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Characterisation of a West African Myrmeleontinae assemblage (Neuroptera Myrmeleontidae): first evidence of a relationship between adult occurrences and climatic conditions

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Antlions of the sub-family Myrmeleontinae in the Sikasso region of southern Mali were studied for almost 6 consecutive years. In total, 51 species or morpho-species were recorded. The assemblage is dominated by the tribe Nemoleontini (33 species). Other tribes represented are Nesoleontini (7 species), Myrmeleontini (5 species), Myrmecaelurini (3 species) and Acanthaclisini (3 species). Most of the identified species are new for Mali and, indeed, for sub-Saharan Africa. Six species are very abundant, 17 abundant, 13 fairly abundant and 15 rare. The average sex ratio of the whole assemblage is about 1 male to 1 female. An uninterrupted succession of species, with conspicuous temporal segregation, occurs throughout the year with varying overlap of the flight periods. The number of species recorded by month is highly correlated with temperature, rainfall and relative humidity (r^2 = 0.99). Species richness peaks in October and February, and is lowest in August. The estimated duration of flight periods ranges from 10-20 days to 365 days. The average flight period is 80 days.

KEY WORDS: antlion ecology, biodiversity, seasonality, sex ratio, climate, Africa, Mali.

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INTRODUCTION

Approximately 2,100 species of antlions (Neuroptera Myrmeleontidae) are known from almost all regions of the world, with maximum biodiversity in the tropics. These insects are found in all terrestrial ecosystems, from deserts to tropical rain forests, but occur mainly in arid regions (MANSELL 1999). Larvae and adults prey on small insects, including other antlion larvae and spiders (GRIFFITHS 1980, NEW 1986, CAIN 1987, STELZL & GEPP 1990), but adults of some species feed on pollen (STANGE 1970, STELZL & GEPP 1990). Larvae of some taxa build funnel-shaped pitfall traps in sandy soil to capture prey. The most recent classification of Myrmeleontidae was proposed by STANGE & MILLER (1990) who distinguished three subfamilies: Stilbopteryginae with 10 species restricted to Australia; Palparinae with about 100 species mainly distributed in Africa, but also in the Mediterranean basin, Middle East, India and South-East Asia; Myrmeleontinae with approximately 2,000 species, with a worldwide distribution. The same three subfamilies were recognised by STANGE (2004) in his Catalogue of World Antlions.

The ecology of Myrmeleontinae is essentially known from studies on larvae, particularly those that build pitfall traps. Adult ecology has been poorly investigated (STANGE 1970, NEW 1986, GEPP & HÖLZEL 1996) and only a few publications deal with the ecology of adult assemblages. The most comprehensive information on this topic was provided by GÜSTEN (2002) who studied the antlion assemblages of two arid habitats in Tunisia. Apart from the species inventory, he provided information on adult seasonality, habitat association and sex ratio and discussed the performance of light-trapping for the sampling of antlion populations. More information on the seasonal distribution of some species was collected mainly in North America, Hungary, Cape Verde Islands and Australia (STANGE 1970, MACKEY 1988, HÖLZEL & OHM 1990, SZENTKIRÁLYI & KAZINCZY 2000). Our study carried out in southern Mali is the first attempt to describe an antlion assemblage of continental Africa south of the Sahara. Results concerning the subfamily Palparinae have already been published (MICHEL 1999). The present paper deals with the subfamily Myrmeleontinae.

MATERIAL AND METHODS

The region of Sikasso

The study was carried out in the region of Sikasso (11°21'N 05°41'W) in southern Mali (Fig. 1). This area is located at 374 m above sea level and has an undulating topography. Apart from cultivated plots, most of the region is covered by low density forest broken by graminaceous savanna. It is included in the Sudanian Regional Endemism Area as identified by WHITE (1986). The climate is characterised by a rainy season from May to October and a dry season from November to April. The average temperature ranges from 24 to 28 °C and the annual rainfall is about 1,000 mm.

Insect collection and identification

Collections were made from October 1993 to December 1999. During this period five localities were sampled at least once a week throughout the year:

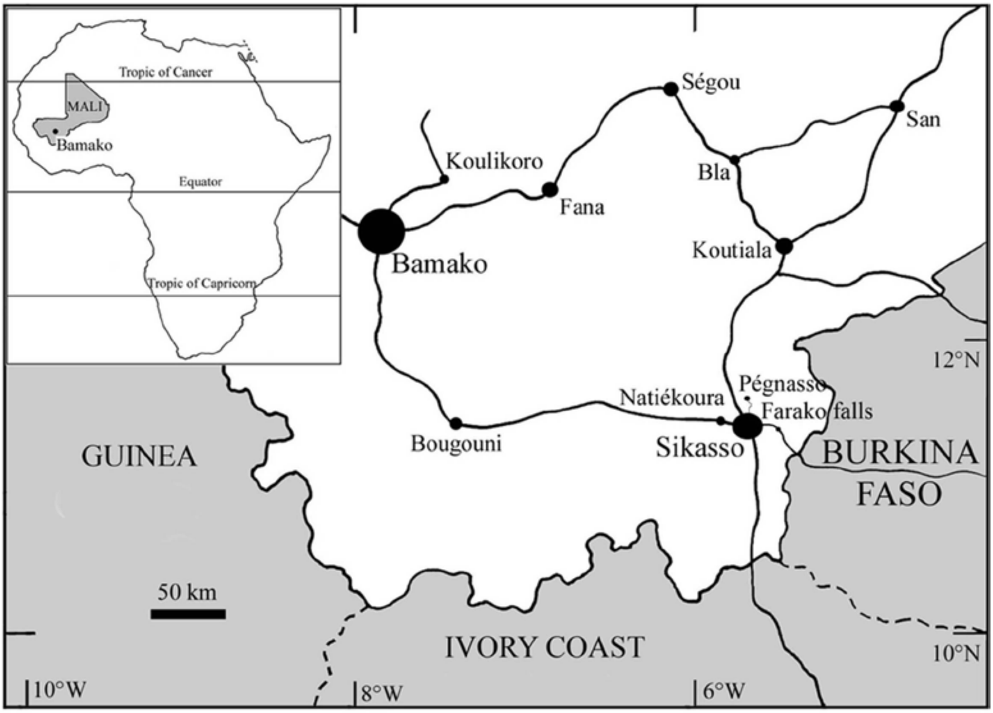


Fig. 1. — Location of the region of Sikasso and of the collection localities.

- the city of Sikasso and the graminaceous savanna, surrounded by cultivated plots and fallows, located in the immediate vicinity of the city;
- graminaceous savanna located 11 km north of Sikasso. The soil is covered by ferruginous gravels and hydromorphic ground patches;
- graminaceous savanna located 15 km north of Sikasso, close to the village of Pégnasso. The soil is covered by ferruginous gravels.
- low density shrubby savanna in the vicinity of the village of Natiékoura, 25 km west of Sikasso;
- grassland at Farako Falls, 35 km east of Sikasso where the grassy vegetation is adjacent to a gallery forest and established on sandy soil with sandstone-like outcrops.

Insects were collected with an entomological net during the day or in the late afternoon. In these localities, sampling was carried out along parallel transects covering the whole delimited area. A light-trap, equipped with a fluorescent lamp, was operational all year at Sikasso and occasionally at Farako Falls.

We used the classification proposed by Stange & Miller (1990) and the tribes were determined by means of the key provided by Stange (1994) for adults. Specimens that could not be identified to the specific level are listed by a generic name followed by a number. Species were sorted according to morphology, including male genitalia when necessary.

Meteorological data

The meteorological data, average temperature, maximum and minimum temperatures, rainfall, maximum and minimum humidity, relative humidity, vapour tension, sunlight, visibility, evapotranspiration, consisted of daily information obtained from the Sikasso meteorological station from 1993 to 2000.

Statistical analysis

To evaluate the correlation between adult occurrence and climate, we first calculated cross correlations between different variables and the number of species collected per month to select both better regressions and corresponding lags. Then, using the SAS system (SAS Institute Inc. 2003), we initiated progressive regression analyses from a previously obtained model (with 4 or 5 terms), and we performed a stepwise procedure to eliminate or introduce variables, such as temperature (maximum, minimum, mean), or rainfall, or relative humidity, either in the same month or with a lag of 1, 2 or 3 months.

The present study is based on a mean value of between-year observations and does not provide an inter-annual variation analysis.

RESULTS

Species richness

In total, 1,069 individuals of Myrmeleontinae were collected, representing 51 species or morpho-species (Fig. 2). When the 11 species of Palparinae already listed are added (Michel 1999), the family Myrmeleontidae in the region of Sikasso exhibits an outstanding species richness with 62 recorded species.

Nemoleontini is the predominant tribe with 65% of the species (Table 1). The genera *Neuroleon* Navás 1901 and *Nemoleon* Navás 1909 are the most abundant. The identified species were already known from West Africa but, with the exception of *Neuroleon linarixius* Navás 1924 described from Koulikoro (12°51’N 07°33’W),

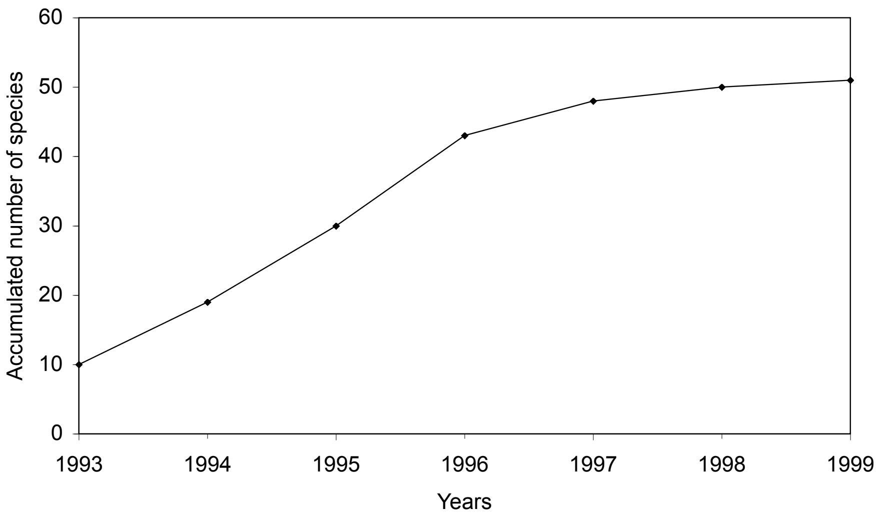


Fig. 2. — Evolution of the accumulated number of species from 1993 to 1999.

Table 1

Inventory of the Myrmeleontinae recorded from the region of Sikasso.

Nemoleontini	Nesoleontini
Banyutus guttifer (Navás 1924)	*Cueta bourboni* Navás 1935
Banyutus sp.	*Cueta martini* Navás 1914
Creoleon africanus (Rambur 1842)	*Cueta* sp. 1
Creoleon nubifer (Kolbe 1897)	*Cueta* sp. 2
Creoleon sp. aff. *mortifer* (Walker 1863)	*Cueta* sp. 3
Creoleon sp. aff. *murinus* (Klug 1834)	*Cueta* sp. 4
Distoleon sanguinolentus (Navás 1912)	*Cueta* sp. 5
Distoleon sp. 1	
Distoleon sp. 2	Myrmeleontini
Ganguilus pallescens Navás 1912	*Hagenomia lethifer* (Walker 1853)
Ganguilus sp. 1	*Hagenomia tristis* (Walker 1853)
Ganguilus sp. 2	*Myrmeleon obscurus* Rambur 1842
Gymnoleon exilis Banks 1911	*Myrmeleon* sp. 1
Macronemurus sp. aff. *loranthe* Banks 1911	*Myrmeleon* sp. 2
Nemoleon filiformis (Gerstaecker 1885)	
Nemoleon sp. 1	Myrmecaelurini
Nemoleon sp. 2	*Myrmecaelurus sectorius* Navás 1912
Nemoleon sp. 3	*Solter* sp. cf. *neglectus* (Navás 1940)
Nemoleon sp. 4	Undetermined: 1 species
Neuroleon linarixius Navás 1924	
Neuroleon sp. 1	Acanthaclisini
Neuroleon sp. 2	*Centroclisis infernalis* (Navás 1912)
Neuroleon sp. 3	*Centroclisis rufescens* (Gerstaecker 1885)
Neuroleon sp. 4	*Jaya atrata* (Fabricius 1781)
Neuroleon sp. 5	
Undetermined: 8 species	

none had previously been recorded from Mali. Nesoleontini includes seven *Cueta* Navás 1911 species. *Cueta martini* Navás 1914 was described from Koulikoro, but *Cueta bourboni* Navás 1935, described from Niger, is newly recorded for Mali. Myrmeleontini include species in the genera *Myrmeleon* Linnaeus 1767 and *Hagenomia* Banks 1911. *Myrmeleon obscurus* Rambur 1842 and *Hagenomia tristis* (Walker 1853) are widespread African species, but were not previously known from Mali. *Hagenomia lethifer* (Walker 1853), described from South Africa and reported from Kenya by Navás (1933), is recorded for the first time from West Africa. Myrmecaelurini includes three species. *Myrmecaelurus sectorius* Navás 1912 was reported by Fraser (1953) from Dogo (15°09'N 04°25'W) in the interior delta of the Niger River in Mali. We examined specimens of *Solter neglectus* (Navás 1940) in the collection of the Muséum National d'Histoire Naturelle in Paris, collected at Koulouba, close to Bamako (12°40'N 07°59'W). This species is very similar to the one from Sikasso, but further investigation is needed to confirm the identification. Acanthaclisini is represented by three species, if one agrees with Prost (1998) that *Centroclisis rufescens* (Gerstaecker 1885) and *Centroclisis infernalis* (Navás 1912) are valid species. According to the information provided by Prost (1998), *Jaya atrata* (Fabricius 1781) and *C. infernalis* are new for Mali. No specimens of the tribe Dendroleontini were collected.

Species abundance

Six species, *Creoleon africanus* (Rambur 1842), *Creoleon nubifer* (Kolbe 1897), *Neuroleon* sp. 5, *Gymnoleon exilis* Banks 1911, *Nemoleon* sp. 1 and *C. rufescens*, are very abundant (at least 50 specimens collected). The remaining species can be sorted as abundant (20 to 49 specimens collected), fairly abundant (5 to 19 specimens) and rare (less than 5 specimens) (Fig. 3). Collection of all the observed specimens was possible only for the few abundant and rare species. Concerning the other groups, the number of individuals caught is less than the number of individuals observed. Consequently, the population density of abundant and very abundant species is underestimated. However, according to our field observations, this bias probably did not modify the break-down of the species by relative abundance groups, and could only influence the placement of some species within each group.

Sex ratio

Taking into account the whole sample, whatever the mode of capture (netting or light trapping), the sex ratio (proportion of males to one female) is 0.95:1. It is 0.94:1 when we consider only the 29 species represented by at least 10 individuals

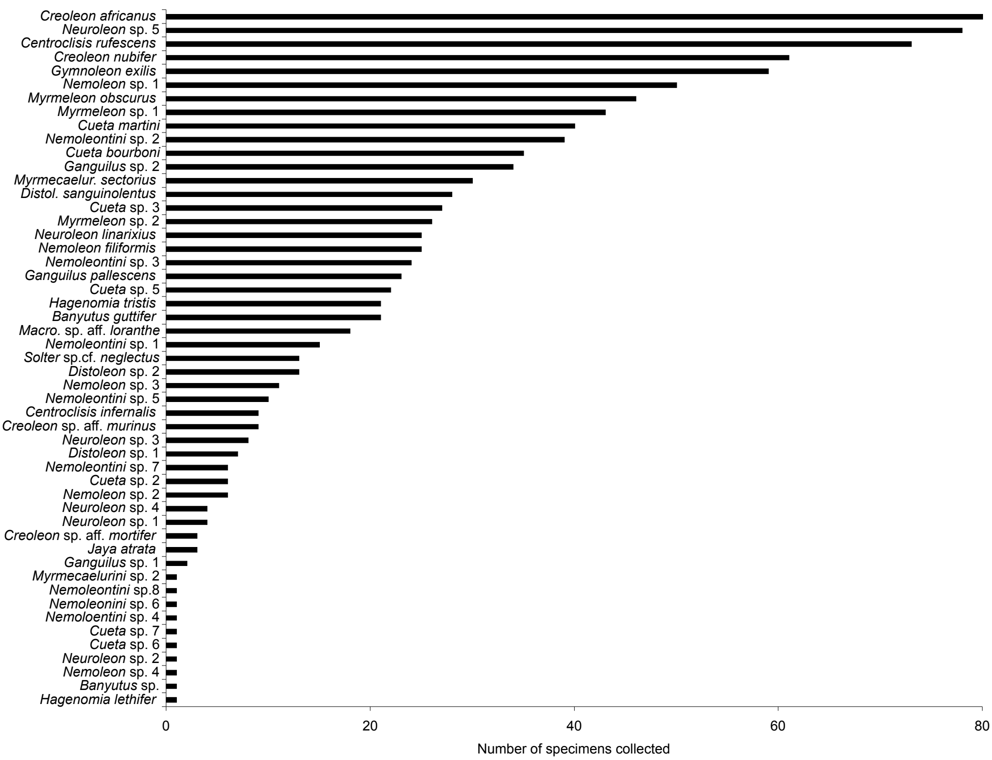


Fig. 3. — Relative abundance of the species expressed by the number of specimens collected.

and which together represent 92.7% of the specimens collected. In these species, the range of the sex ratio is quite variable, from 0.22:1 to 4.5:1 (Fig. 4), but the estimations are symmetrically distributed on both sides of the value 1:1 and 15 of 29 species have a sex ratio between 0.8:1 and 1.2:1. Conversely, a drastically different result becomes evident when we consider the method of collection (light trapping vs netting). The sex ratio calculated from collecting at light is 0.73:1, while that from netting is 1.04:1. Statistical analyses showed that the sex ratio of all species together is not different from 1:1, although, for the species with the greatest difference between male and female proportion, it is not possible to conclude if the predominance of one sex is the consequence of the sampling procedure or whether it reflects reality.

Seasonality and flight patterns

Collecting carried out regularly from January to December for more than 6 years facilitated the identification of the flight activity period for most species and provided an annual seasonality pattern for the antlion assemblage in southern Mali (Table 2). The results showed a continuous succession of adult activity periods throughout the year with varying inter-specific overlaps, as well as a conspicuous temporal segregation of the species.

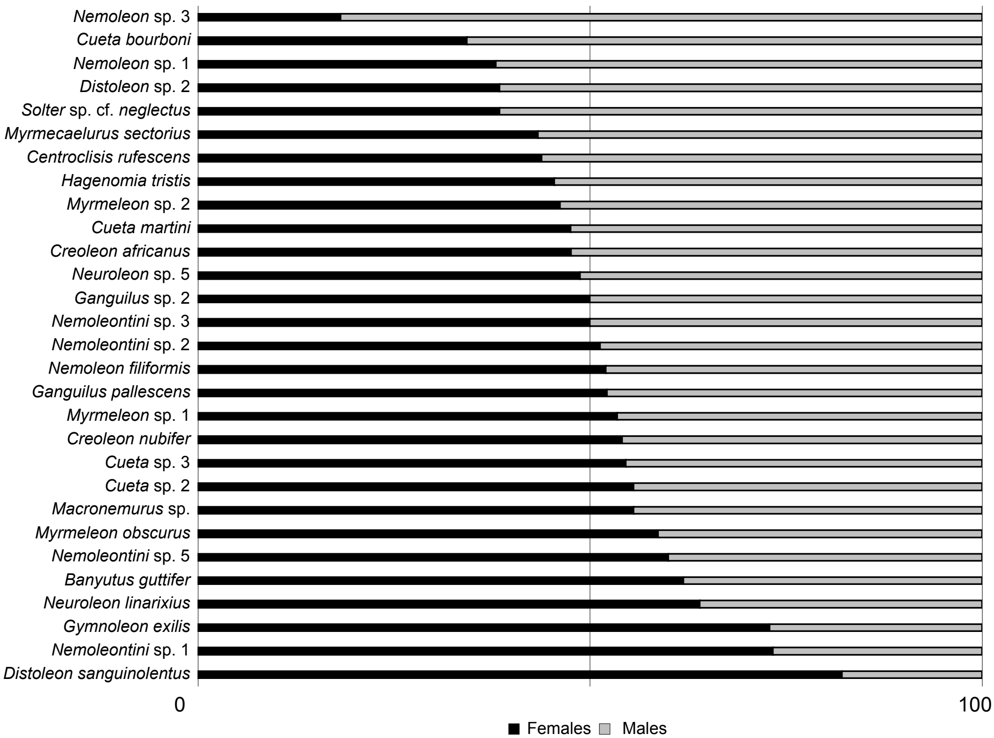
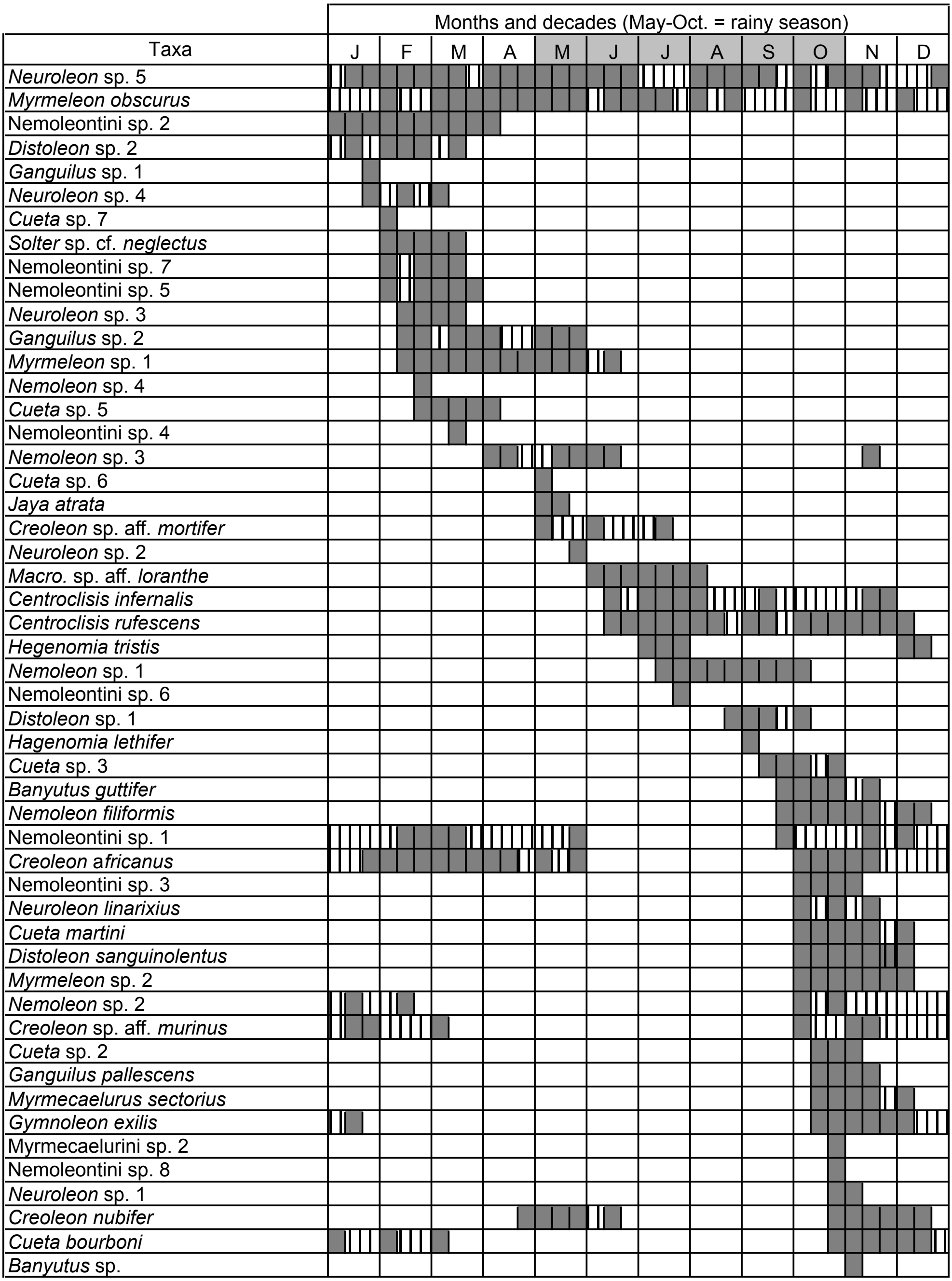


Fig. 4. — Proportion of males and females for the species represented by at least 10 specimens.

Table 2.

Seasonality of the species (grey square: 10 day period with effective capture; hatched square: 10 day period without capture).



In the course of the species succession, two peaks of maximum species occurrence were recorded. The most important was in October at the end of the rainy season, with 27 species and the other in February during the dry season, with 19 species. By contrast, the number of species decreased drastically from the end of the dry season in April and was minimal in August, with only 7 species, when the rainfall was highest (Fig. 5). Correlation analyses showed that the number of synchronised species was highly correlated with some climatic factors, particularly temperature, rainfall and relative humidity ($r^2 = 0.99$) (Table 3), and could be described by the following linear equation.

$$y = -158.90 + 2.29\,a + 2.28\,b + 2.45\,c + 0.21\,d - 0.94\,e$$

where
y = monthly number of species at adult stage,
a = mean temperature of the considered month,
b = mean temperature recorded 2 months before the considered month,
c = maximum temperature recorded 3 months before the considered month,
d = rainfall recorded 2 months before the considered month,
e = mean relative humidity recorded during the considered month.

Therefore, the presence of adults of a species is not only dependent on the climatic conditions prevailing during the period of emergence, but can also be explained by the climatic conditions that prevailed 2 to 3 months before adult emergence, during the larval and pupal stages.

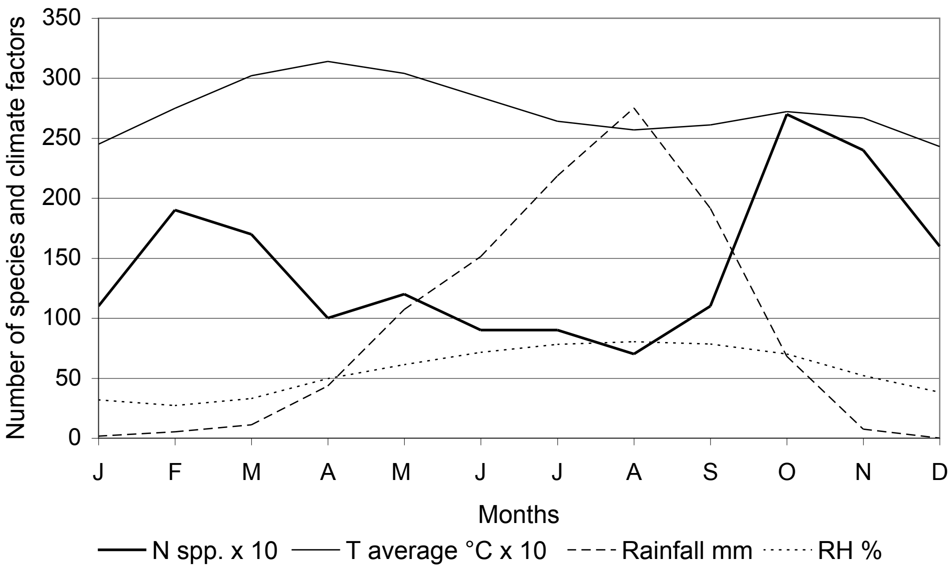


Fig. 5. — Annual variations of the species richness of the antlion assemblage and climatic factors.

Table 3.

Parameters and tests of the regression model of the number of Myrmeleontinae species (for explanation of the variables, see text).

Variables	df	Estimate	Error	t Value	Pr> [t]
Intercept	1	– 158.9	15.1	– 10.53	<0.0001
T mean	1	2.29	0.17	13.59	<0.0001
T mean (– 2)	1	2.28	0.25	9.25	<0.0001
T max (– 3)	1	2.45	0.29	8.38	0.0002
Rainfall (– 2)	1	0.206	0.013	16.4	<0.0001
Rel. Humidity	1	– 0.943	0.06	– 15.77	<0.0001

Duration of flight period

The duration of adult occurrence is variable, depending upon the species. Some species were collected during only 10 or 20 days, while others, particularly *Neuroleon* sp. 5 and *M. obscurus*, were active virtually all year (Table 2). Most of the species display an activity period lasting from 10-20 days to 140 days (Fig. 6). The mean flight period duration, for the whole assemblage is around 80 days. Most of the species have a single flight activity period. However, three species, *C. nubifer*, *H. tristis* and *Nemoleon* sp. 3, were regularly collected during two periods separated by a gap of four months or more during which no adults were recorded. This flight pattern suggests that these species could be bivoltine. The presence of the very abundant *C. nubifer*, which is easy to detect in the field, probably represents a confirmation of this result.

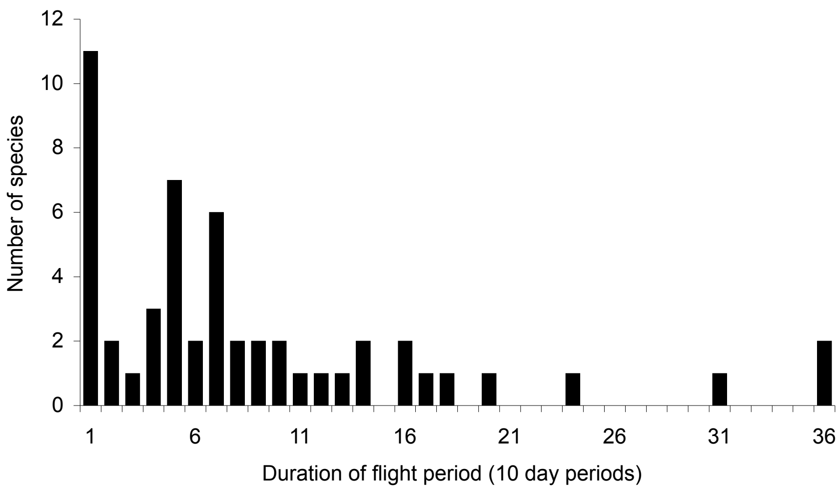


Fig. 6. — Number of species in relation to the estimated flight period duration.

DISCUSSION

Except for Acanthaclisini (PROST 1998), the lack of recent taxonomic studies on West African Myrmeleontinae often renders species identification uncertain, or even impossible, without reference to type specimens. The distribution of the extant type material over numerous collections complicates the examination of this material. Moreover, the old and brief descriptions of most of the species are often unreliable. This survey of Myrmeleontinae in Mali also revealed that several species are undescribed. Consequently, many species remain to be determined to the specific or generic levels, or require description. A taxonomic work is in progress to compile an up-dated species list and to improve our knowledge of the antlions in Mali. In spite of the intensive prospecting carried out during 6 years, two species, *Centroclisis ustulata* (Navás 1908) (Acanthaclisini) and *Cymothales liberiensis* Van der Weele 1904 (Dendroleontini), were not found. These species are mentioned in the literature as collected near Bamako (12°40'N 07°59'W) in 1929 and 1930 respectively (MANSELL 1987, PROST 1998) and they are currently known from more southern and wetter localities of West Africa. Their absence could be a consequence of environmental differences between the two regions. Unlike to the region of Sikasso, the region of Bamako has cliffs with crevices and small caves and it is crossed by the Niger River. But the absence of these species could also be a consequence of a southward shift of the populations in response to climate change that has been recorded during the last 40 years in sub-Saharan West Africa (ZENG 2003). Both hypotheses remain to be verified.

The survey carried out in Mali showed that the sex ratio of most, if not all, species is equal or close to 1:1. YASSERI & PARZEFALL (1996), observing the individuals in the field without capturing them, determined an average sex ratio of 0.95:1 for *Euroleon nostras* (Fourcroy 1785) in northern Germany. However, these authors recorded strong inter-annual variability ranging from 0.68:1 to 1.38:1. Their results led to an average proportion of males and females close to 1:1. The result of 0.32:1 obtained by GÜSTEN (2002) using light trapping exclusively is far from this value but, according to the valid arguments provided by this author, is probably a consequence of the sampling method. In his study, the sex ratio was below 0.7:1 for 15 of 21 species and ranged from 0.8: to 1.2:1 only for 3 species. We observed the same tendency, although to a lesser degree, in light-trap catches in Mali. This result highlights once again the importance of the sampling methods to estimate parameters such as presence/absence, abundance or sex ratio.

Certain traits of the assemblage present in southern Mali, such as the seasonality, the high variability in the length of the imaginal flight period and interspecific overlaps in flight activity, have been reported for assemblages from other regions of the world (STANGE 1970, SZENTKIRÁLYI & KAZINCZY 2000, GÜSTEN 2002). Nevertheless, in the region of Sikasso, there is no interruption in the species succession from January to December and two peaks of maximum species occurrence were recorded in October and February. A survey of the information reported in the literature revealed that such a dynamic pattern is described here for the first time with regard to antlion assemblages. In Hungary (SZENTKIRÁLYI & KAZINCZY 2000) and Tunisia (GÜSTEN 2002), adults fly from April-May to October and from May to September respectively; in the Cape Verde Islands they fly from January to October (HÖLZEL & OHM 1990); in California, from March to October (STANGE 1970); in Australia, adult activity has been reported from September to April (MACKEY 1988).

These results show the importance of climate as a determinant factor influencing antlion activity.

In Mali, two species, *Neuroleon* sp. 5 and *M. obscurus,* occur throughout the year. The same pattern was reported for the latter species in Madagascar by Penny (www.calacademy.org/research/entomology). This confirms that some flight patterns are not related to a particular season, e.g. the dry or rainy seasons. Concerning the other species, the flight period is clearly determined by climatic conditions. A similar pattern was already observed for the Palparinae of the region of Sikasso. In this case, however, two periods were found, from mid-July to the beginning of September and from late December to late January, during which no adult activity was detected (Michel 1999).

Bivoltinism is shared by three species in southern Mali. It is also suspected in Australia for five species of Myrmeleontidae (Mackey 1988) and in North America for *Brachynemurus sackeni* Hagen 1888 (Stange 1970). However, further studies are needed to confirm this assumption.

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