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Diversity, dynamics, direction, and magnitude of high-altitude migrating insects in the Sahel

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Long-distance migration of insects impacts food security, public health, and conservation–issues that are especially significant in Africa. Windborne migration is a key strategy enabling exploitation of ephemeral havens such as the Sahel, however, its knowledge remains sparse. In this first cross-season investigation (3 years) of the aerial fauna over Africa, we sampled insects flying 40–290 m above ground in Mali, using nets mounted on tethered helium-filled balloons. Nearly half a million insects were caught, representing at least 100 families from thirteen orders. Control nets confirmed that the insects were captured at altitude. Thirteen ecologically and phylogenetically diverse species were studied in detail. Migration of all species peaked during the wet season every year across localities, suggesting regular migrations. Species differed in flight altitude, seasonality, and associated weather conditions. All taxa exhibited frequent flights on southerly winds, accounting for the recolonization of the Sahel from southern source populations. "Return" southward movement occurred in most taxa. Estimates of the seasonal number of migrants per species crossing Mali at latitude 14°N were in the trillions, and the nightly distances traversed reached hundreds of kilometers. The magnitude and diversity of windborne insect migration highlight its importance and impacts on Sahelian and neighboring ecosystems.

Migration is key to individual reproductive success, population abundance and range, community composition, and thus, habitat function across the biosphere[1,2]. We follow the definition of migration as persistent movements unaffected by immediate cues for food, reproduction, or shelter, with a high probability of relocating the animal in a new environment[1–3]. Long-distance insect migration influences food security[2,4–9], public health[10–15], and ecosystem vigor[16,17]. Over the past decades, knowledge of the migration of a handful of large insects (> 40 mg) provided insights into migratory routes and the underlying physiology and ecology of migration with implications ranging from pest control to conservation[18–21]. Radar studies have revealed the magnitude of insect migration, highlighting its role in ecosystem biogeochemistry via the transfer of micronutrients by trillions of insects moving annually in Europe[22,23]. Yet, radar studies seldom provide species-level information[24], which is needed to

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Order	Percent	Families identified	Families
Coleoptera	53.3	Aderidae, Anthicidae, Attelabidae, Bostrichidae, Brentidae, Carabidae, Chrysomelidae, Coccinellidae, Curculionidae, Dytiscidae, Elateridae, Erorhinidae Hydrophilidae, Mordellidae, Nitidulidae, Phalacridae, Scarabaeidae, Staphylinidae	18
Hemiptera (Heteroptera)	8.2	Berytidae, Corixidae, Cydnidae, Geocoridae, Gerridae, Hydrometridae, Lygaeidae, Miridae, Nabidae, Notonectidae, Oxycarenidae, Pentatomidae, Pyrrhocoridae, Reduviidae, Rhopalidae, Rhyparochromidae, Stenocephalidae, Tingidae, Veliidae	19
Hemiptera (Homoptera)	19	Aphididae, Cicadellidae, Delphacidae, Flatidae, Ricaniidae	5
Diptera	11.2	Anthomyiidae, Calliphoridae, Cecidomyiidae[b], Ceratopogonidae[b], Chironomidae[b], Chloropidae, Culicidae[b], Curtonotidae, Diopsidae, Dolichopodidae, Drosophilidae, Ephydridae, Lauxaniidae, Limoniidae[b], Lonchaeidae, Milichiidae, Muscidae, Mycetophilidae[b], Phoridae, Pipinculidae, Platystomatidae, Rhiniidae, Sepsidae, Simuliidae, Tachinidae, Tephritidae, Tipulidae, Ulidiidae	28
Hymenoptera	4	Apidae, Bethylidae, Braconidae, Chalcididae, Chrysididae, Crabronidae, Diapriidae, Dryinidae, Eulophidae, Eupelmidae, Eurytomidae, Figitidae, Formicidae, Ichneumonidae, Megachilidae, Pompilidae, Rhopalosomatidae, Scelionidae, Sphecidae	19
Lepidoptera	3.9	Gelechiidae[b], Nolidae[b]	2
Orthoptera	0.3	Acrididae, Gryllidae, Pyrgomorphidae, Tetrigidae, Tettigonidae, Trigonidiidae	6
Neuroptera	0.2	Chrysopidae, Mantispidae, Myrmeleontidae	3
Total			100

Table 1. Overall diversity of insects collected in aerial samples (40–290 m agl) as reflected by insect order composition (see also Fig. 2). The insect families sent for identification by taxonomists represent a small fraction of the predicted total diversity (see text). Orders represented by 1–2 specimens (Blattodea, Thysanoptera, Megaloptera, Psocoptera, and Phasmatodea) are not shown. [a] In total, 4,824 insects from 77 sticky nets (panels) were used to estimate the order composition. The full collection awaits additional study and the authors would be pleased to hear from readers who might be interested in undertaking further study of particular taxa. [b] Identified through DNA barcoding correlations by Dr. Yvonne-Marie Linton.

discern the adaptive strategies, drivers, processes, and impacts of long-distance migration of the vast majority of the species[22,25]. Ideally, addressing these issues requires tracking insects over hundreds of kilometers, a task that remains beyond reach for most species due to their small size, speed, and flight hundreds of meters above ground level (agl)[26]. Given migration's pervasive and critical role, knowledge of the species identity, sources, routes, destinations, schedules, and impacts would be especially valuable for sub-Saharan Africa, with its growing human population, nutritional demands, public health problems, and conservation challenges. Past migration studies in Africa focused on a handful of crop pests such as grasshoppers[4,7,27,28] and the African armyworm[24,29], yet as recently demonstrated by the diversity of mosquitoes among high-altitude migrants[15], the scope and impacts of African insect migration represent major gaps in our knowledge. We contend that monitoring of insect migrants in Africa will not only fill that gap, but will lead to effective and comprehensive solutions inspired by the locust and armyworm monitoring and control programs[4,28,29], which fit well with the One Health paradigm[30]. Accordingly, a longitudinal, systematic, comparative study on the high-altitude migration of multiple species of insects in the same region would be useful to gauge the species composition, regularity, dynamics, and directionality, which are fundamental to understand these movements' predictability, sources, and impacts. Specifically, we focused on the following questions: Which taxa are the dominant windborne migrants? Do species migrate regularly every year? Within a year, does migration occur rarely, under specific weather conditions, or throughout the season? What are the prominent flight directions, how variable are they within and between species, and does the direction change with the season? Using nets mounted between 40 and 290 m agl on tethered helium balloons, we undertook a three-year survey of flying insects in central Mali. Here, focusing on a dozen collected insect species—representing broad phylogenetic groups and ecological "guilds"—we identify variation in migration patterns, and infer underlying strategies.

Results

In total, 461,100 insects were collected on 1,894 panels between 2013 and 2015. Sorting of 4,824 specimens from 77 panels (between 40 and 290 m agl) revealed a diverse assembly representing thirteen orders (Fig. 2a and Table 1). Members of the Coleoptera dominated these collections at 53%, followed by Hemiptera (27%)—especially Auchenorrhyncha (18.5%), Diptera (11%), and Hymenoptera and Lepidoptera at 4% each, together accounting for > 99% of the insects collected (Table 1). Additional specimens were identified totaling 100 insect families (Tables 1 and S1).

Thirteen species representing diverse phylogenetic and ecological groups were identified and counted from subsamples consisting of a total of 25,188 specimens. These were subsamples (see Methods) of 58,706 insects captured on 222 panels over 125 aerial collections, carried out over 96 sampling nights, in one or more of the Sahelian villages (Fig. 1).

Control panels were examined to determine if insects were inadvertently trapped near the ground as the nets were raised and lowered: a total of 564 insects were captured on 508 control panels compared with 58,706 captured on the 222 experimental (standard) panels. The control panels spent 3–5 min above 30 m and thus could be expected to contain ~ 0.5% of a normal panel that remained at high altitude for 14 h, assuming aerial density of the insects remained constant over that time. To assess if insects were intercepted below 30 m agl, we tested if the mean panel density (Methods) of each taxon on the control panel was (i) significantly lower than corresponding mean on standard panel, and (ii) that it was not significantly higher than the equivalent of a 4-min aerial nightly sampling with a standard panel (Table 2). Except for the bee, *Hypotrigona* sp. (Hymenoptera), both

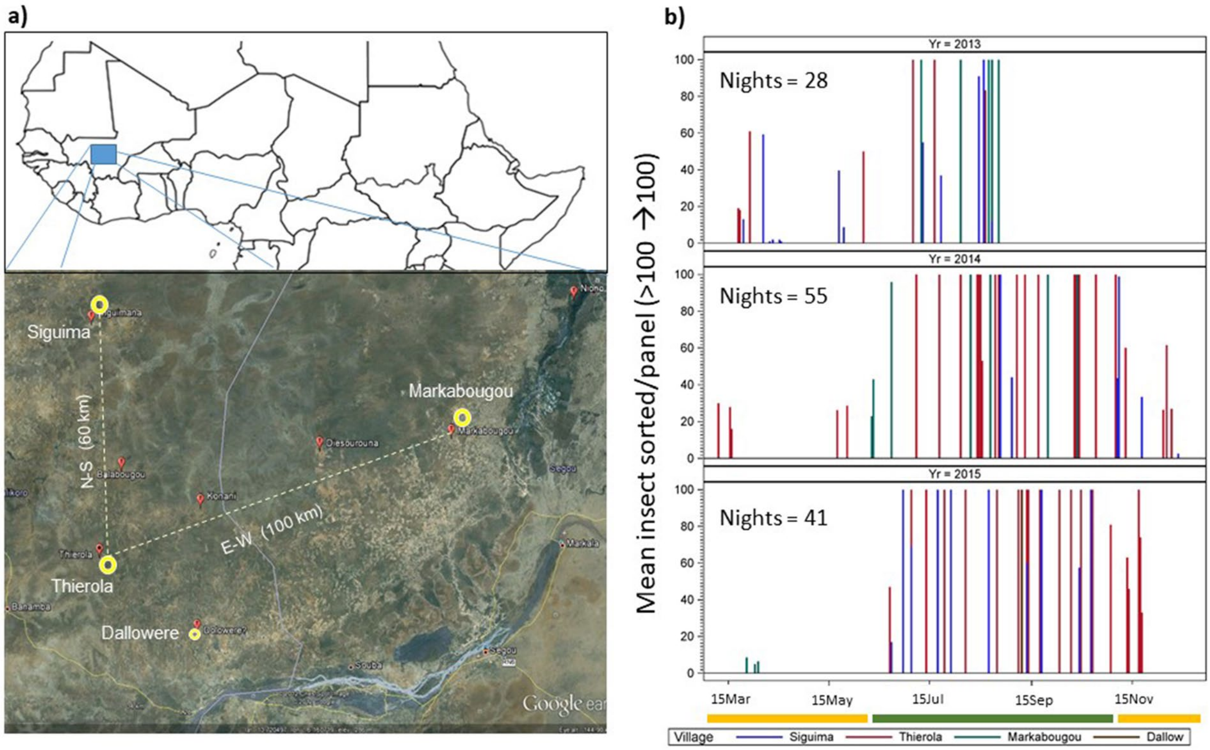

Figure 1. (**a**) Map of study area (Map data: Google, Maxar Technologies) under a schematic map of Africa above the equator. The base map was generated using the ggplot2 package in R[74], under a GPL-2 license. Aerial collection sites are shown in yellow with distance between them (the small symbol of Dallowere indicates that only two sampling nights in Dallowere were included in the present study). (**b**) Sampling effort of high-altitude flying insects by year. Needles represent sampling nights (by village: color) extending up to 100 insects per panel (actual number of insects can exceed 2000). Dry and wet seasons are indicated by yellow and green bands, respectively, under the x axis. Note: no sampling was done during January–February.

expectations were met for all taxa, with a control to standard mean density ratio of 0–0.003 (Table 2). This low ratio suggests that the high-altitude flight of most insects was reduced during the crepuscular periods, during which the panels were launched and retrieved, compared with night period. For *Hypotrigona* sp., however, the ratio of mean control to standard panel was 0.167, suggesting that ~ 17% of its aerial density could have been collected near the ground. For this reason, this taxon was removed from further analysis.

Overall abundance, sampling distribution, and correlation between taxa. Mean panel density of the selected taxa ranged over two orders of magnitude, from 0.05 for the *Dysdercus* sp. (Hemiptera) and *Anopheles coluzzii* (Diptera) to 11 for *Chaetocnema coletta* (Coleoptera, Table 2, Fig. 2b). The distribution of captured insects on (standard) panels was "L shaped," typical of clumped distributions (Fig. S2), with a median panel density of zero for all species except *Ch. coletta*, *Cysteochila endeca* (Hemiptera) and *Zolotarevskyella rhytidera* (Coleoptera, Table 2), and a maximum of 246 specimens per panel, suggesting that flight activity was concentrated on one or a few nights. The frequency of nights with at least one specimen per taxon per night (nightly occurrence frequency) varied between 4 and 71% (Table 2), indicating that all taxa engaged in high-altitude flight activity over multiple nights. Moreover, panel occurrence frequency was positively correlated with taxon panel density ($r_P = 0.92$, $P < 0.001$, $N = 12$, Fig. 2b), indicating that taxa that appeared on fewer nights were the least abundant. Nonetheless, the high values of the variance to mean ratios (2.7–83.6, Table 2 and Fig. 2c) of all taxa, except *A. coluzzii*, suggest that the distribution of insects was temporally clustered.

All taxa exhibited marked seasonality in high-altitude flight activity (Fig. 3a), peaking between July and October, following considerably lower activity in May–June. Overall, flight declined substantially in November–December, and virtually none was recorded in March–April. Visual examination of the seasonality of individual taxa (Fig. 3a) suggests variability among species in flight activity. For example, *Microchelonus* sp. (Hymenoptera) appeared as early as May and peaked in June, whereas, the leafhopper, *Nephotettix modulatus* (Hemiptera) first appeared in July and peaked in October (Fig. 3a). A unimodal activity best describes *A. coluzzii*, *Dysdercus* sp., *Microchelonus* sp., and *N. modulatus*, while bimodal activity describes the other taxa, e.g., *Paederus fuscipes* (Coleoptera), and *Berosus* sp. (Coleoptera, Fig. 3a). Bimodal distribution was also suggested by the total-insect density/panel (Fig. S3). Likewise, correlations between taxa in nightly flight were low (Spearman, r_S mean = 0.17, $-0.15 < r_s < 0.62$, $n = 96$, Fig. 3b). The highest r -values involved high density taxa, e.g., *Paederus sabaeus* and *Metacanthus nitidus* ($r_s = 0.62$, $n = 96$, $P < 0.001$). The mean pairwise correlation dropped

	Standard panels (222 panels in 125 sampling nights)									Control panels (508 panels)							
Taxon	Mean panel density	Lower 95% CI[a]	Median panel density	Panel Freq[b]	Night Freq[c]	Total	Max panel density	Var / mean	Mean control/ standard[d]	Mean panel density	Upper 95% CI [e]	Four min Standard[f]	Med panel density	Panel Freq[b]	Total	Max panel density	Var/ mean
Dysdercus sp.	0.03	−0.007	0	0.02	0.04	7	4	2.7	0.0000	0	nd	0.0001	0	0.0000	0	0	nd
Cy. endeca	5.00	3.9325	1	0.54	0.67	1110	44	13.0	0.0016	0.0079	0.0156	0.0230	0	0.0079	4	1	0.993
M. nitidus	1.99	0.7636	0	0.27	0.43	442	117	43.2	0.0010	0.002	0.0058	0.0092	0	0.0020	1	1	1
N. modulatus	0.40	0.1898	0	0.12	0.21	88	17	6.2	0.0000	0	nd	0.0018	0	0.0000	0	0	nd
A. coluzzii	0.09	0.0519	0	0.09	0.17	21	2	1.1	0.0000	0	nd	0.0004	0	0.0000	0	0	nd
P. sabaeus	2.66	1.2729	0	0.29	0.42	591	134	41.4	0.0000	0	nd	0.0122	0	0.0000	0	0	nd
P. fuscipes	0.38	0.0414	0	0.09	0.21	84	32	17.2	0.0000	0	nd	0.0017	0	0.0000	0	0	nd
Z. rhytidera	8.61	5.0629	1	0.53	0.61	1912	246	83.6	0.0000	0	nd	0.0396	0	0.0000	0	0	nd
Ch. coletta	11.31	8.1055	2	0.58	0.71	2511	174	51.9	0.0009	0.0099	0.0185	0.0520	0	0.0099	5	1	0.991
Hydrovatus sp.	0.63	0.3414	0	0.18	0.34	139	21	7.4	0.0000	0	nd	0.0029	0	0.0000	0	0	nd
Berosus sp.	0.67	0.3805	0	0.19	0.32	149	20	7.2	0.0030	0.002	0.0058	0.0031	0	0.0020	1	1	1
Microch-elonus sp.	0.26	0.1132	0	0.10	0.19	57	11	4.6	0.0000	0	nd	0.0012	0	0.0000	0	0	nd
Hypotrigona sp.	0.19	0.0519	0	0.05	0.08	42	8	5.7	0.1670	0.0316	0.0754	0.0009	0	0.0316	16	11	7.982
Overall	2.48			0.24	0.34	7153		21.9	0.0005	0.0018				0.0018	27		0.996

Table 2. Overall abundance and occurrence of selected taxa in aerial samples collected on standard panels (220 panels between 40 and 290 m agl, in 125 sampling nights) and control panels (508 nets between 40 and 120 m agl). [a] The lower 95% confidence interval (CI) of the mean panel density of standard panel used to compare with the upper 95% CI of the control panel for each taxon (see text). [b] Panel Frequency – Frequency of panels with at least one specimen per taxon. [c] Night Frequency – Frequency of nights with at least one specimen per taxon per night regardless of village (ie., includes nights when launches occurred in more than one village, n = 96). [d] Overall mean ratio of control/standard panel and mean control panel density were computed excluding *Hypotrigona* sp. (see text). [e] Expected density assuming insects were intercepted while the control panels reached over 20 m and remain there for ~ four minutes (see text).

to 0.09 ($-0.23 < r_s < 0.56$, n = 77, Fig. 3b) after confining the correlation to the migration season (excluding the dry season, when migration was negligible).

Variation between collection sites, years and altitude. The occurrence frequency of each taxon was compared between localities (up to 100 km apart) and years to assess if they were location- or year-specific (Fig. 4). All taxa were found in all locations. The similarity between the localities in the appearance of each taxon is striking since they were partly sampled in different months (Fig. 1). Similarly, all taxa were present in every sampling year except for *Dysdercus* sp. and *N. modulatus*, which were not sampled in 2013. The rarity of *Dysdercus* sp. may account for its absence from the sparse data in 2013, which consisted of 28 sampling nights vs. 41 and 56 in the other years. Likewise, *N. modulatus* appeared late in the season (peaks in October) during 2014 and 2015, thus, it was unlikely to be sampled in 2013, in which collection ended by mid-August.

The typical flight altitude, measured as an average panel height weighted by the taxon's panel density values, varied among taxa from 130 m (*Microchelonus* sp.) to 175 m (*N. modulatus*, Fig. 4c). Despite limited use of the largest balloon (3.3 m in diameter), which allowed sampling up to 290 m agl in Thierola between August–September 2015, all taxa were collected in the top panels (240–290 m agl).

Aerial density and the effects of weather on high-altitude migration. Estimated aerial density of each taxon, (per 10^6 m^3 of air, Methods), was positively correlated with panel density (r = 0.93, P < 0.001, Fig. S3: Inset), suggesting that the results of analyses based on panel- and aerial- density would be similar. This correlation stemmed in part from the modest variability in average nightly wind speed at flight altitude (mean = 5.1 m/s, and the 10^{th} and 90^{th} percentiles are 2.4 and 8.0 m/s, respectively, Fig. S4).

Similar to the results based on panel density (Fig. 4), variation due to year and locality (village) of sampling were not significant in all taxa (P > 0.05, Table 3), whilst seasonality was significant in seven taxa (P < 0.05, Table 3 and Fig. 3a), and a modest effect of altitude was detected in four taxa (P < 0.05, Table 3). In subsequent models, the factors locality and year were therefore removed.

To assess if migration activity occurred during particular weather conditions near the ground or at flight-height, we compared the taxon's mean temperature weighted by its aerial density with that of other taxa and similarly considered the relative humidity (RH), and wind speed (Fig. S5). Variation across taxa was moderate and sizable overlap was apparent among their 95% CI (Fig. S5). Flight activity for most taxa occurred across broad temperature ranges and their 95% CI intersected the wet season mean temperatures at the ground (8 taxa) and at flight altitude (9 taxa, Fig. S5a). Overlapping CI of most taxa were also common with RH and wind speed, although most insect flight took place at lower RH and lower wind speed than their wet season averages

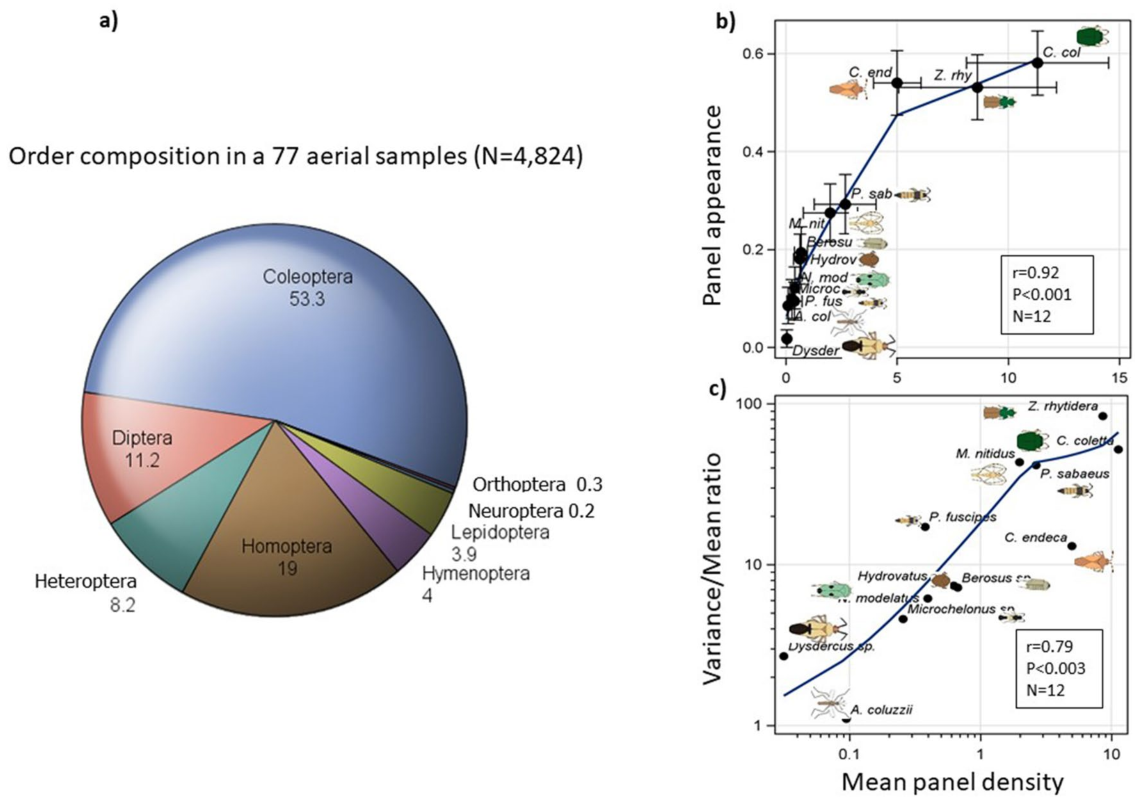

Figure 2. (**a**) Overall diversity (by insect orders) of aerial collection estimated based on samples from 70 sticky nets. Orders represented by less than 3 specimens (Blattodea, Thysanoptera, Megaloptera, Psocoptera, and Phasmatodea) are not shown. (**b**) Relationship between overall species density/panel (+95% CI) and the fraction of nets on which capture occurred on (+95% CI) as a measure of the regularity of high altitude flight activity. Insets show the Pearson correlation coefficient (r), its P value (P) and sample size (N). Schematic insect silhouettes are not to scale. (**c**) The relationship between the variance to mean ratio and its mean panel density.

(Fig. S5b and S5c), possibly because rainstorm conditions inhibit migration[24] or because aerial sampling did not include such nights. Statistical models that evaluated the effects of these weather parameters on high-altitude activity revealed that flights of certain taxa were more common under lower wind speed (seven taxa) and higher RH (four taxa, Table 3).

Seasonal wind and flight directions. As expected[31], wind direction in the Sahel showed marked seasonality, with northerly winds (blowing towards the south) dominating from December to April and reversing course from May to October (Fig. 5a). However, in November, winds are variable and blow towards the south and the north with similar frequencies (Fig. 5a).

All taxa exhibited frequent northward migrations on southerly winds, which ranged widely from WSW to the ESE during the wet season (Fig. 5b). During the wet season (July–September), Sahelian rainfall is associated with large mesoscale convective systems with squall lines which have changeable wind directions. So, insects could have been carried by winds to nearly all directions (Fig. 5) and dispersed widely across the Sahel, albeit with different intensities. The concentration of the circles, denoting the source of mean winds, and their size, which correspond to aerial density (Fig. 5b), signifies the relative position of the source populations. For example, *Z. rhytidera* exhibited a strong influx from the southwest, and *Ch. coletta* from western and southern sources.

To assess if a movement back into the savannas south of the Sahel took place at the end of the rainy season, we examined whether insects exhibited movement with southbound winds during September to December (Fig. 5b). Although they were less common, at least one or a few nights' migration on southward wind were recorded in all except the three least abundant taxa (*Dysdercus* sp., *A. coluzzii*, and *Microchelonus* sp., Fig. 2c). Such southward movements were especially frequent in *Z. rhytidera*, *Cy. endeca*, *Ch. coletta*, and *Berosus* sp. (Fig. 5b). Tests of wind "selectivity", evaluating if aerial density was higher during nights with favorable wind direction (southward during the end of the wet season) were performed using contingency tables contrasting the proportion of nights with northbound and southbound flights during October through December did not support selective southward flight across taxa (P > 0.05 at the individual test level, not shown). Similarly, no significant interaction of wind direction by period was detected in the aerial density analysis (Table 3).

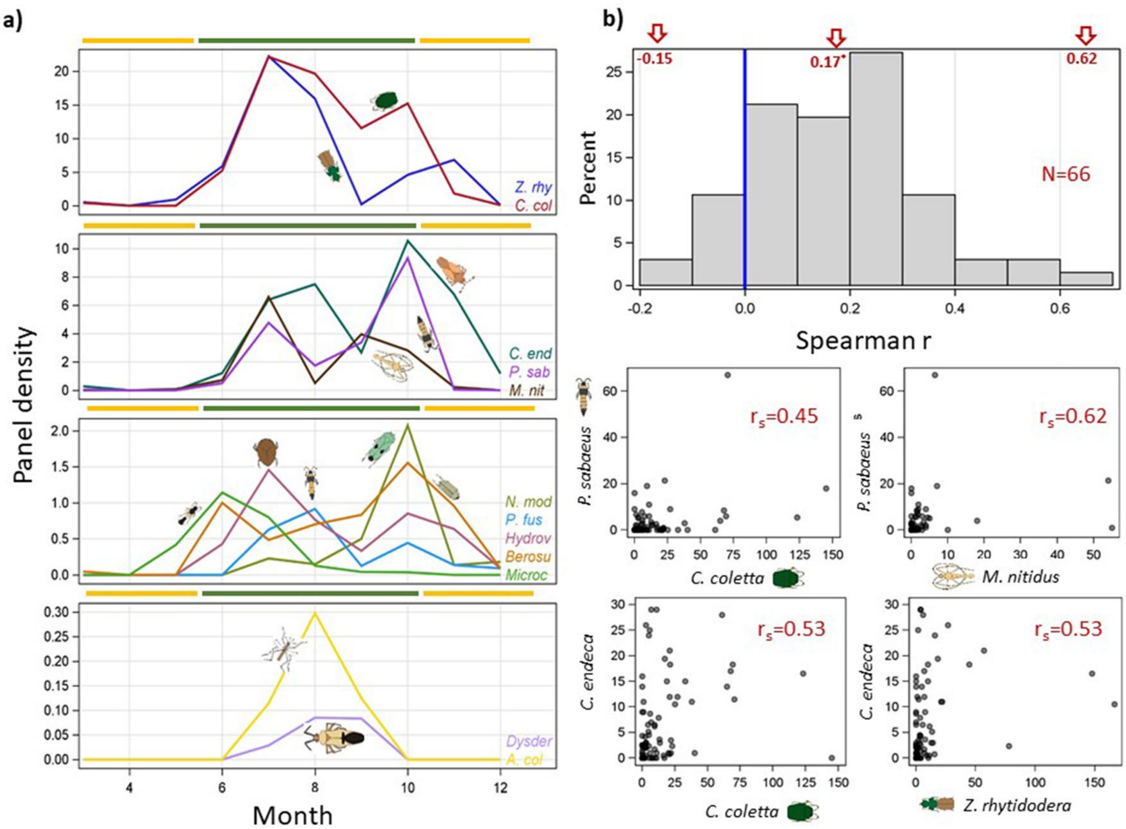

Figure 3. Temporal variation in flight activity across taxa. (**a**) Seasonal variation of migrant insects measured by panel density based on three-year data. Dry and rainy season are shown by yellow and green colors (ruler). (**b**) The distribution of the Spearman correlation coefficient (r_s) between 66 pairs of migrant insects and relationship in nightly mean densities of the taxa pairs with highest Spearman correlation coefficients (b, N = 96 nights). Schematic insect silhouettes are not to scale (species names are truncated to conserve space).

Discussion

This study presents the first cross-season survey of high-altitude migrant insects in Africa. Based on 125 high-altitude sampling nights, yielding 222 samples, we assessed the diversity of migrants and focusing on a dozen taxa, evaluated their compositional regularity, aerial abundance, movement direction, and relationships with key meteorological conditions. This information is fundamental to understanding the scope and impacts of African insect migration and can inform on the value of monitoring aerial migration to address African food security, public health, and conservation issues.

The composition of our collection (Coleoptera—53%, Hemiptera—27%; especially *Auchenorrhyncha*, and Diptera—11%, Table 1) was distinct from aerial collections in Europe, which was dominated by Hemiptera (especially aphids) and Hymenoptera[32], and in North America[5], which was dominated by Diptera and Coleoptera, possibly reflecting taxa more tolerant of xeric environments. The large number of taxa representing a hundred families from thirteen orders already identified from a small fraction of the aerial collection (< 10%, Tables 1, and S1) suggests that migration at altitude is a common and widespread life history strategy in the Sahel, as expected from the impermanence of many habitats[33,34]. Although our taxa selection depended on ease of identification and repeatable appearance in the first subsamples evaluated, we later realized that four represent notable agricultural pests: *Dysdercus* sp., *N. modulatus, Ch. coletta*, and *Cy. endeca;* three affect public health: *P. sabaeus* and *P. fuscipes*, which cause outbreaks of severe dermatitis[35] and the African malaria mosquito, *A. coluzzii*, and six are predators that likely control pests and mosquitoes (e.g., *Microchelonus* sp. and *Hydrovatus* sp. (Dytiscidae), Table S2). Moreover, our results explain the outbreaks of dermatitis due to *Paederus* beetles in Africa[36]. The services provided by an arbitrary assortment of windborne migrants suggests that further studies of insect migration including aerial surveillance may provide useful insights into the causes of human, animal, and plant disease outbreaks. Among the insect genera identified, several included known or suspected windborne migrants: *Dysdercus* sp.[37], *A. coluzzii*[15,38–40], and *M. nitidus*[41]; for the rest, such knowledge is new, as is their reported presence in Mali. Clearly, this aerial collection awaits additional study. Insects flying > 200 m agl and day-flyers were underrepresented in our collection, as were larger insects (e.g., grasshoppers, moths) that could detach themselves from the thin layer of glue. Also, tiny insects (e.g., aphids and midges) might have been overlooked when insects were manually extracted from the panels.

Migration regularity was demonstrated by the similarity of the taxa composition over multiple years (2013–2015), in locations up to 100 km apart, and seasonal highs during the wet seasons (Figs. 3,4 and Table 3) suggesting that it is integral behavior in these taxa. The hypothesis that migration occurred exclusively on

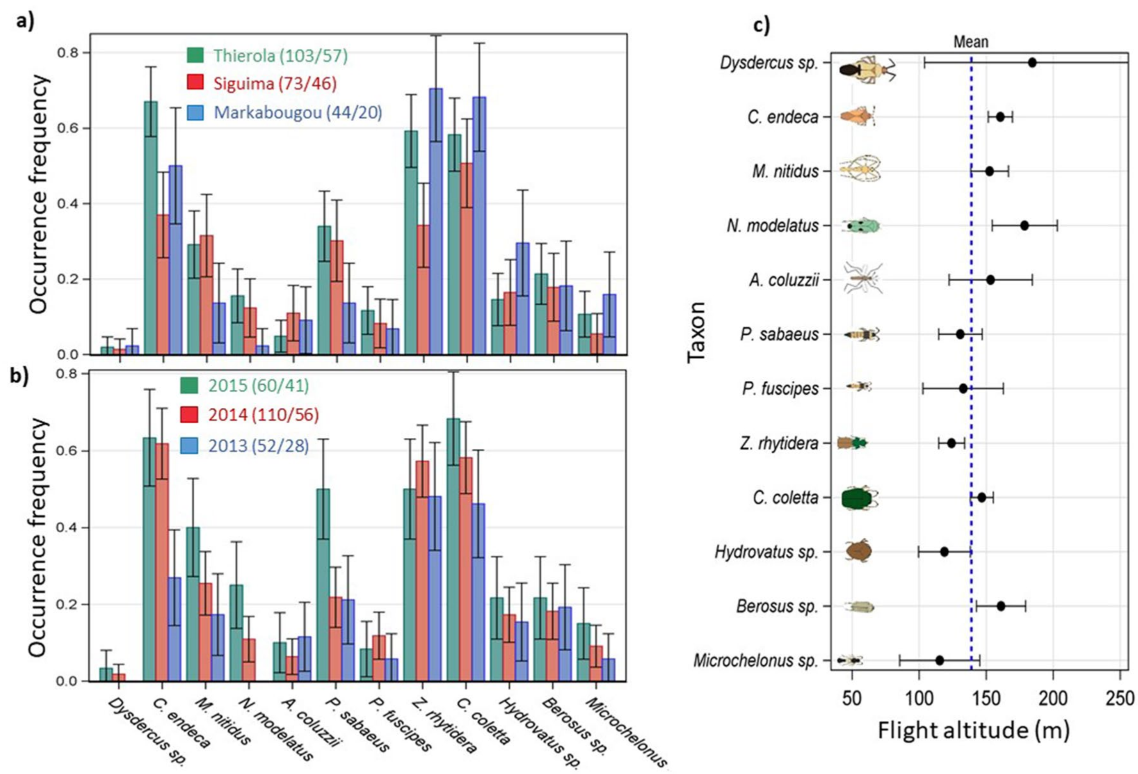

Figure 4. Spatial and annual variation in high altitude migration. Mean frequency of occurrence (+95% CI) of each taxon per panel by (**a**) locality (excluding Dallowere which was sampled in only 2 nights) and (**b**) year. The sampling effort in each year with respect to nets and nights is given in the legend. Between-species variation in flight altitude measured as mean panel altitude (+95% CI) weighted by panel density (**c**). Dotted blue line shows mean panel altitude. Note: the highest panel was typically 190 m agl, but between August and September 2015 we used a larger helium balloon and the highest panel was set at 290 m agl (see Methods). Schematic insect silhouettes are not to scale.

particular nights, was rejected because the nightly occurrence frequencies varied between 4 and 71% and because the positive correlation between the taxon's overall abundance and the nightly occurrence frequency (Fig. 2), indicated that low nightly occurrence reflected the low overall taxon abundance. The low inter-species correlations in nightly densities indicated species-specific migration patterns rather than rare mass-migration events. Altogether, the results suggest that these taxa engaged in migration over many nights, rather than during a few rare events; albeit certain nights, probably near peak activity were of higher density (Figs. 3a, S3). Indeed, accommodating variation due to season, year, village, and altitude, models with a negative binomial error distribution were superior to those with *Poisson* distributions in all taxa (Table 3), suggesting that migration fluctuated during the wet season. The cross-panel occurrence (Table 2) indicated that clumping does not reflect tight flying "swarms".

The magnitude of migration is illustrated as the number of insects expected to cross a 1 km line perpendicular to the wind at altitude over a single night. Because our taxa were captured in altitudes spanning 40 to 290 m agl, a conservative estimate of the depth of the flight layer is 200 m. Using the average nightly wind speed (3.5 m/s, Fig. S5c), we estimated the number of insects crossing this imaginary line throughout the night (14 h sampling duration), yielding an average parcel of air of 176.4 km length, 1 km (width), and 0.2 km (height). The average aerial density was calculated across all sampling nights (including zeros) during the species' "migration period", estimated as the longest annual interval when migration occurred (between the first and the last dates the taxon was captured). The number of insects per taxa crossing the 1 km line each night, between 50 to 250 m agl ranged from 7800 (*Dysdercus* sp.) to 750,000 (*Ch. coletta*, Fig. 6). Extrapolating these values to the annual number of insects crossing the 1000 km line spanning Mali's width at latitude 14.0°N suggests values between one hundred million (*Dysdercus* sp.) and 0.1 quadrillion (10^{14} *Ch. coletta*). The mean total insect density/panel (280, Fig. S3) is > 25 times greater than that of *Ch. coletta*, our most abundant species (Table 2). Considering that these conservative values represent nocturnal migration of single taxa over mere 200 m layer in depth, they underscore the enormous scale of these movements and dwarf the number of insects flying above the UK, which, when converted from the observed 300 km line to 1000 km would total 10^{13} (for all insects)[22].

Flight speeds of small insects (< 3 mg; Table S2) range around 1 m/s[42,43], thus their overall displacement at altitude, where typical wind speed exceeds 4 m/s (Fig. S5, S3, and below) is governed by the wind. The distance covered by windborne migrants depends on wind speed and the duration of their flights. Using a conservative average of wind speed at altitude of 4 m/s (Fig. S5 and S3), an insect flying, for 2–10 h would be transported 30–140 km, respectively. Flight durations can be estimated by flight mills[40,44,45] or, less often, by the distance that they demonstrably flew and knowledge of the wind speed. Flight mill data suggest that leafhoppers (*N. virescens*)

Model (GLIMMIX)	Parameter	Dysdercus sp.	Cy. endeca	M. nitidus	N. Modulatus	A. coluzzii	P. sabeus	P. fuscipes	Z. rhytidera	Ch. coletta	Hydrovatus sp.	Berosus sp.	Microchelonus sp.
None	Var/Mean (mean)	3.5 (0.05)	27.3 (8.1)	108.8 (3.8)	12.3 (0.74)	2.3 (0.17)	59.3 (4.6)	14.5 (0.45)	142.9 (13.5)	116.9 (20.6)	16.8 (1.3)	17.0 (1.4)	9.6 (0.40)
Random vars: *Poisson*	Pearson χ^2/df (BIC)	2.65 (111)	24.26 (4155)	57.55 (3925)	5.98 (737)	2.30 (245)	34.19 (3654)	8.42 (617)	59.75 (7617)	91.78 (11,867)	10.81 (1216)	16.07 (1498)	5.19 (552)
Random vars: Neg. Bin	Pearson χ^2/df (BIC)	0.5 (59.2)	0.7 (1199)	1.4 (663)	0.5 (309)	0.7 (188)	0.8 (751)	1.1 (240)	0.9 (1241)	0.9 (1450)	0.6 (441)	0.8 (464)	0.9 (2344)
	Scale^a	103.2^{ns}	4.1^{ne}	10.4***	13.4***	12.9**	10.2^{ne}	24.7^{ne}	4.8***	5.0^{ne}	14.1***	13.9***	21.3**
Fixed & random vars:	Pearson χ2/df (BIC)	0.3 (57.4)	1.0 (1131)	1.0 (626)	0.9 (286)	0.4 (162)	0.8 (699)	0.6 (227)	1.0 (1198)	1.4 (1386)	0.8 (426)	0.8* (463)	0.7 (229)
Negative Binomial	Scale^a	30.7^{ns}	2.5ne	6.8***	9.2***	4.7**	5.5*	13.9^{ne}	3.8***	3.3***	10.2***	12.1**	11.3**
	Year^b (SD)	0 (ne)	0.0^{ne} (ne)	0.001^{ns} (0.13)	0^{ne} (ne)	0^{ne} (ne)	0.43^{ne} (0)	0^{ne} (0)	0^{ne} (ne)	0.09^{ns} (0.13)	0^{ne} (ne)	0^{ne} (ne)	0^{ne} (ne)
	Village^b (SD)	0 (ne)	0.2ne (0)	0^{ne} (ne)	0^{ne} (ne)	0ne (ne)	0 (ne)	0.17ne (0)	0^{ne} (ne)	0.10^{ns} (0.15)	0^{ne} (ne)	0^{ne} (ne)	0^{ne} (ne)
	Period^c	Sep^{ns}	October^{ns}	Sep***	Oct**	Aug^{ns}	Sep***	Aug***	July***	July***	July**	October^{ns}	July^{ns}
	Panel Height	0.02^{ns} (0.022)	0.007*** (0.002)	0.002^{ns} (0.004)	0.010*** (0)	0.003*** (0)	−0.005*** (0)	−0.016*** (0)	−0.004^{ns} (0.003)	0.007^{ns} (0.004)	−0.01* (0.006)	−0.004^{ns} (0.005)	−0.004*** (0)
Fixed variables:	Pearson χ^2/df, (BIC)	0.28 (60.8)	1.2 (1135)	1.2 (618)	0.5 (290)	0.3 (162)	2.3 (683)	0.4 (223)	0.9 (1202)	2.0 (1357)	0.6 (421)	0.9 (450)	0.8(228)
Negative Binomial	Scale^a	41.2^{ns}	2.7***	6.8***	8.4***	4.1**	4.^{7}***	12.4***	3.6***	2.8***	9.6***	9.8***	11.8***
	Period^d	Jul-Sep^{ns}	Oct-Dec***	Oct-Dec**	Oct-Dec^{ns}	Jul-Sep^{ns}	Oct-Dec^{ns}	Oct-Dec^{ns}	Jul-Sep**	Jul-Sep*	Oct-Dec^{ns}	Oct-Dec^{ns}	Mar-Jun^{ns}
	Wind dir. vector (N-S)^e	1.99^{ns}	−0.59^{ns}	0.6^{ns}	−0.19^{ns}	0.12^{ns}	0.09^{ns}	−1.07 ns	−0.82^{ns}	−0.75^{ns}	0.13^{ns}	0.22^{ns}	0.12^{ns}
	Per x Wind dir. (N-S)^f	1.89^{ns}	−0.30^{ns}	0.96^{ns}	−0.39^{ns}	0.02^{ns}	−0.56^{ns}	−3.0^{ns}	0.01^{ns}	0.18^{ns}	0.40^{ns}	−0.10^{ns}	−0.80^{ns}
	Wind speed^g	−0.23^{ns}	−0.12^{ns}	−0.37**	−0.41*	−0.17^{ns}	−0.46***	0.43*	−0.09^{ns}	−0.26***	−0.44***	−0.41***	−0.80^{ns}
	Temperature (°C)^g	1.04^{ns}	−0.06^{ns}	0.81**	−0.02^{ns}	−0.31^{ns}	0.72**	0.30^{ns}	−0.10^{ns}	0.09^{ns}	−0.06^{ns}	0.08^{ns}	0.94*
	RH (%)^g	0.23 ns	0.01 ns	0.11***	0.03^{ns}	−0.001 ns	0.17***	0.05^{ns}	−0.01^{ns}	0.04 **	0.03^{ns}	0.03^{ns}	0.20 *

Table 3. Variation in taxon's aerial density among years, locality (villages), altitude, and meteorological conditions (GLIMMIX models of random (year and village) and fixed (season, panel height, wind speed and direction, temperature and RH at flight height, 222 nets between 40 and 290 m agl, in 125 sampling nights). ^{a}For negative bionomial scale parameter estimates the k parameter of this distribution. ^{b}The effects of year and village could not be estimated simultaneously, so the estimates were produced in two separate models, each including only one of the factors. ^{c}Two month periods were used (Mar-Apr, May-Jun, Jul-Aug, Sep-Oct, and Nov-Dec). The period of highest panel density is shown with its statistical significance. $^{***,**,*,\ ns,\ ne}$ refer to significance probability of 0.001, 0.01 and 0.05, > 0.05, and to parameters that could not be estimated, respectively. ^{d}To better reflect seasonal variation in wind direction (Fig. 5a), periods for this analysis were Mar-Jun, Jul-Sep, and Oct-Dec. The period of highest panel density is shown with its statistical significance. ^{e}The main effect of wind direction, measured from south (−1) to north (1) of each sampling location on aerial density. This measures the south-north component of the average angle of nightly wind direction (see text and Fig. 5a). ^{f}The interaction between Period and S–N vector of wind is shown for the difference between Oct-Dec and Jul-Sep. ^{g}Measured at flight altitude using MERRA2 database based on panel height (see text for details).

can fly over 10.75h[46], similar to *A. gambiae* s.l. (10 h)[47,48]. Because all taxa were collected in the top panels, our sampling has not reached their highest flight altitude and our results likely underestimate the actual flight altitude as well as total abundance, diversity, speed and displacement distance. Indeed, radar data have shown that migrants reach (and often exceed) 450 m agl[24,49–51]. The low abundance of *Dysdercus* sp. may be accounted for by incomplete altitude sampling, as is the case for *N. modulates,* which tend to fly at higher altitudes (Fig. 4c). This variation between species suggest that low-flying insects including *P. sabaeus*, *Z. rhytidera*, and *Hydrovatus* sp. may engage in shorter flights than high-flying taxa, e.g., *N. modulatus*, *Cy. endeca*, *Berosus* sp., and *M. nitidus*.

Meteorological radar data from the Sahel revealed wind speed means between 8 and 12 m/s, with occasional nights when wind speed in the lower jet stream (LJS, 150–500 m agl) exceed 15 m/s[52]. Reanalysis datasets such as MERRA-2 or ERA5 consistently underestimate wind speed in that layer[53]. Because migrant insects often concentrate at the layer with maximal air speed[24], a small insect flying between 1 and 10 h in a realistic average windspeed of the LJS (10 m/s) will cover on average 36–360 km per night (over 500 km in some nights).

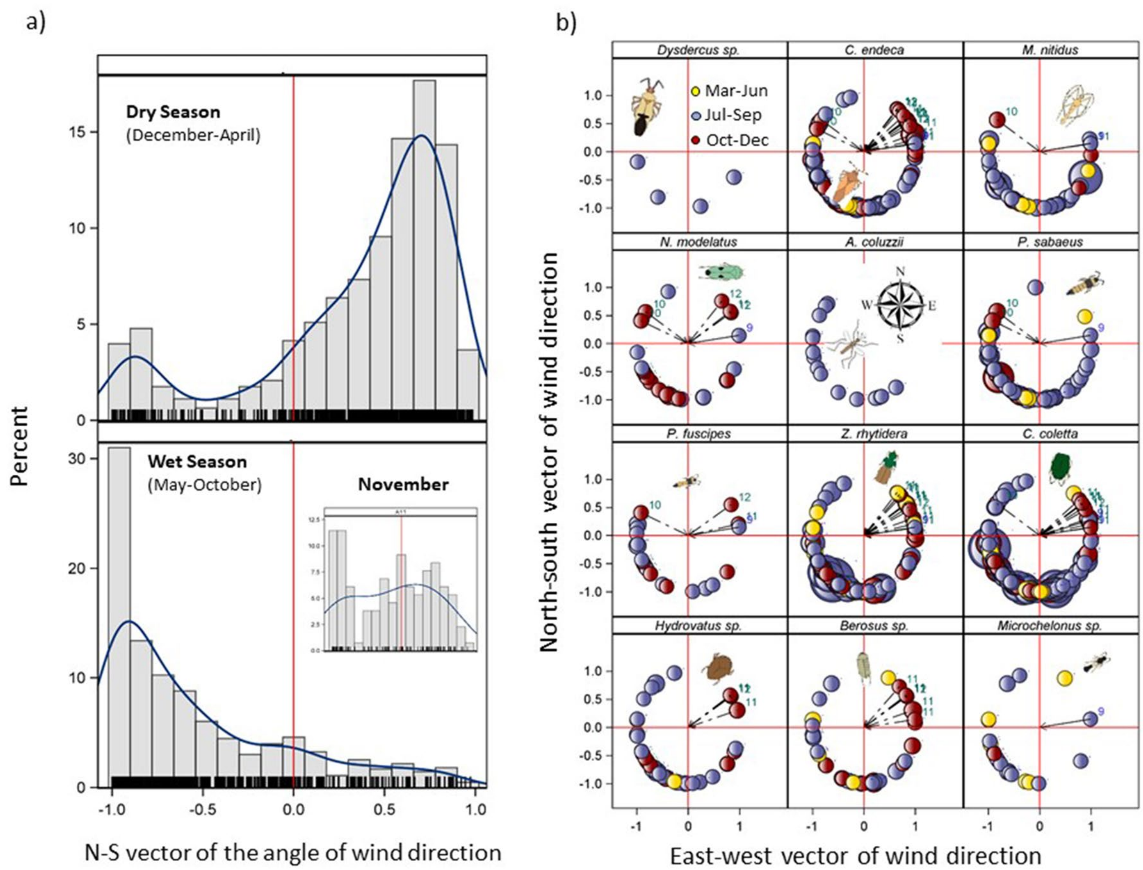

Figure 5. Seasonality of the south-north component of nightly wind direction in the Sahel and nightly wind direction during high-altitude flights of each taxon. (**a**) To explore the possibility of north–south migration into the Sahel from more equatorial regions, the north–south component of nightly wind direction (2012–2015 MERRA2 data; all nights) shows the frequencies of winds during the dry (top) and wet (bottom) season in Thierola (the other villages exhibited similar distributions). Kernel distributions are shown in blue. Wind direction from the N and S are indicated by positive and negative south–north vector values, respectively. INSET: November is a transition month with variable wind direction. Red reference line at the origin indicates easterly or westerly winds. Fringe marks indicate actual values south-north component of wind direction. (**b**) Wind direction during high-altitude flights of selected taxa. Circles denote source of mean nightly winds in relation to the capture location (origin) with north and east denoted by top and right red lines, respectively. Circle size reflects nightly aerial density and their color denotes the period (top left). Dotted arrows highlight southbound winds during the end of the wet season, that could be used for the "return" migration from the Sahel towards tropical areas closer to the Equator (numbers denote the months of such events). Schematic insect silhouettes are not to scale.

The seasonally productive habitats of the Sahel border diverse and "teeming" sub-equatorial habitats; a combination that may increase the abundance of insect migrants and account for concentration of aerial predators such as swifts[54,55], nightjars[56], and bats[57] during peak migration in this region. During their fall migration, swifts arrive in the Sahel (latitudes 11–15°) in mid to late August when insect migration peaks (Fig. S3), and remain in the area for ~ 24d, 30% (9–67%) of their total migration duration, whilst covering only 9% of their total route. This contrasts with their spring migration in May, before insect migration builds up, when they stay in the Sahel ~ 4d, constituting only 14% (3–38%) of their journey[55]. It appears that the swifts rely on the extreme insect abundance before heading to equatorial regions, where they overwinter, suggesting it is greater than in equatorial regions. Hence, it may represent a global hot zone for migratory insects.

The seasonal movement of the Inter-Tropical Convergence Zone (ITCZ), which marks the zone of precipitation, implies continuously shifting resources across the girth of the Sahel . During its short wet season a mosaic of patches receive high and low rainfall in any given year, which in turn reinforces migration[11,33,34,58,59]. Movement between resource patches is predicted, especially for inhabitants of ephemeral water such as puddles, e.g., *A. coluzzii*. Marked seasonality with migration peaking during the rainy season was evident in most taxa and might have been found in all taxa, had larger sample sizes been available (Table 3 and Fig. 3). Migration dynamics in nine taxa exhibited bimodal activity similar to the total density of insects/panel (Fig. S3); only *A. coluzzii*, *Dysdercus* sp., and *Microchelonus* sp. exhibited a unimodal pattern (Fig. 3). A wide unimodal migration peak fits the "residential Sahelian migration" strategy in species that persist in the Sahel throughout the year, but continuously migrate into new environments to maximize exploitation of resource-rich patches and safeguard

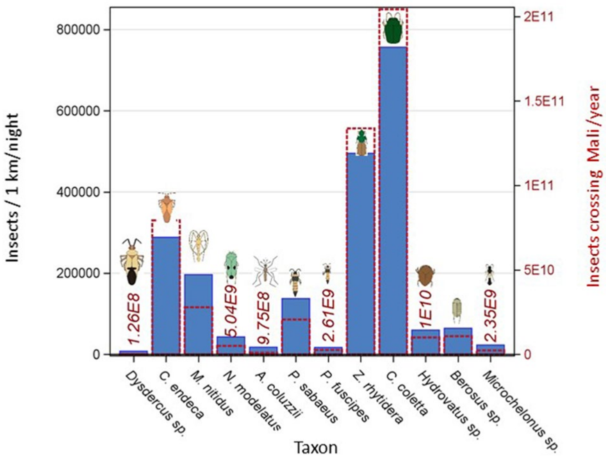

Figure 6. The number of insects per species crossing at altitude (50–250 m agl) imaginary lines perpendicular to the prevailing wind. Migrants per night per 1 km (left Y axis, blue) are superimposed on the annual number per 1,000 km line across Mali (right Y axis, red, see text).

against severe wet-season droughts[31] that could eliminate local populations. This strategy implies an ability to withstand the Sahelian dry season via dormancy as is the case for *A. coluzzii*[38,60–62]. Bi-modal flight activity better fits a "round-trip migration strategy", whereby insects arrive in the Sahel from "perennial" habitats closer to the equator during the early peak, and "return" southwards before the approaching dry season, e.g., *Dysdercus volkeri* in Ivory Coast and Mali[37]. For example, the grasshopper *Oedaleus senegalensis* flies southward from the northern Sahel on Harmattan winds and covers 300–400 km in a night's migration, although its northward movements seem gradual[7,24,58]. The late wet-season peak (October) in total insect density/panel (Fig. S3) supports a rise in population density as predicted. However, contrary to prediction, wind direction during the seven nights with highest total insect density had a predominant northward component (not shown). These strategies are not mutually exclusive as species may exhibit both "round-trip migration" and "residential migration" in different populations. For example, equatorial populations of *A. coluzzii*[63–65], are not expected to extensively engage in windborne migration. Likewise, O. senegalensis (Acrididae) probably uses both strategies. It exhibits aestivation—eggs can survive several years in dry soil—but it can also cross the Sahel into the Savanna and return (over its 3 annual generations)[4,7,24,28,33]. The relative importance of each strategy may vary among populations. Possibly, species employing the "round trip" strategy may incorporate movements similar to "residential Sahelian migration" during the wet season, to better exploit the shifting rains and then return southwards to habitats with perennial resources, as exemplified by *O. senegalensis* (above). Distinguishing among these possibilities and linking them to life history traits require additional information, which currently are unverified for most Sahelian taxa (Table S2).

Wind directions during the period of flight activity spanned well over 180° for all taxa (Fig. 5 and Table 3), suggesting that movement between resource patches in the Sahel is widespread. For example, the nearly uniform distribution over large sectors exhibited by *Hydrovatus* sp. and *Berosus* sp. indicate dispersal with only weak concentration of southerly origin, probably reflecting migration between aquatic habitats in multiple directions. During the rains, movements northwards and eastwards were especially common, following the ITCZ. After the long dry season, rain signifies high productivity, minimal competition, predation, and parasitism[33]. During the end of the wet season, movement southward was observed in 10 of the 12 taxa, however, there was no evidence of selective flight on southbound winds as was found over Europe[22,66]. The prevailing seasonal winds in the Sahel—southwest monsoon and northeast Harmattan—happen to take the migrants in seasonally appropriate directions > 70% of the nights (Fig. 5a), reducing the pressure for wind selectivity that was demonstrated in temperate zones, where selectivity may confer greater benefit. Return migrations were possibly missed given the fewer sampling nights during October–December and because during this time the LJS may have been higher than 190 m and most insects flew above our traps.

In conclusion, our results demonstrate that a multitude of Sahelian insects regularly engage in high-altitude windborne migration, covering hundreds of kilometers, in enormous densities during the rainy season. The implications of this for ecosystem stability, public health, and especially for food security are profound. The dynamics of the studied taxa suggest species-specific drivers. The dominant winds— southerly monsoon during the wet season and northerly Harmattan—during the dry season structure the sources and destinations, yet, all taxa exploited winds that transported them to various directions, indicating an intra-Sahelian patch interchange.

Methods

Study area. Aerial sampling stations were placed in four Sahelian villages (Fig. 1): Thierola (13.6586, − 7.2147) and Siguima (14.1676, − 7.2279; March 2013 to November 2015); Markabougou (13.9144, − 6.3438; June 2013 to June 2015), and Dallowere (13.6158, − 7.0369; July to November 2015). Unless otherwise indicated, Dallowere, situated 25 km from Thierola was excluded from the statistical analysis because it was represented by only two sampling nights.

No aerial samples were taken during January and February (Fig. 1). The study area has been described in detail previously[38,61,67–69]. Briefly, it is a rural area characterized by scattered villages, with traditional mud-brick houses, surrounded by fields, beyond which is a dry savanna, consisting of grasses, shrubs, and scattered trees Over 90% of the rains fall in the wet season (June—October, ~ 550 mm annually), forming puddles and ponds that usually dry by November. Rainfall during the dry season is negligible (0—30 mm, December—May).

Aerial sampling and specimen processing. The aerial sampling methods have been described in detail previously in a study that focused on *Anopheles* mosquito species from the whole collection[15]. Briefly, insect sampling was conducted using sticky nets (panels) attached to the tethering line of 3 m diameter helium-filled balloons, with each balloon typically carrying three panels. Initially, panels were suspended at 40 m, 120 m, and 160 m agl, but from August 2013, after preliminary results showed higher panel densities at higher elevations, the typical altitude was 90 m, 120 m, and 190 m agl. When a larger balloon (3.3 m dia.) was deployed at Thierola (August–September 2015), two additional panels were added at 240 m and 290 m agl. Balloons were launched approximately one hour before sunset (~ 17:00) and retrieved one hour after sunrise (~ 07:30), the following morning. To control for insects trapped near the ground as the panels were raised and lowered, comparable control panels were raised up to 40 m agl and immediately retrieved during each balloon launch and retrieval operation. Between September and November 2014, the control panels were raised to 120 m agl. The control panels typically spent 5 min above 20 m when raised to 40 m, and up to 10 min when raised to 120 m. Following panel retrieval, inspection for insects was conducted in a dedicated clean area. Individual insects were removed from the nets with forceps, counted, and stored in labeled vials containing 80% ethanol.

Taxon selection and identification. Using a dissecting microscope, insects were sorted by morphotype—an informal taxon assigned to specimens with similar morphology that are putative members of a single species— counted and recorded in a database. The remaining insects were sorted to order, counted, and recorded. Selected morphotypes were chosen based on their easily identifiable features and their repeated appearance in a preliminary examination of the collection. Later, a subset were identified by expert taxonomists who narrowed the identification down to species or genus and confirmed that the morphotype likely represents a single species (Tables S1 and S2). The thirteen taxa used in the present study are described in Table S2 and Fig. S1.

Data analysis. During months when aerial sampling was carried out in one, two or three sites, we sampled four, three, or two dates of collections per site, respectively. The dates were spread more or less evenly through the sampling days of each month. From each sampling night, two panels were selected in sequential order (120 m, 160 m, 190 m…) and 1–4 vials of insect specimens, representing > 30% of the total insects collected (based on the count of total insects removed from the panel, above), were sorted and counted as described above. For example, if the total insects removed from a panel in the field were 660 and the first vial had 185 insects, which were sorted, we added a second vial with 155 insects. Because the sum of the insects sorted was 340, which is > 30% of the 660 (220), no additional vial was sorted. Subsampling of the collection for the analysis was carried out to represent variation between years, seasons, sites, and altitude. However, as typical for field studies in remote areas, logistical constraints resulted in sampling that was not perfectly balanced (Fig. 1). The 'panel density' of the selected taxa was computed as the product of the total number of insects collected on that panel and the fraction of specimens from each taxon in the subsample sorted. Thus, using the example above, if the count of the first taxon was 9 in a subsample of 340/660, then the panel density was estimated as the 9*(660/340) = 17.47, which was rounded to 18.

The Modern-Era Retrospective analysis for Research and Applications (*MERRA-2*[70])—selected to represent observed nightly conditions (18:00 through 06:00)—were used to calculate nightly mean temperature, relative humidity (RH), wind speed and direction. Corresponding values were computed for 2, 50, 70, 200, 330 m agl for the nearest grid center (available in ~ 65km^2 resolution) of each village: Siguima, Markabougou and Thierola (Dallowere, located 25 km south of Thierola was included in the same grid of Thierola). Hourly records were available up to 10 m, and 3-hourly records at altitude > 10 m. Conditions at panel height, e.g., mean nightly wind speed, were estimated based on the nearest available altitude. The altitudes of the sampling panels were generally well above the insects' 'flight boundary layer'—the lowest air layer where an insect's self-propelled flight speed is greater than wind speed—so flight direction is governed primarily by wind direction[24,71,72]. Thus, flight direction was estimated from the average nightly wind direction during the night of capture at the location and panel height. The seasonal flight direction was estimated as the weighted average nightly wind direction at the flight altitude at which a taxon was captured, with the taxon aerial density at the panel used as a weight to compute the weighted circular mean angle for that taxon (see below).

Aerial insect density was estimated based on the taxon's panel density (above) and total air volume that passed through that panel that night, i.e.:

$$\begin{aligned}\text{Aerial density} &= \text{total insects per panel/volume of air sampled, and Volume of air sampled}\\ &= \text{panel surface area} * \text{mean nightly wind speed} * \text{sampling duration}\end{aligned}$$

Insect sampling duration was calculated from balloon launch time until its retrieval time (typically 17:30 to 7:30; ~ 14 h). Based on panel altitude, wind speed was selected from the nearest layer (above) to calculate the nightly average for each panel. Analysis was carried out both on panel density, and aerial density, to ensure that all key aspects of the data are well represented. The calculation of aerial density assumed that air passed through the net with minimal attenuation and that the panel remained perpendicular to the wind direction throughout. These are reasonable assumptions because observations showed no flipping of the panels, the thin layer of glue did not block the holes of the net, and insects were always found only on one side of the panel. Under these assumptions (panel surface = $3m^2$, for 14 h) and nightly average wind speed from the MERRA-2 database, the volume of air that would pass through the nets when average nightly wind speed was 1 vs. 7 m/s is 151,200 and $1{,}058{,}400m^3$, respectively.

The variation in the aerial density measured by each panel due to the effects of season, altitude, and other factors was evaluated using mixed linear models with either Poisson or negative binomial error distributions implemented by proc GLIMMIX with a log link function[73]. These models accommodate the non-negative integer-counts and the combination of random and fixed effects. The lower Bayesian Information Criterion (BIC), the significance of the underlying factors, the ratio of the Pearson χ^2 to the degrees of freedom and the significance of the scale parameter (estimating k of the negative binomial distribution) were used to choose between models. Mean nightly wind direction was computed based on the average values of north–south and east–west vectors of the hourly wind direction angle (unweighted by wind speed). The dispersion of individual angles around the mean was measured by the mean circular resultant length 'r' (range: 0 to 1), indicating tighter clustering around the mean by higher values. Rayleigh's test of uniformity was used to test whether there was no mean direction, as when the angles form a uniform distribution over 360 degrees.

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Author contributions

This project was conceived by T.L. Field methods and operations were designed by D.L.H. with input from D.R.R. and J.W.C. Fieldwork, protocol optimization, sampling data acquisition and management, and initial specimens processing was performed by A.D., A.S.Y., M.D., D.S., Z.L.S., and O.Y. Laboratory processing and identification of morphotypes was done by J.F. and L.M.V. with key inputs from M.L.C., E.T., H.J.F., C.M., M.B., C.B., and C.S.S. Data entry and management was done by J.F. and L.M.V. Morphological species identification and molecular analysis of specimens were conducted primarily by M.L.C., E.T., Y.-M.L., H.J.F., C.M., M.B., C.B., C.S.S, and R.F. Data analysis were carried out by T.L. with inputs from all authors, especially B.J.K., R.F., D.R.R., J.W.C., E.S. and Y.-M.L. The manuscript was drafted by T.L., J.F., and L.M.V. and revised by all authors. Throughout the project, all authors have contributed key ingredients and ideas that have shaped the work and the final paper.

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Competing interests

The authors declare no competing interests.

Data deposition

The dataset will be deposited in Dryad.

Additional information

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Supplementary Materials:

Diversity, dynamics, direction, and magnitude of high-altitude migrating insects in the Sahel

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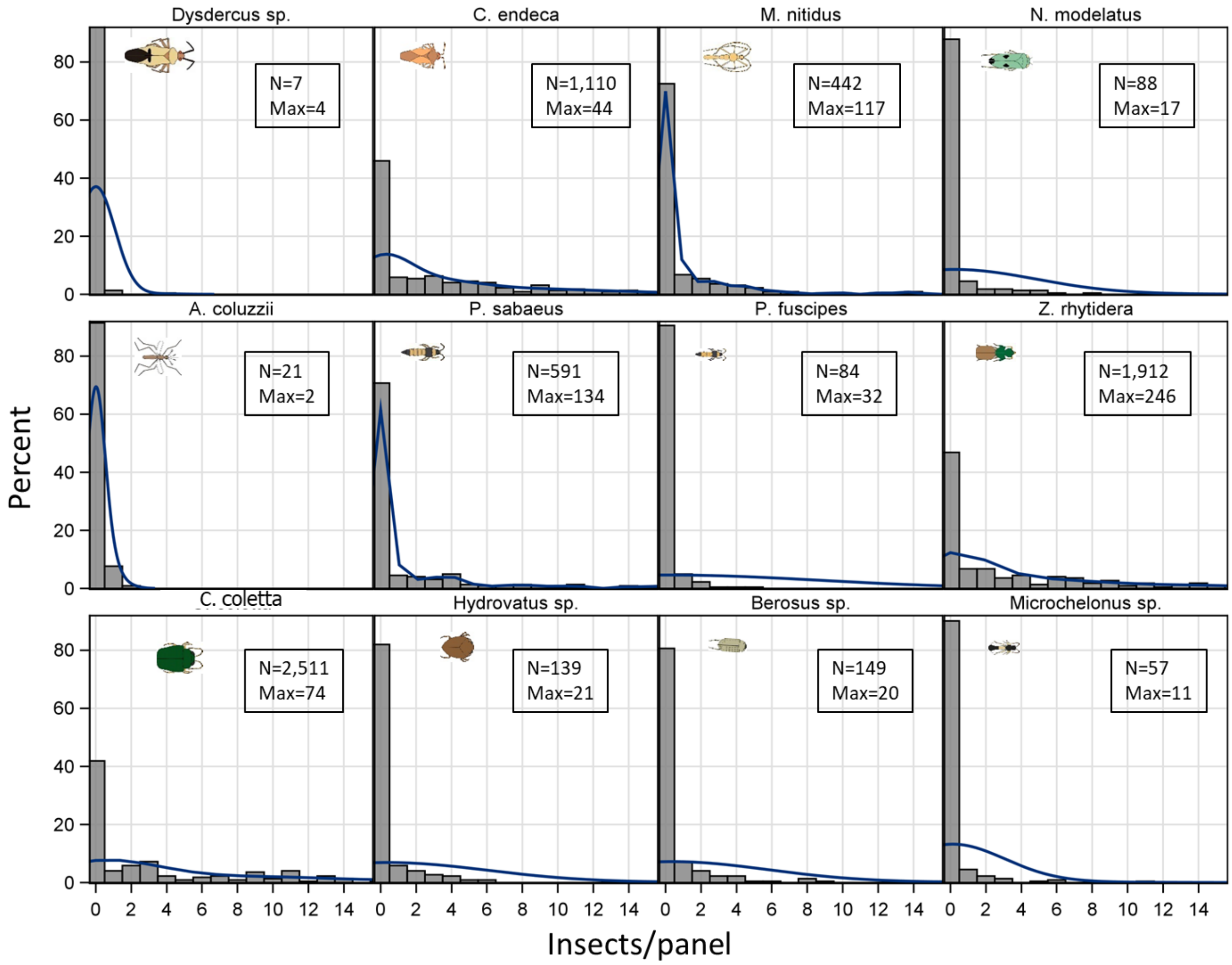
The Supplementary Materials include: Figures S1-S5, Tables S1 (List of identified insects from the project) and S2 (selected taxa: taxonomy and natural history).

Figure S1. Plates 1-15. 1: *Dysdercus* sp. (Pyrrhocoridae), 2: *Cysteochila endeca* Drake (Tingidae), 3: *Metacanthus nitidus* Štusák (Berytidae), 4-6: *Nephotettix modulatus* Melichar (Cicadellidae), 7: *Anopheles coluzzii* Coetzee & Wilkerson (male, Culicidae), 8: *Paederus sabaeus* Erichson, 9: *Paederus fuscipes* Curtis (Staphylinidae), 10: *Zolotarevskyella rhytidera* (Chaudoir) (Carabidae), 11: *Chaetocnema coletta* Bechyn (Chrysomelidae), 12: *Hydrovatus* sp. (Dytiscidae), 13: *Berosus* sp. (Hydrophilidae), 14: *Microchelonus* sp. (Braconidae), 15: *Hypotrigona* sp. (Apidae). Ruler units are mm.

Plates 1-15. Selected species pictured with ruler; lines are 1mm. apart 1: *Dysdercus* sp., 2: *Cy. endeca*, 3: *M. nitidus*, 4-6: *N. modulatus*, 7: *A. coluzzii* (male), 8: *P. sabeus*, 9: *P. fuscipes*, 10: *Z. rhytidera*, 11: *Ch. coletta*, 12: *Hydrovatus* sp., 13: *Berosus* sp., 14: *Microchelonus* sp., 15: *Hypotrigona* sp.

Figure S2. L-shape distributions of the number of insects per panel (histogram) and kernel density function (line) for the selected taxa. Maximum value of the X-axis was truncated to 15 (some values were higher, see Max value, inset). N and Max denote the total and the maximum density/panel in 220 sticky nets.



.

Figure S3. Seasonal variation in total-insect density/panel (note: sampling in 2013 ended in August). Inset: Relationship between panel density and aerial density (log scales). Pearson correlation coefficient (N reflects values larger than 0).

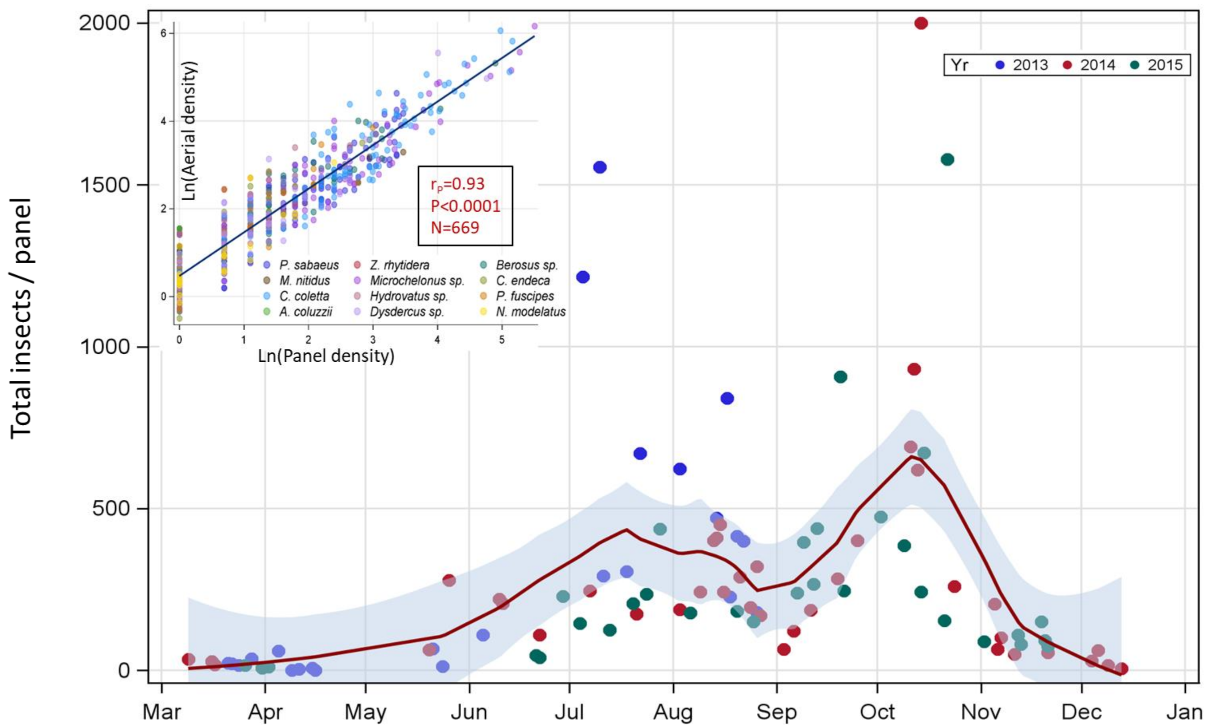


Figure S4. Distribution of mean nightly wind speed at flight height. Estimates are based on MERRA2 database and matched to the nearest panel altitude (50m, 70m and 200 m agl, see text from details).

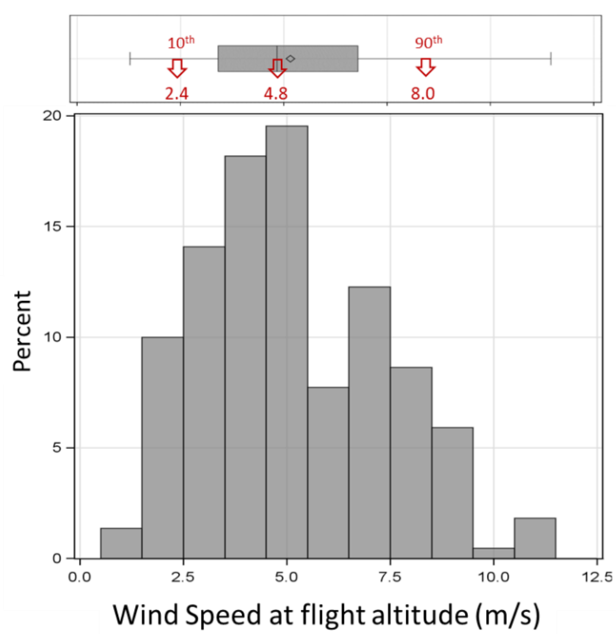


Figure S5: Weather conditions during high-altitude flight on the ground (red) and at flight height (blue) of each taxon. Weighted means (weighted by aerial density) and 95% CI on the ground and at flight height of (a) nightly temperature, (b) RH, and (c) wind speed are shown with corresponding wet season means (dashed lines labeled 'W2m' and 'Air') and year-round means at 2 m agl (dotted red lines labeled 'Y2m'). Schematic insect silhouettes are not to scale.

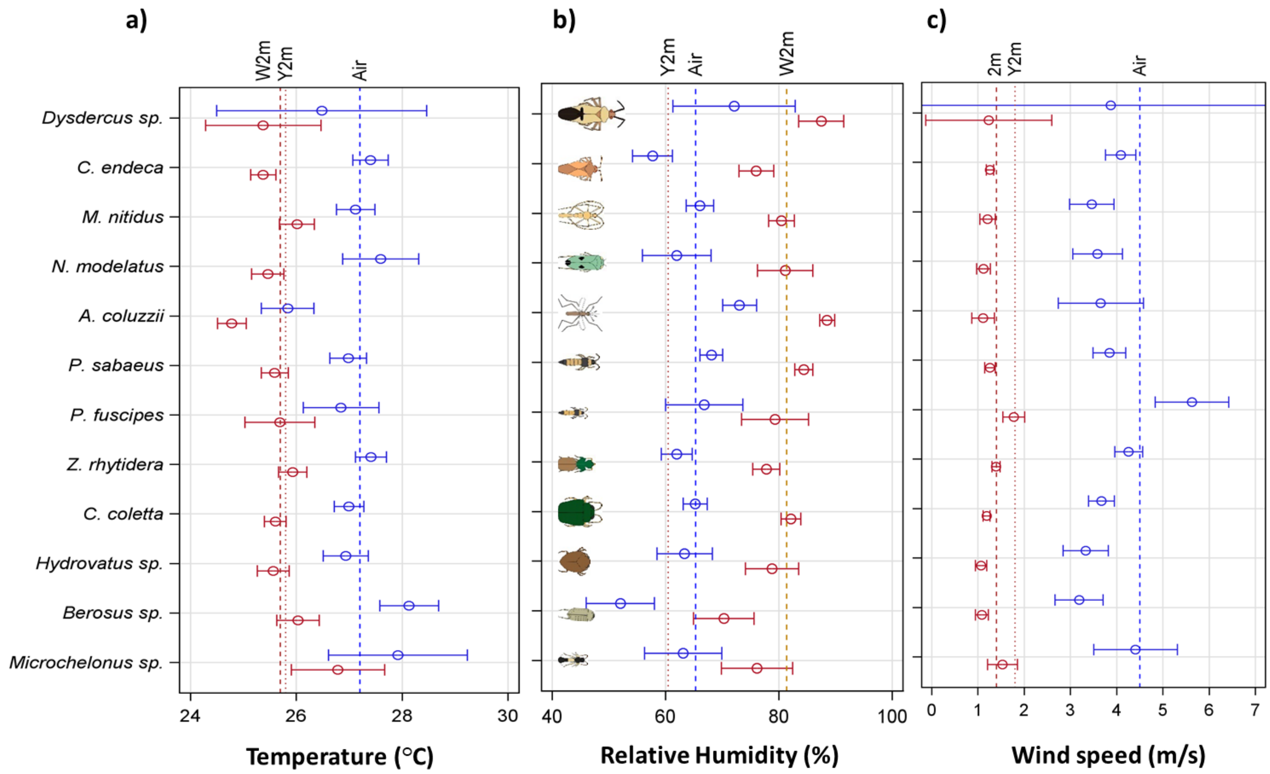


Table S1. List of identified insects from the project to-date.

Collection Site (	Collection Date	Height (m)	TubeIDOrig	Order	suborder	superfamily	family	subfamily	tribe	genus	species	TaxonomistName
Markabougou, Mali	3-Aug-13	40	MB231A	Coleoptera	Adephaga	Caraboidea	Carabidae	Cicindelinae	Cicindelini	*Lophyra*	*senegalensis (Dejean, 1*	Schüle
Thierola, Mali (13.6	18-Aug-13	40	TB386	Coleoptera	Adephaga	Caraboidea	Carabidae	Harpalinae	Amblystomina	*Amblystomus*	*dispar (Basilewski, 1951)*	Schüle
Thierola, Mali (13.6	21-Mar-13	40	TB204	Coleoptera	Adephaga	Caraboidea	Carabidae	Harpalinae	Amblystomina	*Amblystomus*	*katanganus (Burgeon, 1*	Schüle
Thierola, Mali (13.6	7-Sep-15	120	TB960B	Coleoptera	Adephaga	Caraboidea	Carabidae	Harpalinae	Amblystomina	*Amblystomus*	*latefasciatus (Basilewsky*	Schüle
Suigima, Mali (14.1	21-May-13	40	SB111A	Coleoptera	Adephaga	Caraboidea	Carabidae	Harpalinae	Amblystomina	*Amblystomus*	*viridulus (Erichson, 1843*	Schüle
Suigima, Mali (14.1	21-May-13	40	SB111A	Coleoptera	Adephaga	Caraboidea	Carabidae	Harpalinae	Chlaeniini	*Callistochrous*	*baxi (Gory, 1833)*	Schüle
Suigima, Mali (14.1	21-May-13	40	SB111A	Coleoptera	Adephaga	Caraboidea	Carabidae	Harpalinae	Harpalinae	*Afromizonus*	*tecospilus (Basilewsky, 1*	Schüle
Suigima, Mali (14.1	21-May-13	40	SB111A	Coleoptera	Adephaga	Caraboidea	Carabidae	Harpalinae	Harpalini	*Egadroma*	*discriminatis (Basilewsky*	Schüle
Suigima, Mali (14.1	21-May-13	40	SB111A	Coleoptera	Adephaga	Caraboidea	Carabidae	Harpalinae	Harpalini	*Platymetopus*	*tesselatus (Basilewsky, 1*	Schüle
Thierola, Mali (13.6	7-Sep-15	120	TB960A	Coleoptera	Adephaga	Caraboidea	Carabidae	Lebiinae	Lebiini	*Metadromius*	*royi (Mateu, 1969)*	Schüle
Thierola, Mali (13.6	21-Mar-13	40	TB204	Coleoptera	Adephaga	Caraboidea	Carabidae	Lebiinae	Lebiini	*Singilis*	*bedimo (Anichtchenko, 2*	Schüle
Suigima, Mali (14.1	21-May-13	40	SB111A	Coleoptera	Adephaga	Caraboidea	Carabidae	Lebiinae	Lebiini	*Syntomus*	*submaculatus (Wollastor*	Schüle
Thierola, Mali (13.6	14-Aug-14	160	TB535B	Coleoptera	Adephaga	Caraboidea	Carabidae	Lebiinae	Odacanthini	*Lasiocera*	*nitidula (Dejean, 1831)*	Schüle
Thierola, Mali (13.6	7-Sep-15	120	TB960A	Coleoptera	Adephaga	Caraboidea	Carabidae	Lebiinae	Pentagonicini	*Pentagonica*	*elegans (Peringuey, 189*	Schüle
Thierola, Mali (13.6	7-Sep-15	120	TB960A	Coleoptera	Adephaga	Caraboidea	Carabidae	Trechinae	Bembidiini	*Polyderis*	*sp.*	Schüle
Suigima, Mali (14.1	21-Nov-14	160	SB574A	Coleoptera	Adephaga	Caraboidea	Carabidae			*Sphaerotachys*	*tetraspilus (Solsky, 1874*	Schüle
Markabougou, Mali (13.9128, -6.3425)			MB231A	Coleoptera	Adephaga	Dytiscoidea	Dytiscidae	Hydroporinae		*Hydrovatus*		Saverio Rocchi
Markabougou, Mali	20-Aug-13	40	MB255A-CO-2	Coleoptera	Adephaga	Dytiscoidea	Dytiscidae	Laccophilinae	Laccophilini	*Laccophilus*		Warren Steiner
Markabougou, Mali	13-Aug-14	190	MB395A-CO-2	Coleoptera	Adephaga	Dytiscoidea	Dytiscidae					Warren Steiner
Thierola, Mali (13.6	28-Oct-14	160	TB682A-CO-1	Coleoptera	Adephaga	Caraboidea	Carabidae	Brachininae	Brachinini	*Brachinus*	*prob. dorsalis Dejean*	Lourdes Chamorro
Thierola, Mali (13.6	4-Jul-15		TB820A	Coleoptera	Adephaga	Caraboidea	Carabidae	Lebiinae	Lebiini	*Zolotarevskyella*	*prob. rhytidodera (Csiki)*	Lourdes Chamorro
Thierola, Mali (13.6	7-Sep-15	120	TB960A	Coleoptera	Adephaga	Caraboidea	Carabidae	Trechinae	Bembidiini	*Tachyura*	*biplagiatus (Dejean, 183*	Schüle
Thierola, Mali (13.6	7-Sep-15	120	TB960A	Coleoptera	Adephaga	Caraboidea	Carabidae	Trechinae	Bembidiini	*Tachyura*	*cfr. vagans (Peringuey, 1*	Schüle
Thierola, Mali (13.6	7-Sep-15	120	TB960A	Coleoptera	Adephaga	Caraboidea	Carabidae	Trechinae	Bembidiini	*Tachyura*	*fumicata (Motschulsky, 1*	Schüle
Thierola, Mali (13.6	18-Aug-13	40	TB386	Coleoptera	Adephaga	Caraboidea	Carabidae	Trechinae	Bembidiini	*Tachyura*	*spec.*	Schüle
Suigima, Mali (14.1	7-Jul-14	40	SB286A-CO-8	Coleoptera	Adephaga	Caraboidea	Carabidae					Leonid Friedman
Thierola, Mali (13.6583, -7.2155)			TB669A	Coleoptera	Polyphaga	Bostrichoidea	Bostrichidae					Laura Verú
Suigima, Mali (14.1	7-Jul-14	40	SB286A-CO-8	Coleoptera	Polyphaga	Chrysomeloidea	Brentidae	Galerucinae				Leonid Friedman
Thierola, Mali (13.6583, -7.2155)			TB21A-CO-1	Coleoptera	Polyphaga	Chrysomeloidea	Chrysomelidae	Bruchinae	Pachymerini	*Caryedon?*		Laura Verú
Thierola, Mali (13.6	13-Aug-14	190	TB533B-CO-5	Coleoptera	Polyphaga	Chrysomeloidea	Chrysomelidae	Bruchinae				Leonid Friedman
Markabougou, Mali	15-Oct-14		MB446A-CO-1	Coleoptera	Polyphaga	Chrysomeloidea	Chrysomelidae	Criocerinae				Lourdes Chamorro
Markabougou, Mali	20-Aug-13	40	MB255A-CO-2	Coleoptera	Polyphaga	Chrysomeloidea	Chrysomelidae	Eumolpinae				Lourdes Chamorro
Markabougou, Mali	7-Jul-14	120	MB320A	Coleoptera	Polyphaga	Chrysomeloidea	Chrysomelidae	Galerucinae	Alticini	*Aphthona*	*laevissima (Wollaston)*	Maurizio Biondi
Markabougou, Mali	7-Jul-14	120	MB320A	Coleoptera	Polyphaga	Chrysomeloidea	Chrysomelidae	Galerucinae	Alticini	*Aphthona*	*signatifrons (Wollaston)*	Maurizio Biondi
Markabougou, Mali	13-Aug-14	190	MB395B-CO-3	Coleoptera	Polyphaga	Chrysomeloidea	Chrysomelidae	Galerucinae	Alticini	*Aphthona*	*sp. 1*	Furth
Markabougou, Mali	7-Jul-14	120	MB320A	Coleoptera	Polyphaga	Chrysomeloidea	Chrysomelidae	Galerucinae	Alticini	*Aphthona*	*whitfieldi (Bryant)*	Maurizio Biondi
Markabougou, Mali	14-Aug-14	190	MB398B	Coleoptera	Polyphaga	Chrysomeloidea	Chrysomelidae	Galerucinae	Alticini	*Chaetocnema*	*coletta (Bechyné)*	Maurizio Biondi
Markabougou, Mali	24-Oct-14	120	MB474A	Coleoptera	Polyphaga	Chrysomeloidea	Chrysomelidae	Galerucinae	Alticini	*Longitarsus*	*sp. 1*	Maurizio Biondi
Markabougou, Mali	7-Jul-14	120	MB320A	Coleoptera	Polyphaga	Chrysomeloidea	Chrysomelidae	Galerucinae	Alticini	*Longitarsus*	*sp. 2*	Maurizio Biondi
Suigima, Mali (14.1	10-Aug-14	190	SB362A-CO-9	Coleoptera	Polyphaga	Chrysomeloidea	Chrysomelidae	Galerucinae	Alticini			Maurizio Biondi
Markabougou, Mali	9-Aug-14	190	MB386A	Coleoptera	Polyphaga	Chrysomeloidea	Chrysomelidae	Galerucinae	Luperini	*Afromaculepta*	*decemmaculata*	Thomas Wagner
Thierola, Mali (13.6	16-Mar-14	40	TB416A-CO-4	Coleoptera	Polyphaga	Chrysomeloidea	Chrysomelidae	Galerucinae	Luperini	*Monolepta*	*sp. 1*	Furth
Thierola, Mali (13.6583, -7.2155)			TB392A-CO-3	Coleoptera	Polyphaga	Chrysomeloidea	Chrysomelidae	Galerucinae	Luperini	*Monolepta*	*sp. 2*	Furth
Thierola, Mali (13.6	14-Oct-14	120	TB639A	Coleoptera	Polyphaga	Chrysomeloidea	Chrysomelidae	Galerucinae	Luperini	*Monolepta*	*sp. 3*	Furth
Thierola, Mali (13.6	5-Jul-13	40	TB321A	Coleoptera	Polyphaga	Chrysomeloidea	Chrysomelidae	Galerucinae		*Panafrolepta*	*dahlmani*	Thomas Wagner
Suigima, Mali (14.1	17-Aug-13	160	SB179A	Coleoptera	Polyphaga	Cucujoidea	Coccinellidae	Coccidulini				Shockley
Markabougou, Mali	15-Oct-14		MB446A-CO-2	Coleoptera	Polyphaga	Cucujoidea	Coccinellidae					
Markabougou, Mali	13-Aug-14	190	MB395A-CO-2	Coleoptera	Polyphaga	Cucujoidea	Nitidulidae					Warren Steiner
Suigima, Mali (14.1	11-Sep-14	120	SB444A-CO-1	Coleoptera	Polyphaga	Cucujoidea	Phalacridae					Warren Steiner
Thierola, Mali (13.6	20-May-14		TB426B	Coleoptera	Polyphaga	Curculionoidea	Attelabidae	Rhynchitinae			*sp. 1*	Lourdes Chamorro
Markabougou, Mali	15-Aug-14	160	MB397A-CO-9	Coleoptera	Polyphaga	Curculionoidea	Brentidae	Nanophyinae		*Nanophyes*	*poss. errans*	Lourdes Chamorro
Thierola, Mali (13.6	10-Aug-14	190	TB527A-CO-5	Coleoptera	Polyphaga	Curculionoidea	Brentidae	Nanophyinae		*Nanophyes*	*sp. 1*	Lourdes Chamorro
Thierola, Mali (13.6	18-Aug-13	40	TB386A	Coleoptera	Polyphaga	Curculionoidea	Brentidae	Nanophyinae		*Nanophyes*	*sp. 2*	Lourdes Chamorro
Suigima, Mali (14.1	11-Sep-14	120	SB444A-CO-6	Coleoptera	Polyphaga	Curculionoidea	Brentidae	Apioninae				Lourdes Chamorro
Suigima, Mali (14.1	7-Sep-15		SB725	Coleoptera	Polyphaga	Curculionoidea	Curculionidae	Bagoinae		*Bagous*	*sp. 1*	Lourdes Chamorro
Thierola, Mali (13.6	16-Mar-14		TB418A	Coleoptera	Polyphaga	Curculionoidea	Curculionidae	Baridinae			*sp. 1*	Lourdes Chamorro
Thierola, Mali (13.6	17-Mar-14	120	TB420A	Coleoptera	Polyphaga	Curculionoidea	Curculionidae	Baridinae	Baridini	*Baris*	*picturatus*	Lourdes Chamorro
Suigima, Mali (14.1	21-Nov-16	160	SB574A-CO-11	Coleoptera	Polyphaga	Curculionoidea	Curculionidae	Baridinae			*sp. 3*	Lourdes Chamorro
Markabougou, Mali	22-Aug-13		MB262A	Coleoptera	Polyphaga	Curculionoidea	Curculionidae	Brachycerinae			*sp. 1*	Lourdes Chamorro
Suigima, Mali (14.1	7-Jul-14		SB288A	Coleoptera	Polyphaga	Curculionoidea	Curculionidae	Brachycerinae			*sp. 2*	Lourdes Chamorro
Thierola, Mali (13.6	7-Sep-15		TB960A	Coleoptera	Polyphaga	Curculionoidea	Curculionidae	Brachycerinae			*sp. 3*	Lourdes Chamorro
Suigima, Mali (14.1	20-Jul-15	190	SB662A	Coleoptera	Polyphaga	Curculionoidea	Curculionidae	Ceutorhynchinae	Ceutorhynchini	*Nr. Neocoeliodes*	*sp. 1*	Lourdes Chamorro

Thierola, Mali (13.6	13-Nov-15	120	TB1095A-CO-17	Coleoptera	Polyphaga	Curculionoidea	Curculionidae	Conoderinae		*Lobotrachelus*	*sp. 1*	Lourdes Chamorr
Thierola, Mali (13.6	6-Sep-14	190	TB593A-CO-19	Coleoptera	Polyphaga	Curculionoidea	Curculionidae	Curculioninae	Ochyromerini	*Endaeus*	*sp. 1*	Lourdes Chamorr
Suigima, Mali (14.1	10-Jul-13	120	SB127A-CO-5	Coleoptera	Polyphaga	Curculionoidea	Curculionidae	Curculioninae	Rhamphini		*sp. 1*	Lourdes Chamorr
Thierola, Mali (13.6	5-Jul-13	40	TB321A	Coleoptera	Polyphaga	Curculionoidea	Curculionidae	Curculioninae	Smicronychini	*Afrosmicronyx*	*dorsomaculatus (Julien H*	Lourdes Chamorr
Markabougou, Mali	26-Mar-15	190	MB544A-CO-6	Coleoptera	Polyphaga	Curculionoidea	Curculionidae	Curculioninae	Smicronychini	*Afrosmicronyx*	*umbrinus*	Lourdes Chamorr
Thierola, Mali (13.6	9-Mar-14	160	TB397A	Coleoptera	Polyphaga	Curculionoidea	Curculionidae	Curculioninae	Smicronychini	*Sharpia*	*bella*	Lourdes Chamorr
Suigima, Mali (14.1	7-Jul-14	160	SB288A	Coleoptera	Polyphaga	Curculionoidea	Curculionidae	Curculioninae	Smicronychini	*Smicronyx*	*gossypii (Haran)*	Lourdes Chamorr
Markabougou, Mali	15-Aug-14	160	MB397A-CO-8	Coleoptera	Polyphaga	Curculionoidea	Curculionidae	Curculioninae	Smicronychini	*Smicronyx*	***zambianus n. sp. (Hara***	Julien Haran & Lo
Suigima, Mali (14.1	22-May-13	160	SB113A-CO-7	Coleoptera	Polyphaga	Curculionoidea	Curculionidae	Lixinae	Lixini	*Microlarinus*	*sp.*	Lourdes Chamorr
Suigima, Mali (14.1666, -7.2332)			SB573	Coleoptera	Polyphaga	Curculionoidea	Curculionidae	Scolytinae				Laura Verú
Markabougou, Mali	13-Aug-14	190	MB395A-CO-8	Coleoptera	Polyphaga	Curculionoidea	Curculionidae					Lourdes Chamorr
Markabougou, Mali	22-Aug-13		MB262A	Coleoptera	Polyphaga	Curculionoidea	Erorhinidae	Erirhininae			*sp. 1*	Lourdes Chamorr
Markabougou, Mali	7-Jul-14		MB319A	Coleoptera	Polyphaga	Curculionoidea	Brentidae	Apioninae			*#1 female*	Lourdes Chamorr
Thierola, Mali (13.6	5-Jul-13		TB322C	Coleoptera	Polyphaga	Curculionoidea	Brentidae	Apioninae			*#1 male*	Lourdes Chamorr
Markabougou, Mali	25-Sep-14		MB429E	Coleoptera	Polyphaga	Curculionoidea	Brentidae	Apioninae			*#2 female*	Lourdes Chamorr
Thierola, Mali (13.6	5-Jul-13		TB322A	Coleoptera	Polyphaga	Curculionoidea	Brentidae	Apioninae			*#2 male*	Lourdes Chamorr
Thierola, Mali (13.6	11-Oct-14		TB630A	Coleoptera	Polyphaga	Curculionoidea	Brentidae	Apioninae			*#3*	Lourdes Chamorr
Thierola, Mali (13.6	11-Oct-14		TB630A	Coleoptera	Polyphaga	Curculionoidea	Brentidae	Apioninae			*#4*	Lourdes Chamorr
Thierola, Mali (13.6	21-Jul-14		TB502B	Coleoptera	Polyphaga	Curculionoidea	Brentidae	Apioninae			*#5*	Lourdes Chamorr
Markabougou, Mali	24-Oct-14		MB474A	Coleoptera	Polyphaga	Curculionoidea	Brentidae	Apioninae			*#6*	Lourdes Chamorr
Thierola, Mali (13.6	7-Jul-14		TB463D	Coleoptera	Polyphaga	Curculionoidea	Brentidae	Apioninae			*#7*	Lourdes Chamorr
Markabougou, Mali	7-Jul-14		MB319A	Coleoptera	Polyphaga	Curculionoidea	Brentidae	Apioninae			*#8*	Lourdes Chamorr
Thierola, Mali (13.6	22-Oct-15		TB1056B	Coleoptera	Polyphaga	Curculionoidea	Brentidae	Apioninae		*Conapium #1*		Lourdes Chamorr
Thierola, Mali (13.6	22-Oct-15		TB1056B	Coleoptera	Polyphaga	Curculionoidea	Brentidae	Apioninae		*Conapium #2*		Lourdes Chamorr
Markabougou, Mali	7-Jul-14		MB319A	Coleoptera	Polyphaga	Curculionoidea	Curculionidae	Curculioninae			*sp. 1*	Lourdes Chamorr
Thierola, Mali (13.6	7-Jul-14		TB463D	Coleoptera	Polyphaga	Curculionoidea	Brentidae	Apioninae	Piezotrachelini		*#1*	Lourdes Chamorr
Markabougou, Mali	26-Aug-13		MB272A	Coleoptera	Polyphaga	Curculionoidea	Brentidae	Apioninae	Pizeotrachelini		*#2*	Lourdes Chamorr
Markabougou, Mali	15-Aug-14	160	MB397A-CO-1	Coleoptera	Polyphaga	Elateroidea	Elateridae					Warren Steiner/Lc
Suigima, Mali (14.1	11-Sep-14	120	SB444A-CO-1	Coleoptera	Polyphaga	Hydrophiloidea	Hydrophilidae	Hydrophilinae	Berosini	*Berosus*		Warren Steiner
Markabougou, Mali	15-Aug-14	160	MB397A-CO-1	Coleoptera	Polyphaga	Hydrophiloidea	Hydrophilidae					Warren Steiner
Thierola, Mali (13.6	3-Aug-14		TB512A-CO-2	Coleoptera	Polyphaga	Scarabaeoidea	Scarabaeidae					Lourdes Chamorr
Markabougou, Mali	13-Aug-14	190	MB395A-CO-2	Coleoptera	Polyphaga	Staphylinoidea	Staphilinidae	Pselaphinae				Warren Steiner
Suigima, Mali (14.1	10-Aug-14	190	SB362A-CO-9	Coleoptera	Polyphaga	Staphylinoidea	Staphylindae					Leonid Friedman
Suigima, Mali (14.1	19-Jul-14	90	SB326A-CO-1	Coleoptera	Polyphaga	Staphylinoidea	Staphylinidae	Aleocharinae	Lomechusini	*Diplopleurus*		Dr. Jan Klimaszev
Thierola, Mali (13.6	13-Aug-14	160	TB532A-CO-1	Coleoptera	Polyphaga	Staphylinoidea	Staphylinidae	Aleocharinae	Lomechusini	*Paramyrmoecia*	*bipustulata*	Dr. Jan Klimaszev
Thierola, Mali (13.6	05-Aug-13	160	TB374A-CO-3	Coleoptera	Polyphaga	Staphylinoidea	Staphylinidae	Aleocharinae	Lomechusini	*Zyras (Ctenodonia)*		Dr. Jan Klimaszev
Thierola, Mali (13.6	13-Aug-14	160	TB532A-CO-1	Coleoptera	Polyphaga	Staphylinoidea	Staphylinidae	Paederinae	Paederini	*Paederus*	*fuscipes (Curtis)*	Dr. Frank
Suigima, Mali (14.1	06-Sep-14	190	SB431A-CO-1	Coleoptera	Polyphaga	Staphylinoidea	Staphylinidae	Paederinae	Paederini	*Paederus*	*sabaeus (Erichson)*	Dr. Frank
Thierola, Mali (13.6	13-Aug-14	160	TB532A-CO-1	Coleoptera	Polyphaga	Staphylinoidea	Staphylinidae	Paederinae	Paederini	*Paederus*		Dr.Frank
Thierola, Mali (13.6	13-Aug-14	160	TB532A-CO-1	Coleoptera	Polyphaga	Staphylinoidea	Staphylinidae	Staphylininae	Staphylinini	*Gabronthus*	*maritimus (Motschulsky)*	Dr. Frank
Thierola, Mali (13.6	14-Sep-14	160	TB616A-CO-1	Coleoptera	Polyphaga	Staphylinoidea	Staphylinidae	Staphylininae	Staphylinini	*Gabronthus*		Dr. Frank
Markabougou, Mali	10-Jul-13	120	MB214A-CO-3	Coleoptera	Polyphaga	Staphylinoidea	Staphylinidae	Staphylininae	Staphylinini	*Philonthus*		Dr. Frank
Thierola, Mali (13.6	10-Aug-14	190	TB527A-CO-6	Coleoptera	Polyphaga	Tenebrionidae	Aderidae					Warren Steiner
Suigima, Mali (14.1	11-Sep-14	120	SB444A-CO-7	Coleoptera	Polyphaga	Tenebrionidae	Anthicidae					Warren Steiner
Markabougou, Mali (13.9128, -6.3425)			MB476B	Coleoptera	Polyphaga	Tenebrionoidea	Mordellidae					Laura Verú
Markabougou, Mali	10-Jul-13	120	MB214A-DI-2	Diptera	Brachycera	Carnoidea	Chloropidae			*Epimadiza*		Amnon Freidberg
Suigima, Mali (14.1	10-Aug-14	190	SB362A-DI-1	Diptera	Brachycera	Carnoidea	Chloropidae					John Ismay
Markabougou, Mali	14-Aug-13	160	MB242A-DI-3	Diptera	Brachycera	Carnoidea	Milichiidae	Madizinae		*Phyllomyza*		Amnon Freidberg
Thierola, Mali (13.6583, -7.2155)			TB513B	Diptera	Brachycera	Diopsoidea	Diopsidae	Diopsinae	Diopsini	*Diopsis*		
Markabougou, Mali	14-Aug-14	190	MB398A-DI-3	Diptera	Brachycera	Empidoidea	Dolichopodidae					Igor Grichanov
Markabougou, Mali	13-Aug-14	160	MB394B-DI-3	Diptera	Brachycera	Ephydroidea	Curtonotidae			*Curtonotum*	*saheliense Tsacas, 1977*	Ashley Kirk-Sprigg
Thierola, Mali (13.6	6-Sep-14	160	TB593A-DI-5	Diptera	Brachycera	Ephydroidea	Drosophilidae	Steganinae	Steganini	*Leucophenga*		Amnon Freidberg
Thierola, Mali (13.6	13-Aug-14	190	TB533A-DI-4	Diptera	Brachycera	Ephydroidea	Drosophilidae					Shane McEvey
Markabougou, Mali	7-Nov-14	160	MB493A-DI-2	Diptera	Brachycera	Ephydroidea	Ephydridae	Discomyzinae	Psilopini	*Psitola*		Amnon Freidberg
Thierola, Mali (13.6	6-Sep-14	160	TB593A-DI-4	Diptera	Brachycera	Ephydroidea	Ephydridae	Hydrellinae		*Notiphila*		Amnon Freidberg
Markabougou, Mali	10-Jul-13	120	MB214A-DI-1	Diptera	Brachycera	Ephydroidea	Ephydridae					Tadeusz Zatwarni
Markabougou, Mali	19-Jul-14	190	MB353A-DI-1	Diptera	Brachycera	Lauxanioidea	Lauxaniidae					Stephen Gaimari
Thierola, Mali (13.6	13-Aug-14	190	TB533B-DI-4	Diptera	Brachycera	Muscoidea	Anthomyiidae					Verner Michelsen
Markabougou, Mali	14-Aug-13	40	MB240A-DI-4	Diptera	Brachycera	Muscoidea	Muscidae	Muscinae	Muscini	*Musca*		Amnon Freidberg
Markabougou, Mali	14-Aug-13	40	MB240A-DI-4	Diptera	Brachycera	Muscoidea	Muscidae	Muscinae	Stomoxyini			Amnon Freidberg
Markabougou, Mali	14-Aug-14	190	MB398A-DI-2	Diptera	Brachycera	Muscoidea	Muscidae	Phaoniinae	Atherigonini	*Atherigona*		Burgert Muller
Markabougou, Mali	14-Aug-13	40	MB240A-DI-4	Diptera	Brachycera	Muscoidea	Muscidae					Marcia Couri
Markabougou, Mali	22-Aug-13	40	MB261A-DI-1	Diptera	Brachycera	Oestroidea	Calliphoridae	Chrysomyiinae	Rhiniini	*Rhynchomyia*		Amnon Freidberg

Markabougou, Mali	14-Aug-13	40	MB240A-DI-2	Diptera	Brachycera	Oestroidea	Calliphoridae	Chrysomyiinae	Rhiniini			Amnon Freidberg
Markabougou, Mali	14-Aug-13	160	MB242A-DI-3	Diptera	Brachycera	Oestroidea	Rhiniidae					Knut Rognes
Markabougou, Mali	14-Aug-13	40	MB240A-DI-4	Diptera	Brachycera	Oestroidea	Tachinidae					Pierfilippo Cerretti
Suigima, Mali (14.1	19-Jul-14	90	SB326A-DI-1	Diptera	Brachycera	Platypezoidea	Phoridae					Amnon Freidberg
Markabougou, Mali	10-Jul-13	120	MB214A-DI-1	Diptera	Brachycera	Sciomyzoidea	Sepsidae					Andrey Ozerov
Thierola, Mali (13.6	13-Aug-14	160	TB532A-DI-1	Diptera	Brachycera	Syrphoidea	Pipunculidae					Marc De Meyer
Thierola, Mali (13.6	13-Aug-14	190	TB533B-DI-3	Diptera	Brachycera	Tephritoidea	Lonchaeidae	Lonchaeinae		*Silba*		Amnon Freidberg
Thierola, Mali (13.6	24-Aug-14	190	TB563B-DI-4	Diptera	Brachycera	Tephritoidea	Platystomatidae					Andrew Whittingtc
Thierola, Mali (13.6	6-Sep-14	160	TB593A-DI-4	Diptera	Brachycera	Tephritoidea	Tephritidae	Dacinae	Ceratidini	*Ceratitis*		Marc De Meyer
Markabougou, Mali	14-Aug-13	160	MB242A-DI-4	Diptera	Brachycera	Tephritoidea	Ulidiidae	Ulidiinae	Ulidiini	*Physiphora*		Elena Kameneva
Thierola, Mali (13.6	13-Aug-14	160	TB532B-DI-1	Diptera	Nematocera	Chironomoidea	Ceratopogonidae					Amnon Freidberg
Markabougou, Mali	14-Aug-13	160	MB242A-DI-2	Diptera	Nematocera	Chironomoidea	Chironomidae					Torbjørn Ekrem
Thierola, Mali (13.6	7-Jul-14	120	TB461A	Diptera	Nematocera	Culicomorpha	Simuliidae	Simuliinae		*Simulium*	*griseicolle*	Peter Adler
Thierola, Mali (13.6	6-Sep-14	190	TB593A	Hemiptera	Auchenorrhyncha	Fulgoroidea	Delphacidae	Delphacinae	Delphacini	*Leptodelphax*	*maculigera*	Charles Bartlett
Thierola, Mali (13.6	17-Oct-14	190	TB650A	Hemiptera	Auchenorrhyncha	Fulgoroidea	Delphacidae	Delphacinae	Delphacini	*Perkinsiella*	*dorsata*	Charles Bartlett
Thierola, Mali (13.6	9/14/2014	160	TB616A	Hemiptera	Auchenorrhyncha	Fulgoroidea	Delphacidae	Delphacinae	Delphacini	*Sogatella*	*albofimbriata*	Charles Bartlett
Markabougou, Mali (13.9128, -6.3425)			MB395B-HO-5	Hemiptera	Auchenorrhyncha	Fulgoroidea	Delphacidae	Delphacinae	Delphacini	*Sogatella*	*cf albofimbriata*	Charles Bartlett
Thierola, Mali (13.6	20-Aug-13	120	TB393A-HO-2	Hemiptera	Auchenorrhyncha	Fulgoroidea	Delphacidae	Delphacinae	Delphacini	*Sogatella*	*cf furcifera*	Charles Bartlett
Thierola, Mali (13.6	14-Sep-14	160	TB616A	Hemiptera	Auchenorrhyncha	Fulgoroidea	Delphacidae	Delphacinae	Delphacini	*Sogatella*	*nigeriensis*	Charles Bartlett
Thierola, Mali (13.6583, -7.2155)			TB462C	Hemiptera	Auchenorrhyncha	Fulgoroidea	Delphacidae	Delphacinae	Delphacini	*Sogatella*	*vibex*	Charles Bartlett
Thierola, Mali (13.6583, -7.2155)			TB616A-HO-3	Hemiptera	Auchenorrhyncha	Fulgoroidea	Delphacidae	Delphacinae	Delphacini	*Sogatella*		Charles Bartlett
Thierola, Mali (13.6	13-Aug-14	190	TB533A	Hemiptera	Auchenorrhyncha	Fulgoroidea	Delphacidae	Delphacinae	Delphacini	*Thriambus*	*strennus*	Charles Bartlett
Thierola, Mali (13.6	13-Aug-14	190	TB533A	Hemiptera	Auchenorrhyncha	Fulgoroidea	Delphacidae	Delphacinae	Delphacini	*Toya*	*ceresensis*	Charles Bartlett
Thierola, Mali (13.6	14-Sep-14	160	TB616A	Hemiptera	Auchenorrhyncha	Fulgoroidea	Delphacidae	Delphacinae	Delphacini	*Toya*	*tuberculosa*	Charles Bartlett
Thierola, Mali (13.6583, -7.2155)			TB527A-HO-1	Hemiptera	Auchenorrhyncha	Fulgoroidea	Delphacidae	Delphacinae	Delphacini			Charles Bartlett
Thierola, Mali (13.6	6-Sep-14	160	TB593A-HO-8	Hemiptera	Auchenorrhyncha	Fulgoroidea	Delphacidae	Stenocraninae		*Stenocranus*		Tatina Novoselsky
Thierola, Mali (13.6583, -7.2155)			TB426A	Hemiptera	Auchenorrhyncha	Fulgoroidea	Flatidae					Charles Bartlett
Thierola, Mali (13.6583, -7.2155)			TB650A	Hemiptera	Auchenorrhyncha	Fulgoroidea	Ricaniidae					Charles Bartlett
Thierola, Mali (13.6	13-Aug-14	160	TB532B	Hemiptera	Auchenorrhyncha	Membracoidea	Cicadellidae	Deltocephalinae	Chiasmini	*Exitianus*	*distanti*	Charles Bartlett
Thierola, Mali (13.6 3-Aug-14			TB512A-HO-1	Hemiptera	Auchenorrhyncha	Membracoidea	Cicadellidae	Deltocephalinae	Chiasmini	*Exitianus*		James Zahniser
Markabougou, Mali	7-Nov-14	160	MB493A	Hemiptera	Auchenorrhyncha	Membracoidea	Cicadellidae	Deltocephalinae	Chiasmini	*Nephotettix*	*modulatus*	Charles Bartlett
Thierola, Mali (13.6583, -7.2155)			TB752A-HO-4	Hemiptera	Auchenorrhyncha	Membracoidea	Cicadellidae	Deltocephalinae	Chiasmini	*Nephotettix*	*cf modulatus*	Charles Bartlett
Thierola, Mali (13.6	13-Aug-14	190	TB533A-HO-1	Hemiptera	Auchenorrhyncha	Membracoidea	Cicadellidae	Deltocephalinae	Paralimnini	*Psammotettix*		Tatina Novoselsky
Thierola, Mali (13.6	24-Aug-14	190	TB563A	Hemiptera	Auchenorrhyncha	Membracoidea	Cicadellidae	Deltocephalinae	Paralimnini			James Zahniser
Thierola, Mali (13.6583, -7.2155)			TB650A	Hemiptera	Auchenorrhyncha	Membracoidea	Cicadellidae	Deltocephalinae	Vartini?			Charles Bartlett
Thierola, Mali (13.6583, -7.2155)			TB688A	Hemiptera	Auchenorrhyncha	Membracoidea	Cicadellidae					Charles Bartlett
Thierola, Mali (13.6	17-Oct-14	190	TB650A	Hemiptera	Heteroptera	Cimicoidea	Nabidae					Carsten Morkel
Thierola, Mali (13.6	14-Oct-15	120	TB1035A	Hemiptera	Heteroptera	Coreoidea	Rhopalidae					Carsten Morkel
Thierola, Mali (13.6	13-Aug-14	190	TB533B-HE-1	Hemiptera	Heteroptera	Coreoidea	Stenocephalidae			*Dicranocephalus*		Thomas Henry
Thierola, Mali (13.6583, -7.2155)			TB533A-HO-4	Hemiptera	Heteroptera	Corixoidea	Corixidae					Charles Bartlett
Thierola, Mali (13.6583, -7.2155)			TB534A	Hemiptera	Heteroptera	Gerroidea	Gerridae	Trepobatinae				
Thierola, Mali (13.6	5-Nov-14	160	TB688A	Hemiptera	Heteroptera	Gerroidea	Gerridae					Carsten Morkel
Thierola, Mali (13.6	19-Sep-14	120	TB627A	Hemiptera	Heteroptera	Gerroidea	Veliidae	Microveliinae	Microveliini	*Microvelia*	*sp.*	Andreas Krüger
Thierola, Mali (13.6	13-Aug-14	160	TB532A-PH-1	Hemiptera	Heteroptera	Hydrometroidea	Hydrometridae	Hydromerinae		*Hydrometra*		Tatina Novoselsky
Thierola, Mali (13.6	10-Aug-14	190	TB527A-HE-2	Hemiptera	Heteroptera	Lygaeoidea	Berytidae	Metacanthinae	Metacanthini	*Metacanthus*	*nitidus*	Carsten Morkel
Thierola, Mali (13.6	24-Aug-14	190	TB563A-HE-4	Hemiptera	Heteroptera	Lygaeoidea	Berytidae	Metacanthinae		*Yemma*		Tatina Novoselsky
Thierola, Mali (13	19-Sep-14	190	TB629A	Hemiptera	Heteroptera	Lygaeoidea	Geocoridae	Geocorinae		*Geocoris*	*aff. erytrops*	Andreas Krüger
Markabougou, Mali	19-Jul-14	190	MB353A-HE-5	Hemiptera	Heteroptera	Lygaeoidea	Lygaeidae	Orsillinae	Nysiini	*Nysius*		Thomas Henry
Suigima, Mali (14.1	24-Oct-14	190	SB488A-HE-3	Hemiptera	Heteroptera	Lygaeoidea	Lygaeidae	Rhyparochromina	Drymini	*Stilbocoris*		Tatina Novoselsky
Suigima, Mali (14.1	24-Oct-14	120	SB486A-HE-2	Hemiptera	Heteroptera	Lygaeoidea	Lygaeidae					Thomas Henry
Thierola, Mali (13.6	24-Aug-14	190	TB563A-HE-4	Hemiptera	Heteroptera	Lygaeoidea	Oxycarenidae			*Camptotelus*		Tatina Novoselsky
Thierola, Mali (13.6	13-Aug-14	160	TB532A-HE-1	Hemiptera	Heteroptera	Lygaeoidea	Phyparochromida	Rhyparochromina	Rhyparochromini	*Beosus*		Tatina Novoselsky
Thierola, Mali (13.6	14-Oct-15	120	TB1035A	Hemiptera	Heteroptera	Lygaeoidea	Rhyparochromida	Rhyparochromina	Myodochini	*cf. Paromius*		Carsten Morkel
Thierola, Mali (13.6	14-Oct-15	120	TB1035A	Hemiptera	Heteroptera	Lygaeoidea	Rhyparochromida	Rhyparochromina	Myodochini	*Paromius*	*gracilis*	Carsten Morkel
Suigima, Mali (14.1	24-May-13	40	SB120A	Hemiptera	Heteroptera	Lygaeoidea	Rhyparochromida	Rhyparochromina	Ozophorini	*Ethaltomarus*	*glabrosus (Scudder)*	Andreas Krüger/E
Markabougou, M	21-Jul-14	190	MB359A	Hemiptera	Heteroptera	Lygaeoidea	Rhyparochromida	Rhyparochromina	Stygnocorini	*cf.Lasiosomus*	*sp.*	Andreas Krüger
Suigima, Mali (14.1	19-Jul-14	120	SB327A-HE-2	Hemiptera	Heteroptera	Lygaeoidea	Rhyparochromidae					Thomas Henry
Thierola, Mali (13	19-Sep-14	190	TB629A	Hemiptera	Heteroptera	Miroidea	Miridae					Andreas Krüger
Thierola, Mali (13	14-Aug-14	160	TB535B	Hemiptera	Heteroptera	Notonectoidea	Notonectidae	Anisopinae		*Anisops*	*spec.*	Andreas Krüger
Markabougou, Mali (13.9128, -6.3425)			MB261A-HO-4	Hemiptera	Heteroptera	Notonectoidea	Notonectidae					Charles Bartlett
Suigima, Mali (14.1	24-Oct-14	190	SB488A-HE-3	Hemiptera	Heteroptera	Pentatomoidea	Cydnidae	Cydnidae	Geotomini	*Dallasiellus*	*discrepans*	Tatina Novoselsky

Suigima, Mali (14.1	24-Oct-14	120	SB486A-HE-1	Hemiptera	Heteroptera	Pentatomoidea	Cydnidae	Cydninae	Geotomini	*Aethus*		Thomas Henry
Suigima, Mali (14.1	14-Oct-15	120	SB795A	Hemiptera	Heteroptera	Pentatomoidea	Cydnidae					Carsten Morkel
Suigima, Mali (14.1	24-Oct-14	120	SB486A-HE-3	Hemiptera	Heteroptera	Pentatomoidea	Pentatomidae	Pentatominae	Antestini	*Adria*	*parvula*	Thomas Henry
Suigima, Mali (14.1	14-Oct-15	120	SB795A	Hemiptera	Heteroptera	Pentatomoidea	Pentatomidae					Carsten Morkel
Thierola, Mali (13.6	14-Jul-14	190	TB484A	Hemiptera	Heteroptera	Pyrrhocoroidea	Pyrrhocoridae	Pyrrhocorinae		*Dysdercus*	*sp.*	Andreas Krüger
Suigima, Mali (14.1	7-Jul-14	40	SB286A-HE-5	Hemiptera	Heteroptera	Reduvioidea	Reduviidae					Carsten Morkel
Thierola, Mali (13.6	14-Sep-14	160	TB616A-HE-1	Hemiptera	Heteroptera	Tingoidea	Tingidae	Tingidae	Tingini	*Cysteochila*	*endeca*	Thomas Henry
Suigima, Mali (14.1	7-Jul-14	40	SB286A-HE-6	Hemiptera	Heteroptera	Tingoidea	Tingidae	Tinginae	Tingini	*Dictyla*		Tatina Novoselsky
Thierola, Mali (13.6	5-Nov-14	160	TB688A	Hemiptera	Heteroptera	Tingoidea	Tingidae					Carsten Morkel
Markabougou, Mali (13.9128, -6.3425)			MB416B	Hemiptera	Sternorrhyncha	Aphidoidea	Aphididae					Laura Verú
Thierola, Mali (13.6583, -7.2155)			TB533A-HO-4	Hemiptera	Sternorrhyncha	Psylloidea						Charles Bartlett
Markabougou, Mali	21-Aug-14	190	MB416B	Hymenoptera	Apocrita	Apoidea	Apidae	Apinae	Meliponini	*Hypotrigona*		Corey Smith/John
Thierola, Mali (13.6	3-Aug-14		TB512A-HY-2	Hymenoptera	Apocrita	Apoidea	Crabronidae					Elijah Talamas
Thierola, Mali (13.6	24-Aug-14	190	TB563B-HY-2	Hymenoptera	Apocrita	Apoidea	Megachilidae					Elijah Talamas
Thierola, Mali (13.6	20-Aug-13	40	TB392A-HY-2	Hymenoptera	Apocrita	Apoidea	Sphecidae					Elijah Talamas
Markabougou, Mali	15-Oct-14		MB446A-HY-1	Hymenoptera	Apocrita	Apoidea						Elijah Talamas
				Hymenoptera	Apocrita	Chalcidoidea	Chalcicidae	Epitraninae		*Epitranus*		Bob Copeland
Thierola, Mali (13.6583, -7.2155)			TB562B	Hymenoptera	Apocrita	Chalcidoidea	Eulophidae					Jason Mottern
Markabougou, Mali	20-Aug-13	40	MB255A-HY-1	Hymenoptera	Apocrita	Chalcidoidea	Eupelmidae					Elijah Talamas
Thierola, Mali (13.6583, -7.2155)			TB838A	Hymenoptera	Apocrita	Chalcidoidea	Eurytomidae					
Thierola, Mali (13.6	24-Aug-14	190	TB563A-HY-3	Hymenoptera	Apocrita	Chalcidoidea						Elijah Talamas
Thierola, Mali (13.6	24-Aug-14	190	TB563B-HY-3	Hymenoptera	Apocrita	Chrysidoidea	Bethylidae					Elijah Talamas
Suigima, Mali (14.1666, -7.2332)			SB053	Hymenoptera	Apocrita	Chrysidoidea	Chrysididae					Laura Verú
Thierola, Mali (13.6	22-Oct-15	120	TB1056B	Hymenoptera	Apocrita	Chrysidoidea	Dryinidae	Gonatopodinae		*Gonatopus*		Massimo Olmi
Thierola, Mali (13.6583, -7.2155)			TB608A	Hymenoptera	Apocrita	Cynipoidea	Figitidae	Eucoilinae		*Afrostilba*		Jason Mottern
Markabougou, Mali	14-Aug-14	160	MB397A-HY-1	Hymenoptera	Apocrita	Diaprioidea	Diapriidae	Diapriinae	Psilini	*Coptera*		Elijah Talamas
Markabougou, Mali	15-Aug-14	160	MB397A-HY-1	Hymenoptera	Apocrita	Diaprioidea	Diapriidae					Elijah Talamas
Markabougou, Mali	19-Jul-14	160	MB352A-HY-4	Hymenoptera	Apocrita	Ichneumonoidea	Braconidae	Cheloninae				Elijah Talamas
Markabougou, Mali	19-Jul-14	160	MB352A-HY-1	Hymenoptera	Apocrita	Ichneumonoidea	Braconidae					Elijah Talamas
Thierola, Mali (13.6583, -7.2155)			TB608A	Hymenoptera	Apocrita	Ichneumonoidea	Ichneumonidae	Tersilochinae				Robert Kula
Thierola, Mali (13.6583, -7.2155)			TB820A	Hymenoptera	Apocrita	Platygastroidea	Scelionidae	Scelioninae	Gryonini	*Gryon*		Elijah Talamas
Thierola, Mali (13.6	10-Aug-14	190	TB527A-HY-2	Hymenoptera	Apocrita	Platygastroidea	Scelionidae	Scelioninae		*Calliscelio*		Elijah Talamas
Thierola, Mali (13.6	24-Aug-14	190	TB563B-HY-3	Hymenoptera	Apocrita	Platygastroidea	Scelionidae	Scelioninae		*Dicroscelio*		Elijah Talamas
Thierola, Mali (13.6	24-Aug-14	190	TB563A-HY-2	Hymenoptera	Apocrita	Platygastroidea	Scelionidae	Scelioninae		*Fusicornia*	*eos*	Elijah Talamas
Thierola, Mali (13.6	24-Aug-14	190	TB563B-HY-3	Hymenoptera	Apocrita	Platygastroidea	Scelionidae	Teleasinae	Teleasini	*Trimorus*		Elijah Talamas
Markabougou, Mali	22-Aug-13	40	MB261A-HY-1	Hymenoptera	Apocrita	Vespoidea	Formicidae	Myrmicinae	Crematogastrini	*Crematogaster*		Brendon Boudinot
Suigima, Mali (14.1	2-Sep-14	190	SB419A-HY-1	Hymenoptera	Apocrita	Vespoidea	Formicidae	Myrmicinae	Crematogastrini	*Tetramorium*		Brendon Boudinot
Thierola, Mali (13.6	3-Aug-14		TB512A-HY-2	Hymenoptera	Apocrita	Vespoidea	Formicidae	Myrmicinae	Stenammini	*Messor*		Brendon Boudinot
Markabougou, Mali	14-Aug-13	160	MB242A-HY-3	Hymenoptera	Apocrita	Vespoidea	Formicidae	Ponerinae	Ponerini	*Anochetus*		Brendon Boudinot
Thierola, Mali (13.6	28-Oct-14	160	TB682A-HY-1	Hymenoptera	Apocrita	Vespoidea	Formicidae	Ponerinae	Ponerini	*Brachyponera*		Brendon Boudinot
Suigima, Mali (14.1 14-Aug-13		160	SB173A-HY-1	Hymenoptera	Apocrita	Vespoidea	Formicidae					
Thierola, Mali (13.6	5-Aug-13	40	TB372A-HY-2	Hymenoptera	Apocrita	Vespoidea	Pompilidae					
Thierola, Mali (13.6	3-Aug-14		TB512A-HY-2	Hymenoptera	Apocrita	Vespoidea	Rhopalosomatidae					Elijah Talamas
Thierola, Mali (13.6	2-Nov-15	120	TB1062A	Neuroptera	Hemerobiiformia	Chrysopoidea	Chrysopidae	Chrysopinae	Chrysopini	*Brinckochrysa*		Stephen J Brooks
Thierola, Mali (13.6	7-Jul-14	160	TB462B	Neuroptera	Hemerobiiformia	Chrysopoidea	Chrysopidae	Chrysopinae	Chrysopini	*Chrysoperla*	*congrua*	Stephen J Brooks
Suigima, Mali (14.1666, -7.2332)			SB113A	Neuroptera	Hemerobiiformia	Mantispoidea	Mantispidae					Laura Verú
Thierola, Mali (13.6	22-Jul-13	120	TB361A-OR-1	Orthoptera	Caelifera	Acridoidea	Acrididae	Gomphocerinae				Hojun Song
Thierola, Mali (13.6	22-Jul-13	120	TB361A-OR-1	Orthoptera	Caelifera	Acridoidea	Acrididae	Oedipodinae				Hojun Song
Thierola, Mali (13.6	5-Aug-13	40	TB372A-OR-2	Orthoptera	Caelifera	Acridoidea	Acrididae					Hojun Song
Thierola, Mali (13.6	23-Jul-13	120	TB364A-OR-1	Orthoptera	Caelifera	Pygromorphoidea	Pygromorphidae	Pyrgomorphinae	Atractomorphini	*Atractomorpha*		Ricardo Marino-Pe
Thierola, Mali (13.6	19-Jul-13	40	TB351A-OR-1	Orthoptera	Caelifera	Pyrgomorphoidea	Pyrgomorphidae	Pyrgomorphinae	Pyrgomorphini	*Pyrgomorpha*		Ricardo Marino-Pe
Thierola, Mali (13.6	13-Oct-15	190	TB1033A-OR-2	Orthoptera	Caelifera	Tetrigoidea	Tetrigidae	Tetriginae	Tetrigini			Hojun Song
Thierola, Mali (13.6	28-Oct-14	190	TB683A-OR-2	Orthoptera	Ensifera	Grylloidea	Gryllidae	Oecanthinae	Oecanthini	*Oecanthus*		Song Lab
Thierola, Mali (13.6	13-Oct-15	190	TB1033A-OR-1	Orthoptera	Ensifera	Tettigonioidea	Tettigoniidae	Conocephalinae				Derek A. Woller &
Thierola, Mali (13.6	12-Oct-14	120	TB633A-OR-1	Orthoptera	Ensifera	Tettigonioidea	Tettigoniidae	Phaneropterinae				Derek A. Woller &
Markabougou, Mali	7-Nov-14	160	MB493A-OR-1	Orthoptera	Ensifera	Tettigonioidea	Trigonidiidae	Trigonidiinae	Trigonidiini			Hojun Song
Thierola, Mali (13.6583, -7.2155)			TB349I	Neuroptera	Myrmeleontiformi	Myrmeleontoidea	Myrmeleontidae					Laura Verú
Thierola, Mali (13.6583, -7.2155)			TB502A	Thysanoptera								Laura Verú
Thierola, Mali (13.6583, -7.2155)							Culicidae					

Table S2. Taxonomical, ecological, and natural history of selected taxa.

Table S2: Identification, size, ecological services, and natural history of selected taxa

Taxon	Order	Family	Taxonomist	Body Length (	Mass (mg)	Ecological Service	Taxa affected	DietA:gen/spec	Habitat	HabitatLarvae	Aestivation	Generatime	Migration (genus level)
Dysdercus sp. Audinet-Serville	Hemiptera	Pyrrhocoridae	Thomas Henry	13.8	43.52	Agricultural Pest	Cotton and many other crops	seeds malvales generalist	Lush vegetation	Baobab/Cotton/malvales, even millet, sorghum			Windborne LDM in Wafrica: Ivory coast
Cysteochila endeca Drake	Hemiptera	Tingidae	Thomas Henry	3.23	0.57	Agricultural Pest	Pest of tamarind, rice	generalist					
Metacanthus nitidus Štusá	Hemiptera	Berytidae	Carsten Morkel	5.7	0.83		Feed on nettle: Fleuria aestuans may also be a predator of crop pests	Generalist	steppe and semi-desert				Suspected LDM
Nephotettix modulatus Melichar	Hemiptera	Cicadellidae	Charles Bartlett	4.56	2.98	Agricultural Pest	Voracious herbivore on crops and a vector of viral diseases	Generalist	Rice, millet, grasses	Rice, millet, grasses			
Anopheles coluzzii Coetzee & Wilkerson	Diptera	Culicidae	Adama Dao	1.2	1.5	Human Disease Vector	Primary vector of malaria and other human diseases	human specific	Standing water, peridomestic	aquatic	Yes: Dec-May	10-14 d	Windbone LDM in W Africa
Zolotarevskyella rhytidera (Chaudoir)	Coleoptera	Carabidae	Lourdes Chamorr	2.93	0.58	Predator of agricultural pests?	Predator agricultural pest species	Generalist					
Paederus sabeus Erichson	Coleoptera	Staphylinidae	Howard Frank	7.5	5.3	Agent of dermititis in people and a predator of agricultural pests	Medically important and predatory on crop pests	generalist predator	Wet habitats: marshes, edges of lakes, streams, rice fields	Wet habitats: marshes, edges of lakes, streams, rice fields			
Paederus fuscipes Curtis	Coleoptera	Staphylinidae	Howard Frank	6.3	3.32	Agent of dermititis in people and a predator of agricultural pests	Medically important and predatory on crop pests. Human infestations coincided with the local rice harvest	generalist predator	Wet habitats: marsh, edges of lakes, streams, rice fields	Wet habitats: marshes, edges of lakes, streams, rice fields		45 d @28C	
Chaetocnema coletta Bechyn	Coleoptera	Chrysomelidae	Maurizio Biondi	2.18	1.15	Agricultural Pest	Genus is a pest of corn, sweet potato, barley, wheat, sorghum, bean, alfalfa, rye, sugarbeet. Feeds voraciously on foliage; vector plant pathogen: RYMV	generalist?	Wet vegetation and montane grasslands, absent from desert areas	moist environments			
Berosus sp. Leach	Coleoptera	Hydrophilidae	Warren Steiner	3.05	1.7	Predators of mosquito larvae	Predator of mosquito larvae	Generalist	Aquatic: ponds, puddles, streams	Aquatic: ponds, puddles, streams	into soil enter domrancy		
Microchelonus sp. (Szépligeti)	Hymenoptera	Brachonidae	Elijah Talamas	3.16	1.02	Parasitoid of agricultural pests?	Unknown host, typically lepidopterans as Tortricidae, Gelechiidae and others	Specialist	Lepidopteran egg/caterpillar	host body			
Hypotrigona sp. Cockerell	Hymenoptera	Megachillidae	Corey Smith, John	3.19	2.74	Pollinator -high importance	Frequent crop visitors in E Africa, collect nectar and pollen from almost all crop plant species.	Generalist	well distributed in the tropics in various habitats. In East Africa: grasslands, natural forests, wetlands, farmlands,	Social bees nest in soils and wood. Uganda: commonly nest on walls of old buildings and in dry wood in forests. Sometimes in termite mounds.			
Hydrovatus sp. Motschulsky	Coleoptera	Dytiscidae	Saverio Rocchi	2.12	1.69	Predators of mosquito larvae	Predator of mosquito larvae	Predator	Aquatic: ponds, puddles, streams	Aquatic: ponds, puddles, streams			