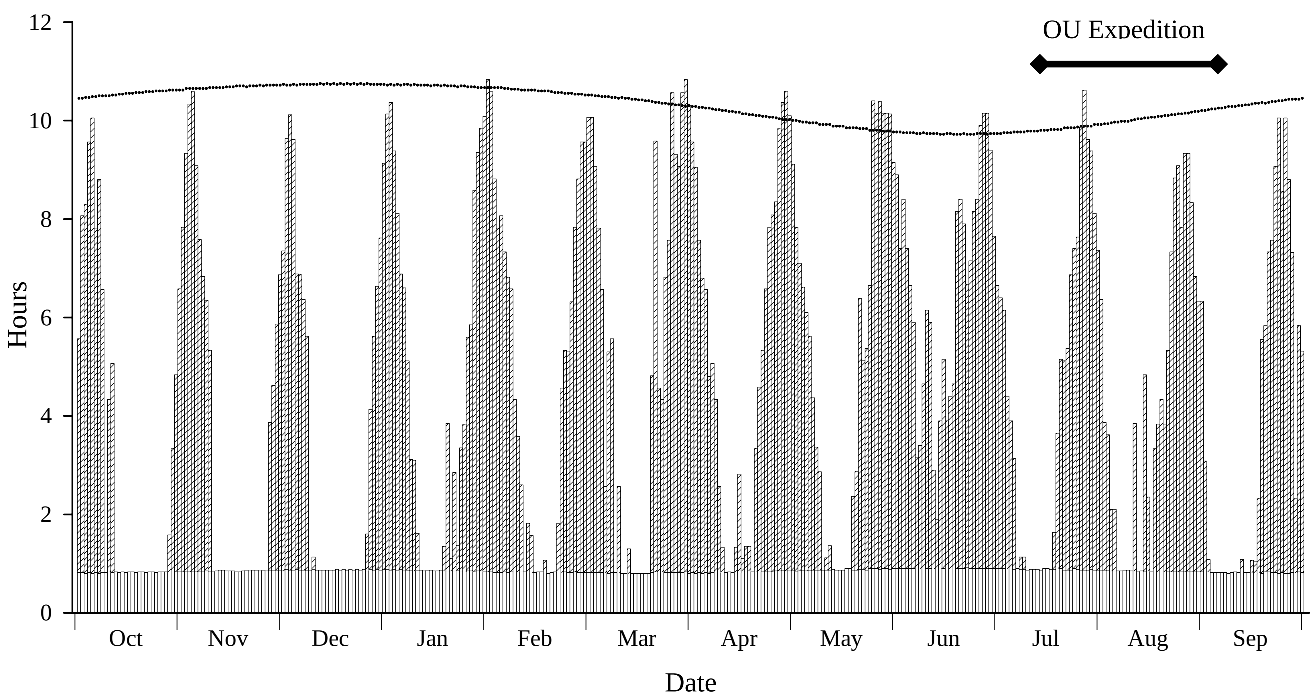


WEATHER CONDITIONS AND VEGETATION AT THE STUDY SITE (6-YEAR AVERAGE, JANUARY 1994 TO NOVEMBER 2000). TOP: MEAN GRASS STEM LENGTH (+/- S.E.) IN SELECTED SAVANNAH PLOT (SELECTED GRASS STEMS ON A SMALL STUDY PLOT IN OPEN SAVANNAH WERE MEASURED TWICE A MONTH). BOTTOM: MEAN (+/- S.E.) SUM OF MONTHLY PRECIPITATION, DAILY MINIMUM (TRIANGLE) AND DAILY MAXIMUM (CIRCLES) TEMPERATURES. AFTER END OF THE WET SEASON, IN NOVEMBER AND DECEMBER, GRASS WAS REDUCED TO LENGTH ZERO BY BUSH FIRES.



SEASONAL PATTERN OF CLIMATE. THE SEASONAL PATTERN OF TEN DAY SUMS OF AMOUNT OF PRECIPITATION AND MEAN MINIMUM (THIN LINE) AND MAXIMUM (THICK LINE) DAILY TEMPERATURES ARE GIVEN FOR THE PERIOD DECEMBER 1998 TO SEPTEMBER 1999.

Periods of twilight are much shorter near the equator than in temperate regions (figure 2). Nights at low latitudes have near-constant duration throughout the year while they vary strongly in length between winter and summer in more extreme latitudes. The seasonal change in duration of twilight (solar azimuth between -6° and -12°) and night conditions at the study site is minimal (figure). However, the monthly variation in duration of light availability is great. In the five to fifteen days around new moon at no time light levels exceed 0.03 mWm^{-2} m. This lunar pattern shows little change seasonally.



ANNUAL PATTERN OF DAILY DURATION OF TWILIGHT (-6° TO –12 ° SOLAR AZIMUTH, OPEN BARS) AND NOCTURNAL LIGHT CONDITIONS >=0.03MW/M^2 (HATCHED BARS, STACKED) AT THE STUDY SITE. DOTS INDICATE DAILY DURATION OF NIGHT (< –12 ° SOLAR AZIMUTH). FROM 1/10/98 TO 1/10/99. HORIZONTAL BAR INDICATES PERIOD OF SAMPLING AS PART OF THE OU EXPEDITION.

3. Methodology

3.1. Weather and light conditions

We recorded climatic conditions at 15-minute intervals at the north-western edge of our study site using an automated weather station with a Campbell CR10X Logger. A Campbell 50Y Temperature and Relative Humidity Probe was used at 1.5m above ground. Both temperature and humidity correlate positively with time of night, they decrease towards the morning. We monitored levels of incident light with a Skye Instruments High Output Light Sensor SKL 2640 at 3m above ground. This sensor has a cosine corrected head (all light rays perpendicular to the sensor are fully measured) and measures incoming levels of energy per unit area uniformly for all wavelengths between 400 and 700nm. The output of this highly sensitive sensor is slightly affected by ambient temperature (zero drift better than 0.048mW/m^2 per 1ºC according to the manufacturer) and therefore all values were corrected for temperature (using a regression equation derived from completely dark new moon nights). We calculated seasonal pattern of night and twilight duration at the study site and selected latitudes using the program Astro (Strickling, 1995).

3.2. Trap Designs

Malaise Trap
(E.S.)
The Malaise trap is a passive flight interception trap. Its design is 'basically an open-fronted tent', made of nylon netting. One of the corners of the central panel slopes upwards and a separate collecting bottle is attached at the apex (see photograph). The trap works as insects have a tendency to migrate to the highest corner once they have come into contact with any of the panels (Southwood & Henderson, 2000). The collecting bottle was filled to a fixed point (almost 1/3 full) with 70% ethanol, which preserves the insects, the alcohol was replenished to prevent evaporation causing a change in alcohol concentration. The upper collecting bottle was attached to a lower bottle containing the alcohol, at the time of collection the lower bottle could be unscrewed and exchanged for another bottle containing fresh alcohol.

As the Malaise trap is passive it catches insects where it intercepts flight paths, thus providing a general description of the ambient aerial habitat, whilst minimising the risk of trap type effecting apparent diurnal activity patterns. However, as the trap relies on insects striking the net panels it has been said to provide bias samples. This investigation will seek to compare the content of samples from 5 sampling days and 5 nights, instead of providing a description of the aerial fauna.

Black Malaise traps from Marris House Nets (54 Richmond Park Avenue, Queen's Park, Bournemouth) were used. Two malaise traps were set up in area's chosen to have similar vegetation (see methods section for habitat similarity coefficient)– in the approximate percentage cover of bushes, trees and grass in the surrounding area and the species of vegetation present. The malaise traps were set up in a north-south orientation. Long sticks were used to support them and Sisal was used for the attachments to minimise the use of artificial materials and bright colours that might have attractive properties.

Window Trap

(E.S.)

A window trap was erected 15-20M from each malaise trap at ninety degrees to the orientation of the malaise trap. A trough was constructed from a grey plastic drainpipe cut in two lengthways with clear perspex super-glued to each end. Initially a combination of blue tack and super glue were used to attach the perspex to the trough, however, this attracted a species of hymenoptera that collected the blue tack on its legs and transported so much of it away from the trap as to render it no longer water tight. Each trough was filled with water before each sampling session began to approximately half way up the trough. The possibility of using some or soap in the water was considered and subsequently abandoned due to the possibility of this also attracting certain taxa as the same species that collected the blue tack were observed to collect soap in another location. The trough rested upon two sticks that were tied in a cross like orientation with Sisal, and the gap between the top of the trough and the lower edge of the net was minimised by tying Sisal around the trough and attaching it to loops on the bottom of the net. This also ensured that the net remained above the trough even in winds.

A trough was constructed from a grey plastic drainpipe cut in two lengthways with perspex super-glued to each end. Each trough was filled with water before each sampling session began to approximately half way up the trough. The possibility of using some or soap in the water was considered and subsequently abandoned due to the possibility of this attracting Hymenoptera, which were observed to collect soap in another location. Furthermore the trough had steep sloping sides and no specimen was seen to successfully climb them, however, it is possible that certain insects were attracted to the water for drinking. The net was attached to the trough to ensured that the net always remained above the trough (see photograph).

WINDOW TRAP AT LOCATION 2, WITH “MALAISE 2” IN THE BACKGROUND.

Light Trap
(JT)
Light traps are probably the most widely used insect traps, and there are several hundred references to them (Southwood & Henderson, 2000). Despite this the variation in efficiency of the trap from insect to insect, from night to night and from site to site is more serious than in almost every other type of trap because light-traps are entirely artificial, relying on the disturbance of normal behaviour for their functioning. In previous methodological comparisons it is often implied that the bigger the catch, the 'better' the trap: although it is true that the larger figures are often more acceptable for statistical analysis it is unwise to assume that they are biologically more valuable. Light trapping is not a new concept, but in recent decades the use of light sources that produce large amounts of ultra-violet radiation has revolutionised light trapping. Light traps exploit the phenomenon that many insects (but by no means all) will fly towards bright lights at night. The exact mechanisms that lead to an insect's capture by a light trap are far from clear. Mikkola (1972) has shown that electroretinograms evoked by different types of light were at variance to the actual reponses of the moths to traps. It seems reasonable to suppose that there is an area, sometimes called the radius of the trap or 'catchment area', within which the insect comes into the influence of the light. In tropical areas, light traps have the potential to attract enormous numbers of insects which is why a modified version of the Robinson trap was used in this investigation.

ROBINSON LIGHT TRAP AS USED IN THE STUDY

This design was the first trap to use ultra-violet light and was designed by Robinson & Robinson (1950) to make maximum catches of the larger Lepidoptera. The high ultra-violet content light bulb is suspended in the centre of plastic ‘baffles’: moths and other insects move towards the light in a spiral flight, are intercepted by the baffles and drop through the open bottom of a cone into a retention chamber. A transparent roof prevents insects from escaping through the cone by encouraging them to fly back up towards the incoming light. An additional plastic ‘cap’ is mounted above the bulb to protect it from potential rainfall. This trap was modified for the investigation with the following two changes. Firstly, a fine-meshed ‘collecting bag’ was made and used to line the inside of the retention chamber. This allowed all insects caught during the sampling session to be efficiently extracted. Secondly, the trap was raised one metre above the ground, so as to be comparable with the other three trapping techniques. The trap was powered by a Honda EX312 generator with a control box to ensure a constant electricity supply. This was placed 25 metres away from the sampling site to minimise noise interference. The sampling session lasted 15 minutes and ran simultaneously with the other trapping methods. The collecting bag was immediately placed in the freezer to ensure that the lepidopteran specimens could be appropriately extracted and stored before the remaining insects were labelled and placed in 80% alcohol. The efficiency of light traps is evidently reliant on lunar conditions, but wind conditions, temperature, precipitation and humidity all affect insect activity and hence amenability to trapping. These effects and the relative taxonomic selectivity of the different traps will figure highly in their methodological comparison.

Rotary Trap
(WJ)
The trap consists of a vertical aluminium tube as an axis, which is rotated by a little (windscreen wiper) engine powered by a lorry battery. Fixed to the axis are horizontal aluminium tubes with a butterfly net of 1m diameter attached at the end, 2m from the axis at three different heights (2m, 4m, 6m). Two different methods can be used to actually trap the insects caught in these large nets. One is to have a plastic collection bottle attached to the large butterfly net, into which flying insects get driven as soon as they are caught in the net by the speed the nets are rotating at. The bottles are filled with water in which some soap is diluted and the catch can be easily collected. An alternative method is to have the bottles replaced with small bag-shaped nets, which through some little thread can be closed after the end of operation in order to prevent insects from escaping. The latter method allows faster air-flow through the nets and has proofed to be more effective.


ROTARY TRAP DURING SET-UP (LEFT) AND IN OPERATION AT DAWN (RIGHT)

The trap takes about half an hour to install, can be set up by one single person (although two are preferable). A fully charged lorry battery is enough to operate it for about two hours continuously. With 17 rotations per minute the angular speed is close to 20km/h and even large fast-flying moths and beetles get caught. The batteries can be recharged from solar panels or generators.

Preliminary analyses suggested a very high efficiency and neutrality with regards to the groups caught. The effect of small to medium wind-speeds on trapping efficiency appears to be negligible. For groups for which full capture rate is assumed, the method allows full density estimation. Operation in heights of up to 6m proofed feasible and allows rigorous quantification of aerial insect communities in these lower layers.

Car Trap

(WJ)

We quantified prey abundance performing standardised car tow transect drives through parts of the study area and an adjacent similar habitat. We used a net of 95x95 cm entrance size and 2.5m length attached to the roof of a Suzuki Samurai off-road vehicle. The lower edge of the net entrance was at a height of 168cm above ground and set 15cm in front and 20cm above the windscreen to avoid insects being drawn in from air turbulence over the car surface. The funnel like net (mesh size 0.5mm) led to a sock-like net bag of 7cm diameter and 25cm length from which we transferred the insects into 90% alcohol within 5 seconds of stopping the car. When stopping the car the air traction brought the net to immediate closure and the number of insects escaping back into the net funnel was negligible. At roughly weekly intervals between 20/12/98 and 1/9/99 we chose a night with stable weather conditions and no rain and took four samples at different times of the night. Sampling took place in the form of a standardised transect drives on a stretch of gravel road of 5000m length between 200m and 800m distance to the gallery forest along the river Comoé, with the last 200m in the study site. The road was between 3m and 3.50m wide and led through habitat very similar to the study site, semi-open tree savannah and plains. We drove at a constant speed of 38km/h (+- 2km/h) with dipped lights (non-main beam) to minimise any effect on insects reacting to light. As the road is hilly, curvy and at no time the lights can be seen from more then 200m distance (and usually well under 100m), we believe the effect of the car lights to be negligible.

THE CAR TRAP SHORTLY BEFORE USE AT DUSK

3.3. Trapping Methodology

Schedule

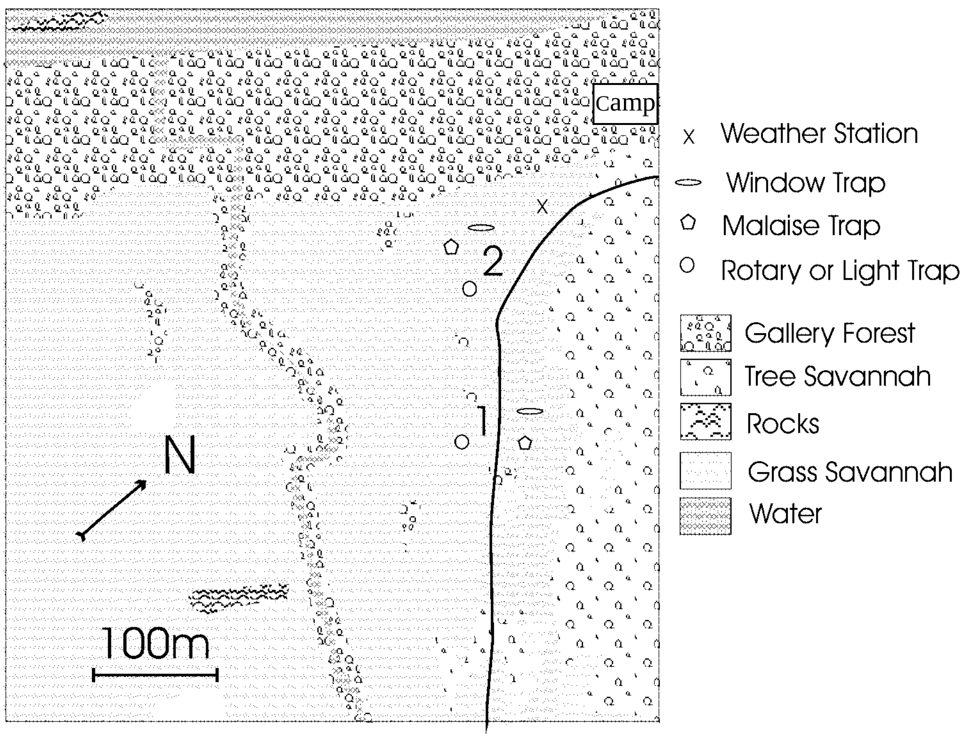
All traps were operated simultaneously in 1h (Window and Malaise) and 2h (Car and Rotary) intervals and times of civil dusk and dawn, except for the light trap which was only operated at dusk, 10pm, 2am and dawn. Window and Malaise Traps were employed continuously, the Rotary Trap was operated for 30min, the Light Trap for 15min and the Car Trap drive had a duration of around 8 minutes.

We used the solar azimuth to standardise the timing of the additional trap catches at twilight. Thus, we started our evening sample at the onset of civil dusk (solar azimuth= -6º) and timed the drive for the morning sample so that it would finish at civil dawn (solar azimuth= -6º).

Trap Type	**Replicates**	**Sampling Intervals**	**Sampling Duration**	**Type**	**Resolution spatial**	**Resolution temporal**
Window	2	1h	1h	non-attractant	high	low
Malaise	2	1h	1h	semi-attractant	high	low
Rotary	1	2h, also dusk, dawn	30min	non-attractant	high	medium
Light	1	dusk, 10pm, 2am, dawn only	15min	attractant	high	high
Car	1	2h, also dusk, dawn	10min	non-attractant	low	high

Sites

Overall five trapping methods were employed, four of them simultaneously at all times. Four traps were stationary and set up in close vicinity to each other in the core study area (see figure). One, the car trap, used a 5km transect outside this area, on a road leading through a mixture of bush and tree savannah woodland. For two methods, Window and Malaise, two replicate traps were operated simultaneously, at fixed sites (1 and 2, see figure and table). At both these sites another designated spot was used for either the Rotary Trap or Light Trap, for which only one replicate existed. Both sites had similar woody vegetation in their surrounding and were similar in their distance to other habitats such as closed woodland.



CORE STUDY AREA AND POSITION OF TRAPS

LOCATION AND SURROUNDING VEGETATION OF TRAPS. NUMBERS IN BRACKETS GIVE DISTANCE AND HEIGHT IN METERS OF WOODY VEGETATION IN 20M RADIUS)

Trap	**Site**	**Position**	**Vegetation over 1m (trees and bushes)**
Rotary/Light	1	8°44.97 N, 3°48.92 W	*Lania spec* (15-4), *Crossopterix febrifuga* (9- 1; 10-1, 11-3, 12-3)
Malaise		8°44.98 N, 3°48.88 W	*Crossopterix febrifuga, Anogeisus leiocarpus, Cochlospermum plankonii*
Window		8°44.99 N, 3°48.89 W	
Rotary/Light	2	8°45.02 N, 3°48.99 W	*Mitragyna inermis* (10-5), *Anogeisus leiocarpus* (20-4), *Crossopterix febrifuga* (12-1, 8-3)
Malaise		8°45.04 N, 3°49.01 W	*Crossopterix febrifuga, Anogeisus leiocarpus, Cochlospermum plankonii*
Window		8°45.08 N, 3°49.00 W	

3.4. Samples and Identification - An Overview

In the core sampling period from 21 July to 8 September 1999 we collected overall 655 Rotary, Light and Car Trap samples. Of these, by now (August 2001) 220 have been sorted to at least the level of order by two master students, Barbara Müller and Johanna Junback. Additionally, with the help of John Ismay and Darren Mann, they identified all Dipterans of the 191 rotary samples to the family level.

For all 10 day and 13 night 12h trapping sessions samples were collected from the two Malaise and Window Traps in 1 to 2 hour intervals. Of these Malaise samples from 5 days and 5 nights have been sorted down to the level of order and for Coleopterans and Dipterans to the level of family and even morphospecies. This work was done by Emily Sheppard.

All collected insects, except for the ones caught with the car trap, are currently stored (in alcohol, at subzero temperature) with Darren Mann and George McGavin at the University Natural History Museum, Oxford. The car trap samples are currently still with Walter Jetz at the Department of Zoology, Oxford (also in alcohol at subzero temperature).

SUMMARY OF SAMPLES TAKEN AND SORTED AT LEAST DOWN TO ORDER (CAR, LIGHT TRAP) OR ORDER AND DIPTERAN FAMILY (ROTARY TRAP).

Trap	**sorted**	**all**
Car	21	174
Light	8	47
Rotary 2m	66	164
Rotary 4m	67	158
Rotary 6m	58	112

DATES OF MALAISE AND WINDOW TRAP SAMPLING SESSIONS USED FOR ANALYSIS (ES).

Date	**Type**
21-Jul-99	day
3-Aug-99	day
7-Aug-99	day
10-Aug-99	day
17-Aug-09	day
21-Jul-99	night
3-Aug-99	night
4-Aug-99	night
18-Aug-99	night
19-Aug-09	night

DATES OF ROTARY TRAP SAMPLING SESSIONS USED FOR ANALYSIS. MOON PHASE FROM 0 = NEW MOON TO 1 = FULL MOON (POSITIVE VALUES INDICATE WAXING, NEGATIVE VALUES WEANING MOON)

Date	**Moon Phase**	**Type**
21-Jul-99	0.57	night
28-Jul-99	1.00	night
29-Jul-99	-0.94	night
4-Aug-99	-0.52	night
12-Aug-99	0.07	night
14-Aug-99	0.20	night
18-Aug-99	0.46	night
19-Aug-99	0.52	night

OVERVIEW OF THE CAR, ROTARY AND LIGHT TRAP SAMPLES TAKEN (X) AND SORTED AT LEAST DOWN TO ORDER (INITIAL OF SORTER).

Date of eve	Actual Date	Hour	TimeLabel	Car	Rotary 2m	Rotary 4m	Rotary 6m	Light
	21-Jul-99	6:00	day - A	x	x	x	x	
	21-Jul-99	8:00	day - B	x	x	x	x	
	21-Jul-99	10:00	day - C	x	x	x	x	
	21-Jul-99	12:00	day - D	x	x	x	x	
	21-Jul-99	14:00	day - E	x	x	x	x	
	21-Jul-99	16:00	day - F	x	x	x	x	
	21-Jul-99	18:00	day - H	x	WJ	WJ	WJ	
21-Jul-99	21-Jul-99	18:59	night - A	JS	WJ	WJ	WJ	x
	21-Jul-99	20:00	night - B	x	WJ	WJ	WJ	
	21-Jul-99	22:00	night - C	WJ				x
	22-Jul-99	0:00	night - D	x	WJ	WJ	WJ	
	22-Jul-99	2:00	night - E	WJ	WJ	WJ	WJ	x
	22-Jul-99	4:00	night - F	x	WJ	WJ	WJ	
	22-Jul-99	5:12	night - G	WJ	WJ	WJ	WJ	x
	22-Jul-99	6:00	day - A	x	WJ	WJ	WJ	
	28-Jul-99	18:00	day - H	x	BM	JJ	JJ	
	28-Jul-99	19:00	night - A	JS	BM	JJ	JJ	x
	28-Jul-99	20:00	night - B	x				
	28-Jul-99	22:00	night - C	JT	BM	JJ		JT
28-Jul-99	29-Jul-99	0:00	night - D	x	BM	JJ	JJ	
	29-Jul-99	2:00	night - E	JS	BM	JJ	JJ	x
	29-Jul-99	4:00	night - F	x	BM	JJ	JJ	
	29-Jul-99	5:13	night - G	JS	BM	JJ	JJ	x
	29-Jul-99	6:00	day - A	x	BM	JJ	JJ	
	29-Jul-99	18:00	day - H	x	BM	JJ	JJ	
	29-Jul-99	18:58	night - A	x	BM	JJ	JJ	x
	29-Jul-99	20:00	night - B	x	BM	JJ	JJ	
	29-Jul-99	22:00	night - C	J	BM	JJ	JJ	JT
29-Jul-99	30-Jul-99	0:00	night - D	x	BM	JJ	JJ	
	30-Jul-99	2:00	night - E	x	BM	JJ	JJ	x
	30-Jul-99	4:00	night - F	x	BM	JJ	JJ	
	30-Jul-99	5:13	night - G	x	BM	JJ	JJ	x
	30-Jul-99	6:00	day - A	x	BM	JJ	JJ	
	3-Aug-99	6:00	day - A	x	x	x	x	
	3-Aug-99	8:00	day - B	x	x	x	x	
	3-Aug-99	10:00	day - C	x	x	x		
	3-Aug-99	12:00	day - D	x	x	x	x	
	3-Aug-99	14:00	day - E	x	x	x	x	
	3-Aug-99	16:00	day - F	x	x	x	x	
	3-Aug-99	18:00	day - H	x	x	x	x	
3-Aug-99	3-Aug-99	18:56	night - A	x	x	x	x	x
	3-Aug-99	20:00	night - B	x				
	3-Aug-99	22:00	night - C	JT	JT	x	x	JT
	4-Aug-99	0:00	night - D	x	x	x	x	
	4-Aug-99	2:00	night - E	x	x	x	x	x
	4-Aug-99	4:00	night - F	x	x	x	x	
	4-Aug-99	5:14	night - G	x	x	x	x	x
	4-Aug-99	6:00	day - A	x	x	x	x	
	4-Aug-99	18:00	day - H	x	BM	JJW	JJW	
	4-Aug-99	18:56	night - A	x	BM	JJW	JJW	x
	4-Aug-99	20:00	night - B	x	BM	JJW	JJW	
	4-Aug-99	22:00	night - C	JT	BM	JJW	JJW	JT
4-Aug-99	5-Aug-99	0:00	night - D	x	BM	JJW	JJW	
	5-Aug-99	2:00	night - E	x	BM	JJW	JJW	x
	5-Aug-99	4:00	night - F	x	BM	JJW	JJW	
	5-Aug-99	5:14	night - G	x	BM	JJW	JJW	x
	5-Aug-99	6:00	day - A	x	BM	x	JJW	
7-Aug-99	7-Aug-99	6:00	day - A	x	x	x	x	
	7-Aug-99	8:00	day - B	x	x	x	x	

	7-Aug-99	10:00	day - C	x	x	x	x	
	7-Aug-99	12:00	day - D	x	x	x	x	
	7-Aug-99	14:00	day - E	x	x	x		
	7-Aug-99	16:00	day - F	x	x	x	x	
	7-Aug-99	18:00	day - H	x	x	x	x	
	7-Aug-99	18:55	night - A	x				
	10-Aug-99	6:00	day - A	x	x	?	?	
	10-Aug-99	8:00	day - B	x	x	x	y	
	10-Aug-99	10:00	day - C	x	x	x	y	
	10-Aug-99	12:00	day - D	x	x	x		
	10-Aug-99	14:00	day - E	x	x	x		
	10-Aug-99	16:00	day - F	x				
	10-Aug-99	18:00	day - H	x				
10-Aug-99	10-Aug-99	18:54	night - A	x	x	x	x	x
	10-Aug-99	20:00	night - B	x	x	x	x	
	10-Aug-99	22:00	night - C	x	x	x	x	x
	11-Aug-99	0:00	night - D	x	x	x	x	
	11-Aug-99	2:00	night - E	x				
	11-Aug-99	4:00	night - F	x	x	x	x	
	11-Aug-99	5:15	night - G	x	x	x	x	x
	11-Aug-99	6:00	day - A	x	x	?	?	
	12-Aug-99	18:00	day - H	x	BM	JJ	JJ	
	12-Aug-99	18:53	night - A	x	BM	JJ	JJ	x
	12-Aug-99	20:00	night - B	x	BM	JJ	JJ	
	12-Aug-99	22:00	night - C	JT	BM	JJ	JJ	JT
12-Aug-99	13-Aug-99	0:00	night - D	x	BM	JJ	JJ	
	13-Aug-99	2:00	night - E	x	BM	JJ	JJ	x
	13-Aug-99	4:00	night - F	x	BM	JJ		
	13-Aug-99	5:15	night - G	x	BM	JJ		x
	13-Aug-99	6:00	day - A	x	BM?	JJ		
	14-Aug-99	18:00	day - H	x	BM	JJ	JJ	
	14-Aug-99	18:52	night - A	x	BM	JJ	x	x
	14-Aug-99	20:00	night - B	x	BM	JJ	JJ	
	14-Aug-99	22:00	night - C	JT	BM	JJ	JJ	JT
14-Aug-99	15-Aug-99	0:00	night - D	x	BM	JJ	JJ	
	15-Aug-99	2:00	night - E	x	BM	JJ	JJ	x
	15-Aug-99	4:00	night - F	x	BM	JJ	JJ	
	15-Aug-99	5:15	night - G	x	BM	JJ	JJ	x
	15-Aug-99	6:00	day - A	x	BM	JJ	JJ	
	17-Aug-99	6:00	day - A	x	x	x	x	
	17-Aug-99	8:00	day - B	x	x	x	x	
	17-Aug-99	10:00	day - C	x	x	x	x	
	17-Aug-99	12:00	day - D	x	x	x	x	
17-Aug-99	17-Aug-99	14:00	day - E	x	x	x		
	17-Aug-99	16:00	day - F	x	x	x		
	17-Aug-99	18:00	day - H	x	x	x		
	17-Aug-99	18:52	night - A	x	x	x		
	18-Aug-99	18:00	day - H	x	BM			
	18-Aug-99	18:51	night - A	JT	BM	JJ	JJ	x
	18-Aug-99	20:00	night - B	x	BM	JJ	JJ	
	18-Aug-99	22:00	night - C	JT	BM	JJ	JJ	JT
18-Aug-99	19-Aug-99	0:00	night - D	x	BM	JJ	JJ	
	19-Aug-99	2:00	night - E	JS	BM	JJ		x
	19-Aug-99	4:00	night - F	x	BM	JJ		
	19-Aug-99	5:15	night - G	x	BM	JJ		x
	19-Aug-99	6:00	day - A	x	BM	JJ		
	19-Aug-99	18:00	day - H	x	x	JJ		
	19-Aug-99	18:50	night - A	x	J	JJ		x
	19-Aug-99	20:00	night - B	x	x	JJ	JJ	
	19-Aug-99	22:00	night - C	JT	JT	JJ	JJ	JT
19-Aug-99	20-Aug-99	0:00	night - D	x	x	JJ	JJ	
	20-Aug-99	2:00	night - E	x	J	JJ	JJ	x
	20-Aug-99	4:00	night - F	x	x	JJ	JJ	
	20-Aug-99	5:15	night - G	x	J	JJ	JJ	x
	20-Aug-99	6:00	day - A	x	x	x	JJ	
	23-Aug-99	6:00	day - A	x	x	x	x	
23-Aug-99	23-Aug-99	8:00	day - B	x	x	x	x	
	23-Aug-99	10:00	day - C	x	x	x	x	

	23-Aug-99	12:00	day - D	x	x	x		
	23-Aug-99	14:00	day - E	x	x	x		
	23-Aug-99	16:00	day - F	x	x	x		
	23-Aug-99	18:00	day - H	x	x	x		
	23-Aug-99	18:48	night - A	x				
	24-Aug-99	6:00	day - A	x	x	x	x	
	24-Aug-99	8:00	day - B	x	x	x	x	
	24-Aug-99	10:00	day - C	x	x			
	24-Aug-99	12:00	day - D	x	x	x		
24-Aug-99	24-Aug-99	14:00	day - E	x	x	x		
	24-Aug-99	16:00	day - F	x	x	x		
	24-Aug-99	18:00	day - H	x	x	x		
	24-Aug-99	18:48	night - A	x	x			
	25-Aug-99	18:00	day - H	x	?			
	25-Aug-99	18:47	night - A	x	?			x
	25-Aug-99	20:00	night - B	x	?			
	25-Aug-99	22:00	night - C	x	x	x	x	x
25-Aug-99	26-Aug-99	0:00	night - D	x	?			
	26-Aug-99	2:00	night - E	x	?			x
	26-Aug-99	4:00	night - F	x	?			
	26-Aug-99	5:15	night - G	x	?			x
	26-Aug-99	6:00	day - A	x	?			
	26-Aug-99	18:00	day - H			x	x	
	26-Aug-99	18:47	night - A			x	x	
	26-Aug-99	20:00	night - B					
	26-Aug-99	22:00	night - C					
26-Aug-99	27-Aug-99	0:00	night - D			x	x	
	27-Aug-99	2:00	night - E			x	x	
	27-Aug-99	4:00	night - F					
	27-Aug-99	5:15	night - G			x		
	27-Aug-99	6:00	day - A					
	1-Sep-99	18:00	day - H	x	x	x	x	
	1-Sep-99	18:43	night - A	JS	x	x	x	x
	1-Sep-99	20:00	night - B	x	x	x	x	
	1-Sep-99	22:00	night - C	JS	x	x	x	x
1-Sep-99	2-Sep-99	0:00	night - D	x	x	x	x	
	2-Sep-99	2:00	night - E	JS	x	x	x	x
	2-Sep-99	4:00	night - F	x	x	x	x	
	2-Sep-99	5:15	night - G	JS	x	x		x
	2-Sep-99	6:00	day - A	x	x	x	x	
	6-Sep-99	6:00	day - A	x				
	6-Sep-99	8:00	day - B	x	x	x		
	6-Sep-99	10:00	day - C	x	x	x		
6-Sep-9	6-Sep-99	12:00	day - D	x	x	x		
	6-Sep-99	14:00	day - E	x	x	x		
	6-Sep-99	16:00	day - F	x	x	x		
	6-Sep-99	18:00	day - H	x	x	x		
	6-Sep-99	18:40	night - A	x				
	7-Sep-99	6:00	day - A			x		
7-Sep-99	7-Sep-99	8:00	day - B			x		
	7-Sep-99	10:00	day - C			x		
	8-Sep-99	6:00	day - A	x	x			
	8-Sep-99	8:00	day - B	x	x	x		
	8-Sep-99	10:00	day - C	x	x	x		
	8-Sep-99	12:00	day - D	x	x	x		
8-Sep-99	8-Sep-99	14:00	day - E	x	x	x		
	8-Sep-99	16:00	day - F	x	x	x		
	8-Sep-99	18:00	day - H	x	x			
	8-Sep-99	18:39	night - A	x	x			

4. Results – a selection

In the following selected results from four core studies are presented. For details and further background information please consult the respective manuscripts.

4.1. Diurnal pattern of insect flight activity, Malaise and Window Trap (ES)

FOR FURTHER INFORMATION SEE:

SHEPARD, E. (2001) AN INVESTIGATION INTO DIURNAL PATTERNS OF ABUNDANCE, BIOMASS AND RICHNESS OF THREE INSECT ORDERS IN A WEST AFRICAN BUSH SAVANNAH. HONOURS THESIS, UNIVERSITY OF OXFORD, OXFORD.

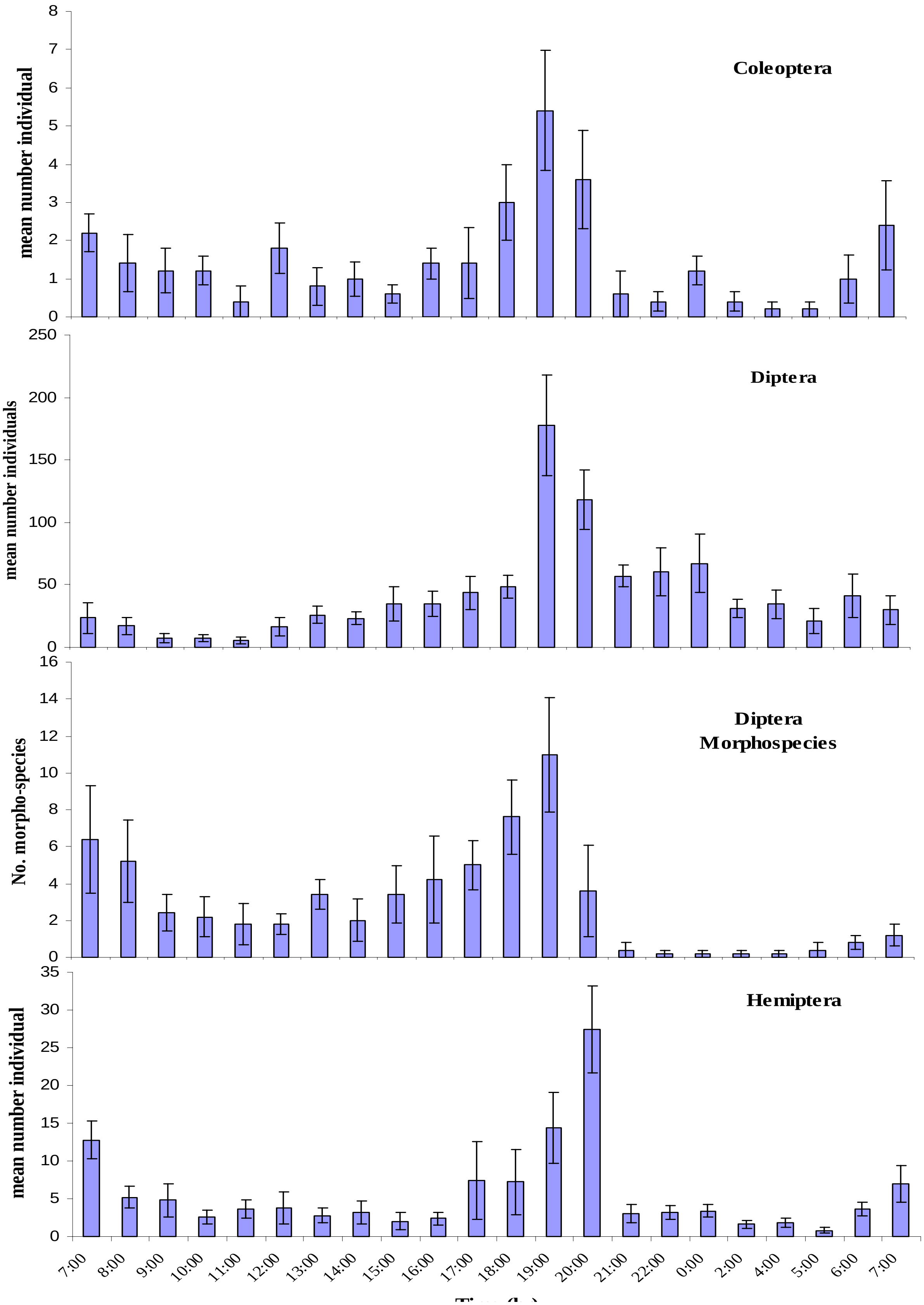
Methods

Two malaise traps were set up approximately 120 metres apart, in locations superficially similar in percentage cover of bushes, trees and grass in the surrounding area and species of vegetation present. A malaise trap was erected in a North-South orientation at each site. A window trap was erected 15-20m from each malaise trap in the same orientation. The samples from both malaise and window traps were combined to give a cumulative result per hour. Sampling was undertaken in continuous 12 or 24-hour stretches, starting at 6am and 6pm respectively. Samples were collected from the malaise and window traps at hourly intervals until 22:00, when they were collected at 2 hourly intervals until 04:00. Insects were identified from five sampling days and nights. The number of individuals, the number of families and the biomass of each sample was calculated and plotted over time. In order to get a representation of patterns of variation in recognizable taxonomic units (RTU), a subgroup of the higher flies were identified to morphospecies.

Results

Overall 5,201 insects were identified to family. The graphs show that for all groups the main abundance peak is at dusk, from 18:00 to 19:00, with a smaller but nonetheless distinct peak at 07:00 in Hemiptera and Coleoptera. The biomass data show similar patterns, with more pronounced peaks at 07:00 for Diptera, due to diurnal activity of the Calyptratae. Family-richness also displays this pattern, although less pronounced. Both the graphs and principal component analysis suggest that time and correlated factors, such as temperature, are the most significant determinants of biomass, abundance and richness, even though this is not always confirmed by statistical analysis.

Overall 97 dipteran morphospecies were encountered. Their pattern over time is very pronounced and suggests that the general curves for the abundance, biomass and richness of all Diptera, mask more refined peaks of dipteran subgroups, which may differ in activity. Our data suggest that time should be given consideration in the design of sampling strategies, particularly as groups such as Scarabaeidae have such specific temperature thresholds. Furthermore, the morphospecies discovery curve suggest that sampling period should be at least 5 days.



MEAN (+- STANDARD ERRORS) NUMBER OF INDIVIDUALS (OR MORPHO-SPECIES) OF THE ORDERS COLEOPTERA , DIPTERA AND HEMIPTERA CAUGHT IN WINDOW AND MALAISE TRAPS OVER TIME, COMBINED FOR 5 SAMPLING DAYS AND NIGHTS.

4.2. Comparison of efficiency of four aerial insect trap designs at night

(JT)

FOR FURTHER INFORMATION SEE:

TURNEY, J. (2000) A METHODOLOGICAL COMPARISON OF FOUR DIFFERENT INSECT TRAPPING DEVICES IN A WEST AFRICAN BUSH SAVANNAH. HONOURS THESIS, UNIVERSITY OF OXFORD, OXFORD.

Methods

10pm - samples from eight nights were selected for a methodological comparison of four traps, namely light, rotary, malaise and car trap (table). Two samples came from each new, waxing, weaning and full moon. Always one of the light or rotary samples was taken from either of the two rotary/light trapping sites (see figure), and the malaise trap data was pooled from sites 1 and 2. Sampling duration varied according to trap design. Insects were sorted down to the level of order.

SAMPLING DATES, DURATION AND TRAP POSITIONS (SITE 1 OR 2) USED IN THE METHODOLOGICAL COMPARISON

Actual Date	Time	Moon Phase	Light (15min)	Rotary 2m (30min)	Malaise (60min)	Car (10min)
28-Jul-99	22:00	1	1	2	1+2	5km Transect
29-Jul-99	22:00	-0.94	2	1	1+2	5km Transect
3-Aug-99	22:00	-0.59	2	1	1+2	5km Transect
4-Aug-99	22:00	-0.52	1	2	1+2	5km Transect
12-Aug-99	22:00	0.07	1	2	1+2	5km Transect
14-Aug-99	22:00	0.2	2	1	1+2	5km Transect
18-Aug-99	22:00	0.46	2	1	1+2	5km Transect
19-Aug-99	22:00	0.52	1	2	1+2	5km Transect

Overview

The sum of all insects caught varied significantly between days and traps. Environmental variables such as temperature and humidity were found to affect the overall number of insects.

TOTAL NUMBER OF INSECTS CAUGHT IN EACH TRAP FOR THE FOR EIGHT SAMPLE SESSIONS

	28-07	29-07	03-08	04-08	12-08	14-08	18-08	19-08
Light Trap	616	148	1960	784	756	468	304	492
Malaise Trap	107	58	164	36	21	22	73	103
Rotary Trap	688	200	230	212	28	52	168	136
Car Trap	4350	582	2304	696	714	630	60	624
TOTAL	**5761**	**988**	**4658**	**1728**	**1519**	**1172**	**1151**	**1355**

Taxonomic Selectivity

Traps showed strong taxonomic selectivity. In comparison, the light trap was particularly effective for beetles (Coleoptera), moths (Lepidoptera), caddisflies (Trichoptera) and bugs and cicadas (Homoptera). The Malaise Trap performed well for flies (Diptera) as did the Rotary Trap and Car Trap.

COMBINED DATA SHOWING THE TAXONOMIC SELECTIVITY OF THE FOUR TRAPS. INSECT NUMBERS IN TERMS OF NUMBER/HOUR (EFFICIENCY).

Order	Light Trap	Malaise Trap	Rotary Trap	Car Trap
Coleoptera	198.5	0.5	4.5	39
Hymenoptera	21.5	0.88	1.25	2.25
Diptera	181	63.25	196	1281.75
Homoptera	79	2.75	3.5	7.5
Lepidoptera	118.5	2	6.5	33
Pscoptera	2.5	0.25	0.25	0
Trichoptera	67.5	0.13	0.75	1.5
Heteroptera	11.5	0.13	0.75	11.25
Neuroptera	1.5	0.63	0.25	3
Arachnida	0	0	0.5	3.75
Ephemeroptera	2	0	0	0
Mantodea	5	0	0	5.25
Orthoptera	2.5	0	0	0

Trap efficiency

The relative efficiencies of the rotary and car trap can be calculated to provide some sort of quantitative assessment of their respective performances. Data can be extracted to give the total number of insects caught per hour sampling effort. If these figures are divided by the total volume of air habitat sampled during a trapping session, it is possible to compare the efficiencies.

Volume of air sampled in car trap session (10 mins): $5000m^3$
Volume of air sampled in rotary trap session (30 mins): $6291.9m^3$
Total No. Insects caught (per hour) car trap: 1388.25/ hour
Total No. Insects caught (per hour) rotary trap: 214.25/ hour

Therefore sampling efficiency:

Car trap: 0.27765 insects/hour/m^3
Rotary trap: 0.03405 insects/hour/m^3

From this analysis it would appear that the car trap is over eight times more efficient in catching insects than the rotary trap. Although these results can not be compared with the non-quantifiable techniques of the light and malaise trap, it is clear that the rotary trap does catch more insects than the malaise and the apparently ‘effective’ car trap, less than the light trap. It is also interesting to note that excluding the count for the Diptera order from the car trap data, a much more comparable result of 0.0213 insects/hour/m^3 is obtained.

4.3. Rotary trap: height selective flight activity of insects

(JJ & BM)

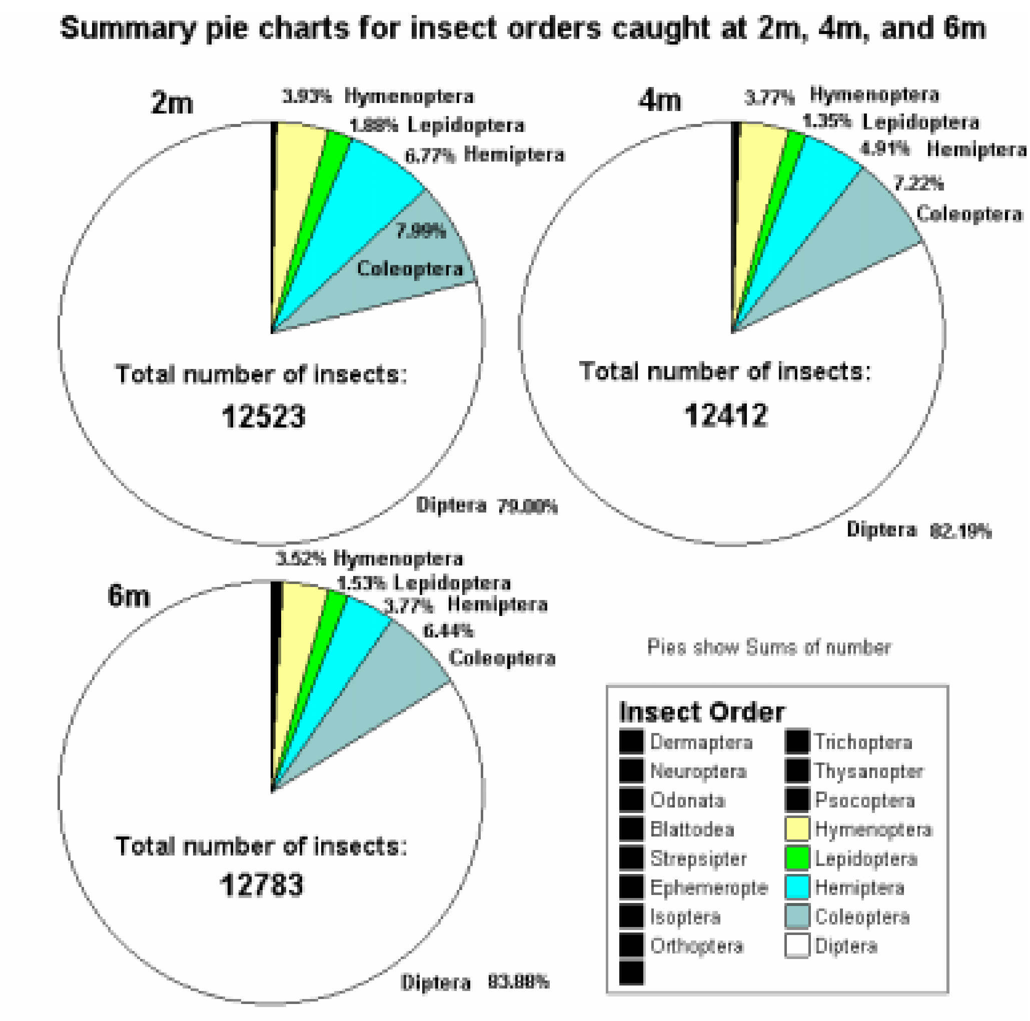
FOR FURTHER INFORMATION SEE:

JUNBACK, J. (2001) THE ABUNDANCE OF AERIAL INSECTS CHANGES OVER HEIGHT AND TIME FROM DUSK TO DAWN WITH CHANGING MOON PHASE. MASTER THESIS, UNIVERSITY OF OXFORD, OXFORD.

MÜLLER, B. (2000) PATTERNS AND DETERMINANTS OF INSECT FLIGHT ACTIVITY IN A WEST AFRICAN BUSH SAVANNAH. MASTER THESIS, UNIVERSITY OF OXFORD, OXFORD.

Height and relative abundance – insect orders

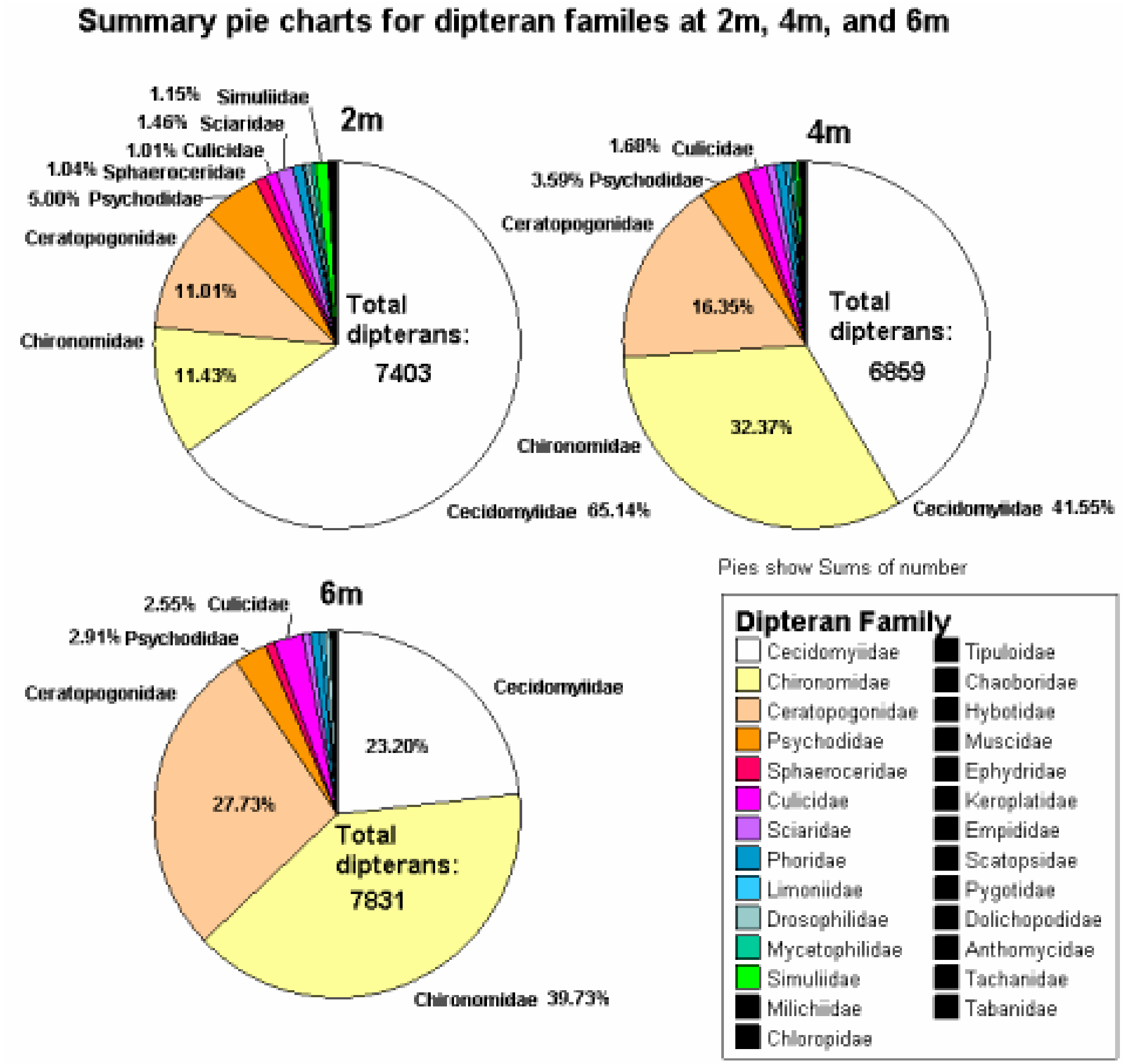
At all heights Dipterans (flies) formed the dominant order, followed by Coleopterans (beetles) and Lepidopterans (moths).



SUMMARY PIE CHARTS FOR THE 37,280 OF INSECTS IDENTIFIED TO 16 ORDER CAUGHT DURING 8 NIGHTS. SLICES SHOW THE RELATIVE ABUNDANCE OF EACH ORDER WITH ORDERS HAVING MORE THAN 1% RELATIVE ABUNDANCE SHOWN.

Height and relative abundance – Dipteran families

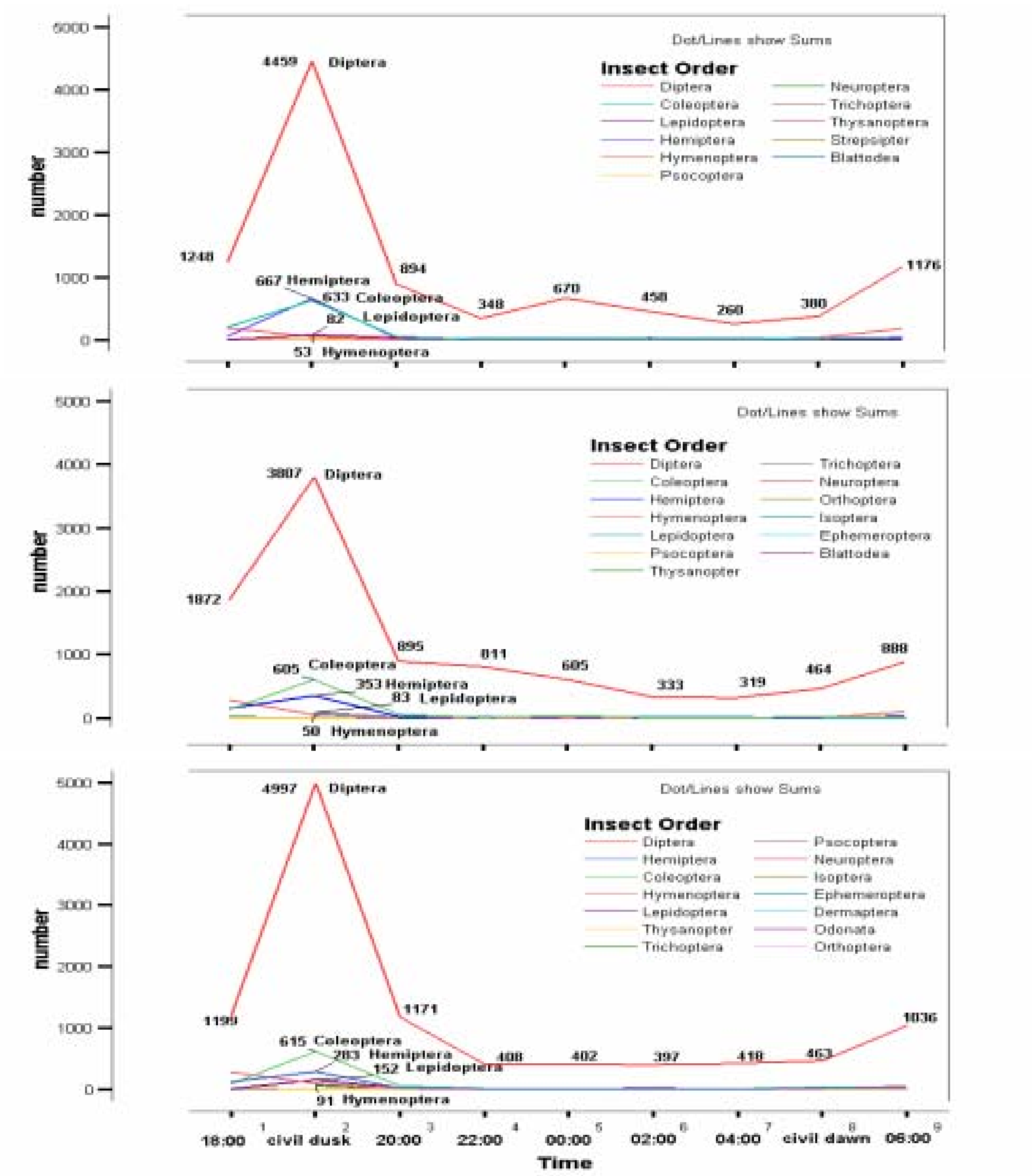
Abundance patterns of Diperan families differ between heights. Cecidomyiidae form the majority of 2m and 4m catches, but at 6m Chironomidae and Ceratopogonidae are equally high in numbers.



SUMMARY PIE CHARTS FOR THE HEIGHT DISTRIBUTION OF THE 21,969 DIPTERAS IDENTIFIED TO 27 FAMILIES. SLICES SHOW THE RELATIVE ABUNDANCE OF DIPTERAN FAMILIES WITH FAMILIES HAVING MORE THAN 1% RELATIVE ABUNDANCE SHOWN.

Height and temporal pattern – insect orders

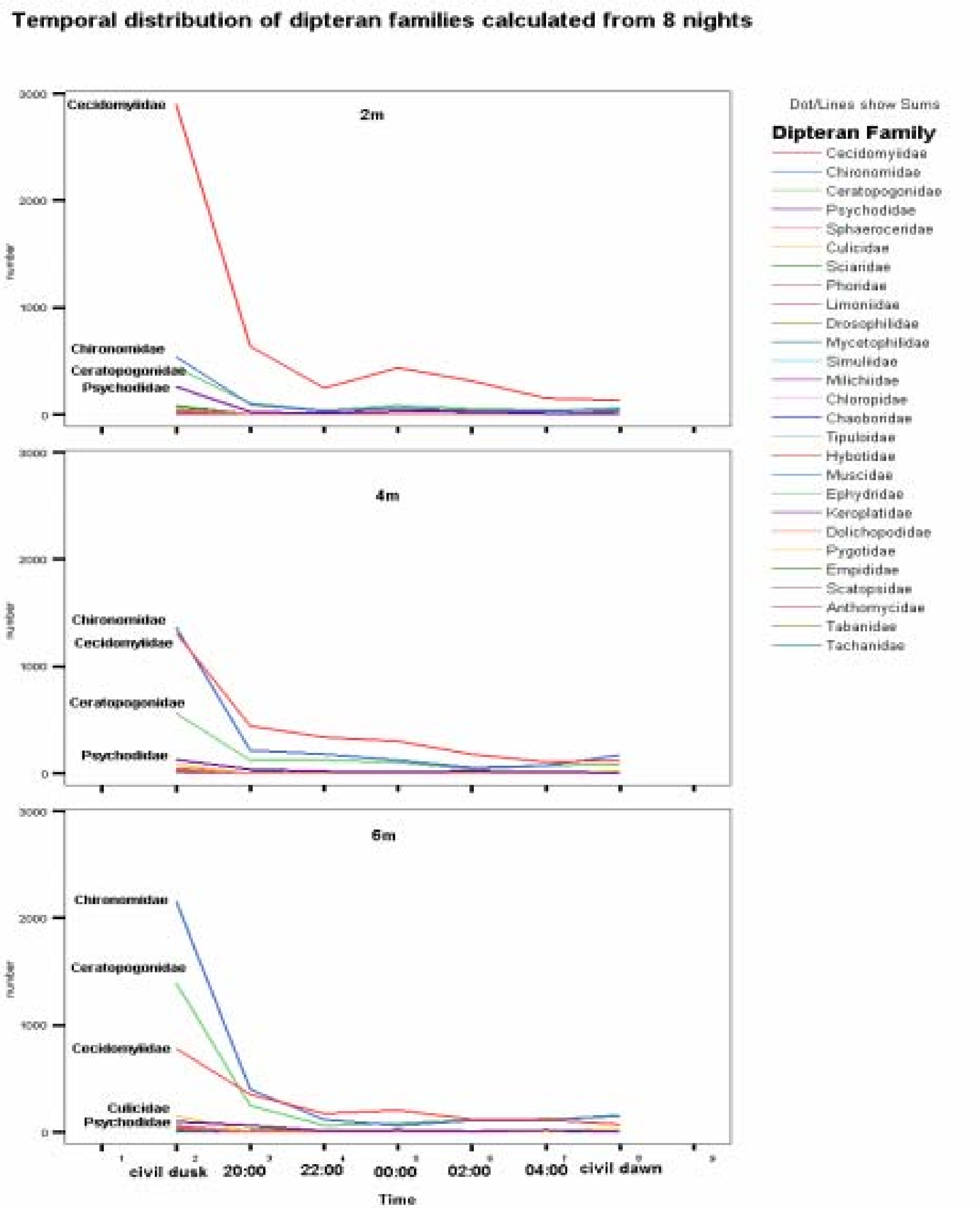
Insect numbers are highest around dusk, dominated by Coleopterans and Dipterans and for some groups show a second, smaller peak around dawn.



TEMPORAL DISTRIBUTION OF THE 37,280 INSECTS IDENTIFIED TO ORDER. LINES AND NUMBERS SHOW THE TOTAL NUMBER OF SPECIMENS PER ORDER WITH THE FIVE MOST COMMON ORDERS MARKED.

Height and temporal pattern – Dipteran families

The nocturnal flight activity pattern of Dipterans differs strongly among heights and taxa.



TEMPORAL DISTRIBUTION OF THE 21,969 DIPTERANS IDENTIFIED TO 27 FAMILIES. LINES SHOW THE TOTAL NUMBER OF SPECIMENS IDENTIFIED TO DIPTERAN FAMILIY WITH THE FOUR (FIVE AT 6M) MOST COMMON FAMILIES MARKED.

4.4 Car Trap: Seasonality of aerial insect biomass

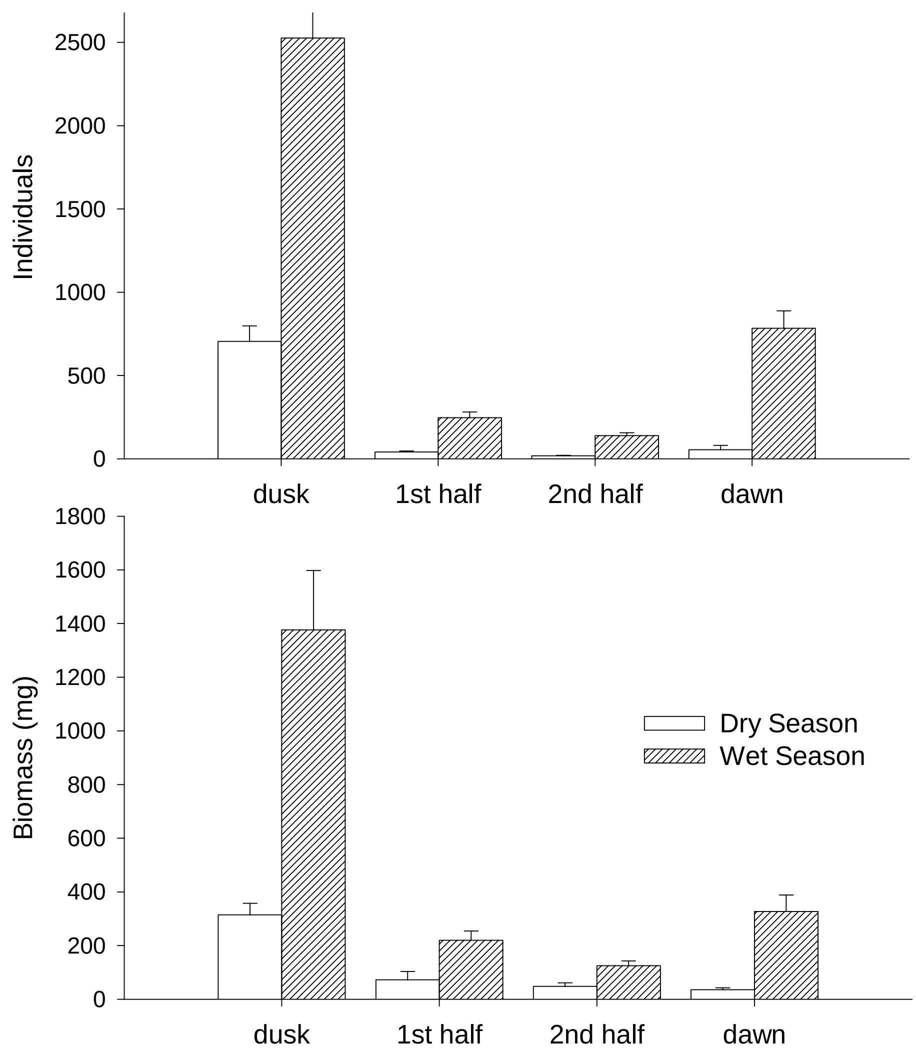
FOR FURTHER INFORMATION SEE:

JETZ, W., STEFFEN, J., & LINSENMAIR, K.E. (2002) CONSTRAINTS OF VISUAL LIFE AT NIGHT - NOCTURNAL, LUNAR AND SEASONAL ACTIVITY OF TROPICAL NIGHTJARS AND THEIR INSECT PREY. MANUSCRIPT.

As part of a study into the seasonality of nocturnal insects, car trapping session took place in weekly intervals already before the core expedition period, from 20 December 1998. The methodology was the same as used in the expedition. However, up to the core expedition period sampling was limited to civil dusk, 10pm, 2am and civil dawn. To date only some of the samples taken during the expedition period have been identified and counted.

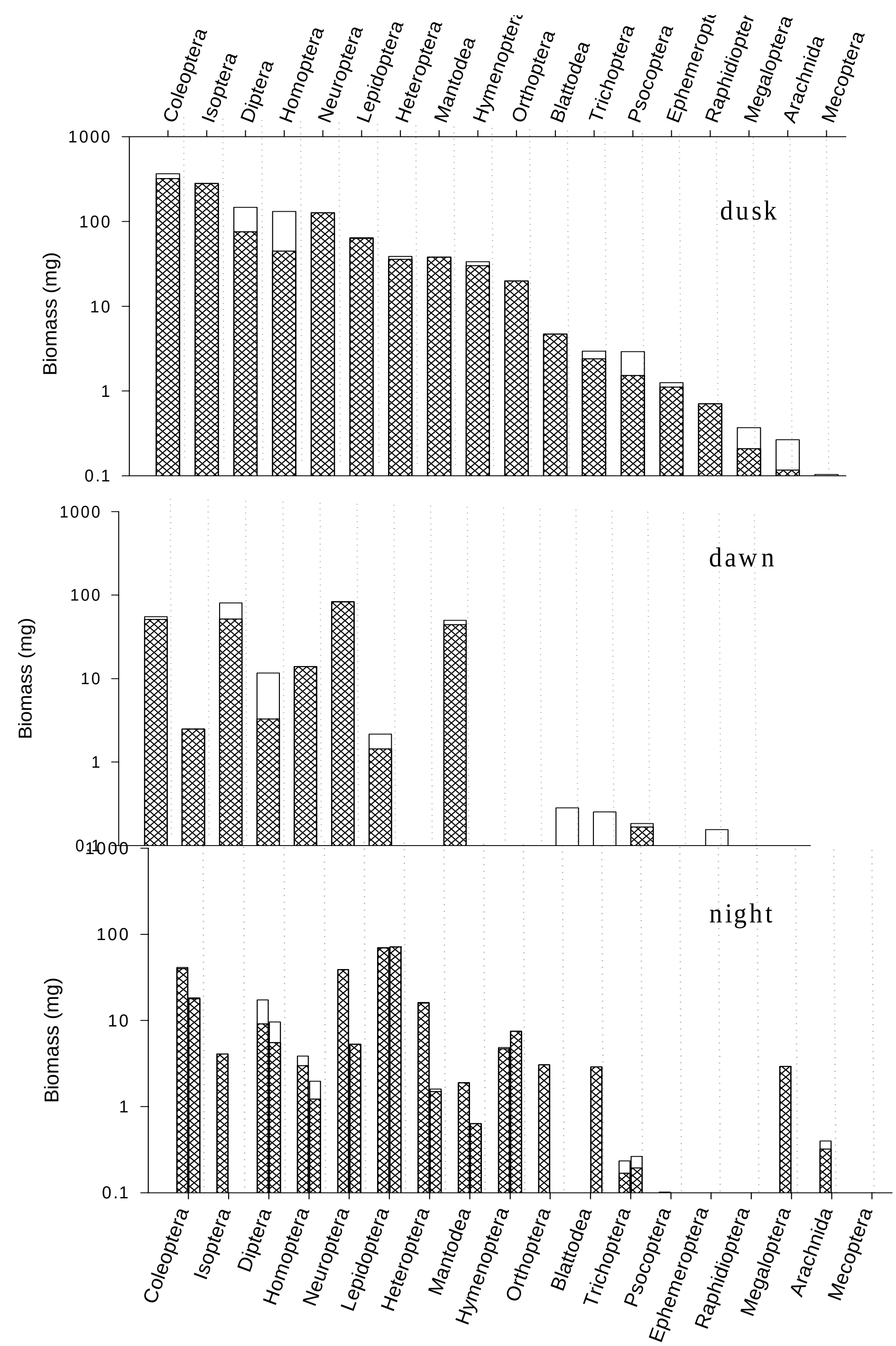
We collected 82,663 aerial arthropods in 127 trapping sessions. All insects (the samples also included several ballooning arachnids) were subsequently sorted down to the level of order, counted and their length recorded in 1mm categories. As the size-distribution of all insects of any given sample was highly right-skewed (W. Jetz, unpublished results), we used the geometric instead of the arithmetic mean between the two envelope sizes of a category to estimate the size of an individual insect. We used the formula given by Rogers et al. (1976) to calculate an estimate of biomass for each individual arthropod.

SUMMARY PICTURE OF NUMBER AND BIOMASS OF INSECTS CAUGHT IN 84 WET SEASON AND 43 DRY SEASON CAR TRAP DRIVES (5KM) BETWEEN AND 20 DEC 98 AND 1 SEP 99.



Taxonomic patterns in biomass

Levels of aerial insect biomass pattern differ highly between orders and times. Certain orders such as termites (Isoptera), mantids (Mantodea) and grasshoppers and crickets (Orthopterans) make up a high proportion of the biomass only at dusk.



BIOMASS OF INSECT ORDERS AS SAMPLED WITH THE CAR TRAP AT DIFFERENT TIMES OF THE NIGHT. WET SEASON, 25/3/99 TO 1/9/99. HATCHED PARTS OF BARS INDICATE BIOMASS OF INSECTS >3MM ONLY. NIGHT: LEFT BAR FIRST HALF, RIGHT BAR SECOND HALF OF THE NIGHT.

Environmental determinants of insect flight activity

Statistical analysis was performed on biomass levels of insect longer than 3mm (potential prey for nocturnal aerial insectivores such as nightjars. For all time levels insect numbers tend to decrease with the amount of time passed since onset of the last wet season. At dusk the seasonal decrease in biomass is especially strong, and season is the sole significant predictor. At night, prey increases with moon phase and thus brightness. This relationship is strongly positive only in the wet season. Prey biomass at dawn, besides the seasonal decrease, is affected by a variety of variables. High levels of light depress aerial insect biomass at dawn. As sampling was done at fixed solar azimuth, this hints a role of cloud cover rather than height of the sun. In contrast to the enhancing relationship at night, at dawn insect biomass is smaller at high moon phase. Full moon nights have light conditions earlier on. Temperature has an increasing effect on prey biomass, and more so around full moon.

We found that aerial insect biomass is much higher at dusk than at any other time of the night. This is in concordance with findings from many groups and habitats (Caveney et al., 1995; Dreisig, 1980; Lewis & Taylor, 1965; Rautenbach et al., 1988). During the wet, but not the dry season, there is another, smaller peak of activity at dawn as it is known from temperate regions (Racey & Swift, 1985; Rydell et al., 1996). The fact that morning temperatures in the dry are much lower than in the wet season may explain this difference (Gupta et al., 1990).

Most investigations into nocturnal patterns of aerial insect flight activity, especially in the tropics, are based on light trap catches. Inferences from these studies for overall biomass are limited by their bias for photophil insects and the change of efficiency with ambient light levels (Siddorn & Brown, 1971; Taylor, 1986). Accordingly, evidence about the determinants of nocturnal insect flight behaviour such as moonlight has been equivocal (Bidlingmayer, 1964; McGeachie, 1989; Williams & Singh, 1951). The response of insects to abiotic factors are likely to be guild- or taxon specific (Fullard & Napoleone, 2001; Lewis & Taylor, 1965; Yela Jose & Holyoak, 1997). Here we find that moon phase (which correlates both with light availability and duration of bright night conditions) in the wet, but not the dry season appears to promote flight activity at least of larger insects.

Environmental determinants of biomass of insects above 3mm at dusk (n = 30 sampling sessions), night (n= 67 sampling sessions) and dawn (n = 30 sampling sessions). Presented are the most parsimonious models selected from full models including all main effects and one-way interactions. Dayswet refers to number of days since onset of the last wet season; MPhase refers to a continuous measure of moon phase between 0 (new moon) and 1 (full moon); Temp refers to temperature. LogLight to log-transformed light levels.

Period	term	d.f.	proportion deviance (%)	F	p	coefficient
dusk	Dayswet	1,28	64.29	47.51	< 0.001	-0.01
	model	1,28	64.29	47.51	< 0.001	
night	MPhase	1,63	7.58	8.32	< 0.01	1.33
	Dayswet	1,63	0.01	0.01	0.93	-2.E-04
	MPhase:Dayswet	1,63	7.66	8.40	0.01	-0.01
	model	3,63	44.35	12.34	< 0.001	
dawn	Dayswet	1,24	6.88	5.89	0.02	-4.E-03
	LogLight	1,24	13.07	11.18	< 0.01	-1.09
	MPhase	1,24	5.52	4.72	0.04	-12.78
	Temp	1,24	0.70	0.60	0.45	-0.08
	Temp:MPhase	1,24	6.94	5.94	0.02	0.64
	model	5,24	72.16	12.34	< 0.001	

5. Administrative and Logistical Report

5.1. Logistics and Permits

The entrance to the national park is a five hour drive on mostly paved road from Bouake, the biggest city in Northern Ivory Coast. The camp is another one hour drive on a bush road. The camp itself has four members of staff, including kitchen staff. Drinking water is readily available, as is water for washing from the river. Solar panels provide energy for 12V bulbs and computers. Accommodation consists of wooden huts. Magnifying lenses, a wide selection of tools, generators as well as bicycles, motor-bikes and a 4-wheel car were at our disposal in the camp. The camp was established by Prof. Linsenmair, Head of Department for Tropical Ecology, University of Wuerzburg some 10 years ago. In collaboration with this department W. Jetz has been running a study on nightjar ecology for one year and the department has happily agreed to host guest researchers for the project proposed here. The field camp and its research is well established with the authorities, and all the permits for guest researchers are covered under this agreement. Thus, with this invitation from the Department in Wuerzburg no further permits were required.

FERRY ACROSS THE RIVER COMOÉ, THE ONLY ACCESS ROUTE TO THE NATIONAL PARK FROM THE WEST.

5.2. Health

(JT)
Being prepared for all eventualities is crucial for a safe and successful expedition. Invariably, the majority of medical supplies that are taken are not used. Indeed a successful expedition is often regarded as one where health is maintained without medication and injury is prevented. The Occupational Health Dep. in Oxford provided essential advice and supplied the necessary medical supplies. These included anti-malarial drugs and vaccinations specific to the region of exploration. In addition, a First Aid course covering the basics of 'accidents and emergencies' and tropical complaints was attended by all expedition members. Prescription and non-prescription drugs were also obtained through the Occupational Health Dep. and the John Radcliffe Infirmary. The most common ailments in tropical countries are often dehydration and stomach problems. Although relatively harmless in the West, this complaint can potentially be a very serious condition in tropical climates. Food poisoning is a threat, but more commonly, violent reactions are a result of a change in diet and acclimation to a different environment. Basic hygiene, both personal and with food preparation should be maintained with religious dedication, to avoid external and internal infection. The majority of health problems overseas are due to bad luck or exposure to high risk situations. The latter can be avoided and the former minimised by using common sense. Insect bites, the harbinger of malaria and other parasitoid diseases, if kept to a minimum, can help prevent infection. Indeed, the tactic of covering up (especially at dawn and dusk) is probably a more effective strategy than any orally taken medication. Previous experience has shown that staying well rested and physically fit ensures that immuno-defence mechanisms are able to satisfactorily contend with most ailments, and very often it is difficult, if not dangerous to prescribe medical treatments with no medical training. The use of machinery on expeditions is sometimes necessary, but the high risk nature of their operation should be taken into account, especially when the nearest hospital may be many hours drive away. Keeping an eye out for colleagues, ensuring that morale, fitness and rest are maintained is an important aspect of a group expedition and should not be underestimated.

5.3. Itinerary

29th June: London - Abidjan

30th June to 2nd July: Travel to Bouaké with public bus. Shopping for food and equipment.

3rd July: Travel to Comoé National Park with camp vehicle and bus.

1st week to 3rd week of July: Acclimatisation, getting accustomed to field site and methods, preliminary trapping. Testing and finalising experimental methods and schedule of each single project. Start with sampling

3rd week July to 1st week of September: Sampling and surveying according to prepared schedule.

ca. 15th September: Leave camp with car for Bouaké, travel to Abidjan by public bus

ca. 18th September: Fly Abidjan – London

1 week in September/October filing and preparation of material for final storage and/or further identification at the University Museum, Oxford

6. Personnel

Participants:

Walter Jetz
3rd year graduate at Magdalen College, Oxford. Age 26. DPhil. in Zoology. Has extensive experience in field research in various parts of Africa. Several publications to his name. Conversational French.

Jonathan Turney
3rd year undergraduate, Biological Sciences at St. Peter's College, Oxford. Age 22. He has spent 12 months teaching in Zimbabwe and participated in Operation Wallacea Expedition 1998. Conversational French.

Sylvie Coupaud
Graduated with 2:1 degree class in Biological Sciences, from Pembroke College, Oxford. (Summer 1999). Age 22. She has one month's travel experience in South and East Africa and worked for a short period in Hwange National Park, Zimbabwe. Fluent French.

Emily Shepard
2nd year undergraduate, Biological Sciences at Lady Margaret Hall, Oxford. Age 21. She worked with Project Seahorse in her gap year on genetic and organisational aspects as well as in the field (a remote island in the Philippines). Basic French.

Rebecca Smith
Graduated with 2:1 degree class in Biological Sciences, from New College, Oxford. (Summer 1999). Age 22. She has spent one month in Phuket, Thailand, working in the Gibbon Rehabilitation Centre. Conversational French. Unfortunately, Rebecca had to leave the expedition early for health reasons.

Yeo Kolo
4th year undergraduate, Biology Sciences at the Université d'Abobo-Adjamé. Age 26. Yeo is from the Sinufu tribe and grew up in a village near Korhogo. He is affiliated with the Centre de recherche en écologie in Abidjan and joined the project for eight weeks.

Advisors:

Patron
Professor Sir Richard Southwood, Department of Zoology, Oxford

Field Agents:
Prof. K.E. Linsenmair, Department Tropical Ecology, Wuerzburg, Germany
Dr. Frauke Fischer, Department Tropical Ecology, Wuerzburg, Germany

Scientific Advisor:
Dr. George McGavin, University Museum, Oxford

Home Agents:
Dr. Andrew Gosler and *Dr. Michael Packer*, Department of Zoology, Oxford

Medical Advisor
Professor David Warrell, Nuffield Department of Medicine, Oxford

7. Budget

7.1. Funds raised:

Oxford University	£2,685
Royal Geographical Society	£ 650
Percy Sladen Memorial Fund (Linnean Society)	£ 400
Albert Ricket Charitable Trust	£ 750
The Benevolent Society of Blues	£ 250
Lady Margaret Hall	£ 250
Lady Margaret Hall travel grant	£ 100
New College	£ 500
St Peters Colllege	£ 250
Magdalen College JCR	£ 50
Magdalen College MCR	£ 250
Personal contribution (5 * £500)	£2,500
Total	**£8,635**

7.2. Expenditure:

Pre-Expedition:

Administration	£ 200
Insurance	£ 121
Medical Preparation	£ 210
Visas (@ £30 * 5)	£ 150
Films & Processing	£ 90
Light trap + other trap designs for methodological comparison	£ 405
Generator	£ 570
Other equipment (for rotary trap, storage bottles, …)	£ 370
Flights @ £45 * 5	£2250

During Expedition:

Accommodation and food during transit days (@£20 *6days * 5)	£ 490
Ground travel	£ 240
Car and lorry batteries (for rotary trap)	£ 370
Material for traps	£ 600
Alcohol for preservation	£ 80
Camp fees (accommodation + basic food)	£ 2120
Various equipment, spare parts	£ 220

Post Expedition

Report Production	£ 20
Contribution to OUEC for expeditions bulletin	£ 150

Total	**£ 8,656**

8. Acknowledgements

In Oxford and the UK

We are greatly indebted to George McGavin from the University Natural History Museum for his advice on trapping techniques and insect identification and his help with fundraising. At the museum, Darren Mann and John Ismay were vital for the subsequent identification efforts – we are very grateful for their help. Barbara Müller and Johanna Junback, both MSc students on the Oxford Integrative Bioscience, thankfully put the collected samples to further use as part of their project work.

Of course we are indebted to the OU Exploration Club and Oxford University for supporting the expedition. Furthermore, we would like to extend our warmest thanks to all other sponsors of the expedition, namely:

- Royal Geographical Society
- The Linnean Society
- Albert Ricket Charitable Trust
- The Benevolent Society of Blues
- Magdalen College MCR and JCR
- Lady Margaret Hall
- New College
- St Peter's College

Without their support the expedition would not have been possible.

In Germany

Thanks are due to the researchers and technicians at the Department of Tropical Ecology of the University of Würzburg, especially its Head, Prof. K.E. Linsenmair, and Norbert Schneider who headed up the rotary trap construction.

In Cote d'Ivoire

We thank Siemens, West Africa, and in particular Nadia Klemet and Kouamé Ebrottié, for their long-term loan of solar panels without which the frequent operation of the rotary trap would have been impossible. In the field, first steps with the rotary trap were undertaken in 1998 with the help of Ingo Werner and Silvia Kunz. Jan Steffen helped setting up and running the car trapping and tried his luck with the rotary trap through early 1999. Subsequently, rotary trap efforts were scaled up by determined Alex Stewart-Jones who also covered a period of car trapping.

Further support at the research station was received from Frank-Thorsten Krell, Dieter Mahsberg, Norbert Reintjes, Frauke Fischer and Kathrin Lampert. Special thanks also to Koffi Kouadio, Ensa and Lakador for help with countless odd jobs from helping building a wooden ladder to scaring off those crocodiles.

For help in advertising our project and in selecting a local expedition member we thank Souleymane Konate from the CRE (Centre de recherche en écologie), Abidjan.

And …

Walter Jetz would like to thank Paul Harvey (Dept Zoology, Oxford) for supporting yet another diversion in Walter's PhD, Prof. K.E. Linsenmair (University of Würzburg) for his all-round supportiveness, Dr. Herbert Biebach (Max-Planck-Research-Centre for Ornithology) for various equipment and plenty of inspiration and Prof. Sir Richard Southwood for helpful advice. Walter's research visits leading up to the expedition were supported by the German Ornithological-Society and the British Ecological Society.

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