Coleopteran biodiversity of Shipstern Nature Reserve in Belize, with a comparison of the fauna of two tropical forest types

- *Holonotus laevithorax* -

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Diploma project

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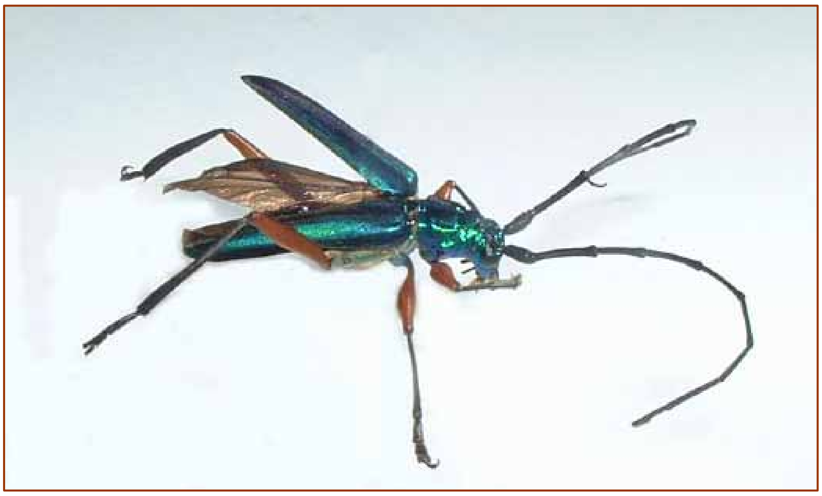


- *Callichroma schwarzerion cyanomelas* White -

1. Abstract

The Neotropics are generally recognized as the region that contains the greatest overall level of terrestrial biodiversity (Gaston & Spicer, 1998). If biological diversity is the variety of life in all its manifestations (Gaston & Spicer, 1998), insects indisputably represent the main part of this. And among them, the Coleoptera show the most remarkable capacity of adaptation, with an extraordinary diversity and still many species waiting to be discovered (WRI, 2002). Unfortunately, up to now, human activities have tended inexorably to disturb and destroy natural habitats, causing many species to disappear. Nowadays, it has become vital to maintain a sustainable situation to conserve this heritage and looked at from that point of view, the knowledge of living organisms is clearly a priority. Therefore, during the summer 2002, the coleopteran biodiversity of Shipstern Nature Reserve, Belize, Central America, was studied with a comparative approach to the coleopteran fauna of two different tropical forest types: the endemic Neotropical dry forest of the Yucatan Peninsula and the more abundant and widely distributed semi-evergreen forest.

The results suggest that Shipstern Nature Reserve contains a very important coleopteran biodiversity and undoubtedly many other species waiting to be described. The composition of the beetle communities are an amazing mix of species occuring in Mexico and the southern States of the USA (Arizona, Florida) and others originating from South America.

Throughout the comparative approach to the fauna, the coleopteran communities demonstrate their specialisation to their environment. The species compositions as well as their behaviours, are never similar between the two tropical forest types. I conclude that due to its important diversity as well as its interesting properties, Shipstern Nature Reserve deserves a high conservation priority and further scientific studies.

2. Introduction

2.1. The Order Coleoptera

By nearly any measure, the most successful animals on the planet are the arthropods. They have conquered land, water and air, and make up over three-quarters of all currently known living and fossil organisms, or over one million species in all. Since many arthropod species remain undocumented or undiscovered, especially in tropical rain forests, the true number of living arthropod species is probably in the tens of millions (WRI, 2002). One recent conservative estimate puts the number of arthropod species in tropical forests at 6 to 9 million species (Thomas, 1990). The Class of Insects presents the greatest species richness ever seen in the animal kingdom, with 751’000 described species and many others awaiting description (WRI, 2002). Among these insects, the tendency of the Coleoptera to evolve with protective structures, as elytra and strongly sclerified body providing protection against predators and diseases, plus their specialization on one or few nutritive resources, are probably a major reason for the remarkable diversity of the beetles. At present, over 350’000 species are known and the order has a worldwide distribution from the polar to the equatorial regions, with many aquatic species. As herbivores, carnivores, coprophages, detrivores, and parasites, they are adapted to feed on all available resources, and are omnipresent in everyday life as economic pests in agriculture (Curculionidae, Melolonthinae), in forestry (Bostrichidae), but also as beneficial agents used for elimination of cow dung in Australia (Scarabaeinae) and biological control of aphid populations on crops (larvae of Coccinellidae). Their impact on the world goes further than only the problems of crops, and the earlier Egyptians even venerated a beetles as a God in their beliefs (*Scarabeus sacer*). In return, like many other taxa, this extraordinary diversity and capacity of specialization makes the Coleoptera very sensitive to perturbation of their habitats and many species disappear each day, without ever being known by mankind.

2.2. Shipstern Nature Reserve

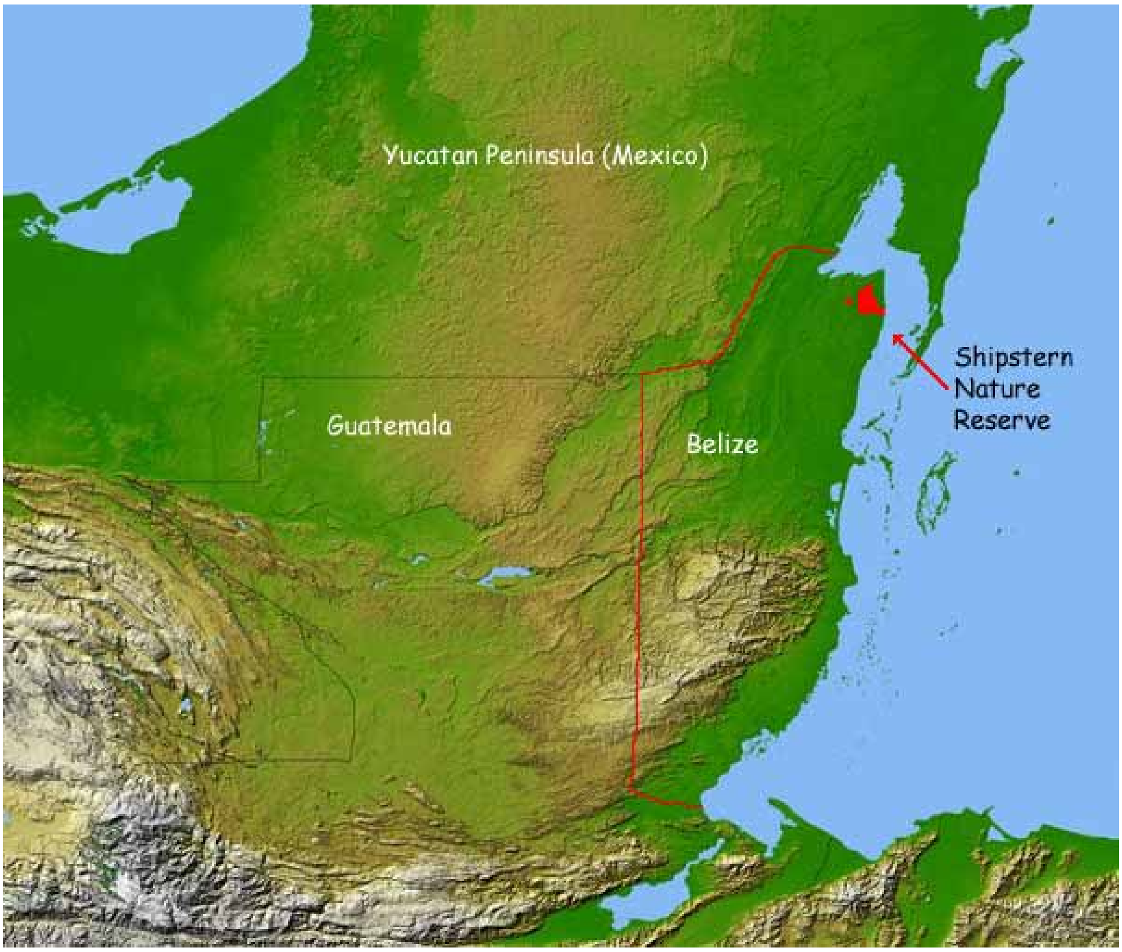
2.2.1. History

The private Shipstern Nature Reserve is owned by the International Tropical Conservation Foundation (ITCF), based in Switzerland. The reserve is located in the northern part of Belize (Central America) in the Corozal District. In 1989, the newly created ITCF, with very little funds to start, obtained a substantial loan from the Papiliorama Foundation (based in

Marin, Switzerland), which allowed the acquisition of a large parcel of land in the south-eastern part of the Corozal District. This land was previously owned by a British Limited Company which managed part of the area as a private reserve. Known then as the Shipstern Wildlife Reserve, the name was changed to Shipstern Nature Reserve. It covered approximately 8'000 hectares, but in 1995, the ITCF acquired an additional 600 hectares of semi-evergreen forest, including a group of small lakes and marshes called Xo-Pol ponds, located a few kilometers from the western side of the reserve. Shipstern Nature Reserve was soon to play a key-role in the network of Belizean protected areas. Although the northern part of Belize contains large forested areas teeming with wildlife, it is unfortunately one of the least protected parts of Belize. The importance of the reserve's geographical position within the national biological network was soon enhanced by the discovery of a flora and fauna unique or very rare for Belize.

2.2.2. The reserve

The Shipstern Nature Reserve is located in the north-eastern part of Belize (Corozal District), a small country of Central America (22'965 km^2) bordered by the Caribbean Sea. The reserve covers approximately 9'000 hectares and consists essentially of three parts. It is covered for one third by the Shipstern Lagoon, one third by dwarf mangroves and saline wetlands (locally called savannah) and, finally, one third by different tropical forest types. The salt water lagoon is very shallow, never exceeding 1 meter, and dotted by many mangrove islands that form breeding habitats for many bird species, such as the rare american woodstork (*Mycteria americana*), the white ibis (*Eudocimus albus*), and the reddish egret (*Egretta rufescens*). The dwarf mangroves and saline wetlands occup vast swampy earth areas inside the reserve, where many animal tracks are recorded, such as the Baird's Tapir (*Tapirus bairdii*). Finally, the forests are of high conservation value, because they are unique for mainland Belize, such as the small, patchy, tropical dry forest, the low semi-deciduous forest with the very rare palm *Pseudophoenix sargentii* (6 km^2 within the boundaries of the reserve), or because they are protected in the whole country only in this reserve, such as the Yucatecan semi-evergreen forest. Here you find some of the major canopy species occurring in the northern hardwood forest of the Belize (Beletsky, 1998), such as the Mahogany (*Swietenia macrophylla*), the Sapote (*Manilkara sapota*), the Chiquibul (*Manilkara chicle*), the Santa Maria (*Calophyllum brasiliense*) and the Cohune palm (*Orbigyna cohune*) in the south of the reserve.

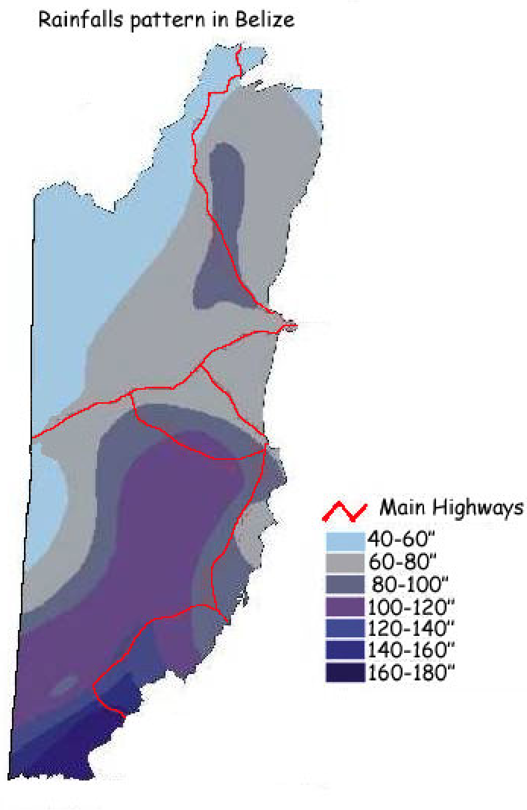


Map 1 : Location of the Belize and Shipstern Nature Reserve, modified from (NASA, 2002).

2.2.3. Climate

Belize is situated in the subtropical region, between 15° and 19° North latitude. The climate of this area differs from that occuring in tropical regions by its amplitude of temperatures. The coolest month in winter presents mean temperatures of 16 - 17°C and 24 - 25°C in summer. From November to February, arctic air masses sometimes penetrate far to the south and these cold masses affect temperatures severely. In the other extreme, the hottest mean in winter is 28°C and 33°C during the summer (Bijleveld, 1998). Nonetheless, some maxima measured in the past exceed 40°C in the Corozal District (Walker, 2002).

Rainfall in Belize increases on a North-South gradient. For example, the village of Sarteneja, near the reserve, has an annual rainfall average under 1524 mm (60''), whereas the Toledo District in the southern part of the country, receives an average of 4064 mm (160'').



Map 2 : North-South gradient of the rainfall in Belize, modified from (Meerman, 2002).

Rainfall at Shipstern Nature Reserve was measured over a period of 4 years between 1989 and 1993 (Meerman, 1993c), and the results showed that the area and its immediate surroundings are the driest areas in Belize with a mean of only 1260 mm per year.

The dry season usually starts in mid January and ends in May, with February and March being the driest months. Generally, the beginning of May sees the first showers and rain falls more regularly, sometimes strongly (tropical storms), during the months of June and July. This period is called the “little rainy season”, because the month of August is again a dry month, just before the highest rainfall occuring in September. The short dry period in August is known as the “little dry” by Belizeans. September and November very occasionally bring the feared hurricanes. Hurricanes are the most powerful of all cyclone types and may have devastating effects, when they reach the coastal areas. Hurricane Janet hit Belize in 1955, and greatly affected the northern part of the country. It destroyed the village of Sarteneja and the town of Corozal but equally all the vegetation of this part of Belize: the forest area was completely flattened (Bijleveld, 1998). After the hurricane, forestry companies retrieved fallen logs by thousands (an estimated 12’000 (Bijleveld, 1998)), a good indication of the state of maturity of the forest before this event.

2.2.4. In the future

The pressure on the area has, until recently, remained relatively low. Occasional hunting during the closure of the fishing season has always been carried out by the villagers of Sarteneja. Nowadays, with the increase in population, agriculture is being developed further and slash and burn cultivation (milpas) are expanding rapidly.

However, the hardest pressure on the area comes from the West, where the Mennonites (european settlers of swiss, dutch and german origin that came to Belize during the sixties) are expanding their agricultural activities. Up to now, only minor conservation problems have occurred within the reserve, such as occasional theft of trees, principally some Santa Maria (*Calophyllum brasiliense*) and Mahogany (*Swietenia macrophylla*).

The pressure on Shipstern Nature Reserve will surely increase as a result of population growth, and it is therefore important to secure more land adjacent to the reserve to ensure its biological viability in the future.

2.3. Earlier coleopteran studies in the area

Scientific research in this part of the country has always been relatively poor, a fact probably due to the isolated position of the area. In addition to the vegetation studies (Waldren, 1985), (Meerman, 1993b; Bijleveld, 1998), various faunal studies have been carried out in the past 20 years, on the butterflies (Meerman, 1993c), dragonflies (Boomsma, 1993) and vertebrates (Bijleveld, 1990; Meerman, 1993a; Bärtschi, 1997). But, none of these studies concerned the Coleoptera. Recently, the Louisiana State Arthropod Museum (LSAM) did an entomological survey of the Rio Bravo Conservation and Management Area, a nature reserve in the north-western part of the country (Kovarik, 1996), and the study took into account the coleopteran biodiversity. This study represents the first and probably the only serious study in this part of the Belize. Other occasional samples were taken by the Belizean Agricultural Health Authority (BAHA), but essentially for the purpose of fighting the pests of fruit farming, because Belize is an important exporter of fruits. Finally, beyond the frontier, some Mexican researchers provide some good ecological and diversity studies of the Coleoptera of the Quintana Roo State (Yucatan Peninsula). In conclusion, this report represents the first coleopteran study in the north-eastern part of the country.

2.4. Aspects of the biological diversity

Until 1980, the reserve and the area surrounding the village of Sarteneja were relatively isolated from the rest of the country. In 1980, the first all-weather road was built between the village of Chunox and Sarteneja, a fishing community of 1500 inhabitants, 7 kilometers from the reserve. Probably for these reasons, its fauna and its forest cover are still particularly rich and well conserved, a rare situation in Central America where the agricultural and forestry activities are usually well developed. Indeed, the Neotropics are generally recognized to be the region that contains the greatest overall level of terrestrial biodiversity (Gaston & Spicer, 1998), but as in many parts of the World, the encroachment on natural habitats creates dramatic losses and scientists estimate that one to three species disappear each hour in the world (Klaus et al., 2001). The Convention on Biological Diversity (Rio de Janeiro, 1992) was the first step to fight against this alarming situation and carried the connotations that the biodiversity is a good thing and that something must be done to maintain it (Gaston & Spicer, 1998). Concretely, some projects aiming to preserve and protect the biodiversity and the ecosystems appeared, such as the Mesoamerican Biological Corridor (MBC), a biological continuum through the American continent. Looked at from that point of view, Belize plays a key-role in environmental protection through its numerous nature reserves as well as its organizations dedicated to the promotion of the sustainable use and preservation of the natural resources in order to maintain a balance between people and the environment. The Northern Belize Biological Corridors Project, a network of natural corridors in the Orange Walk and Corozal Districts of the northern Belize is a crucial component of the MBC, in which the Shipstern Nature Reserve is associated.

2.5. Purpose of this study

This project on the Coleoptera of the Shipstern Nature Reserve was composed of two distinct but nevertheless complementary parts. The first was a description of the biodiversity of this order made through an inventory within the reserve. Due to its extraordinary diversity, the order Coleoptera cannot be treated in its whole without a team of numerous curators and specialists. Nonetheless, all specimens were identified at least to family level, and to species for many.

The second aim was to compare the coleopteran fauna of two very different tropical forest type. The very rare Neotropical dry forest and the more abundant tropical semi-evergreen forest. This study permitted the identification of the factors which determine the patterns of distribution and abundance of the coleopteran communities within these two forest types.

3. Materials and Methods

3.1. Choice of the forest types

Shipstern Nature Reserve presents an extraordinary diversity of biological environments. At least ten different ecosystem types could have been studied within the boundaries of the reserve, from mangroves to tropical evergreen forest.
Yet, many practical and biological aspects, such as tracks through the vegetation or the conservation priority, led to the choice of two very different forest types.

3.1.1. Low semi-deciduous forest at *Pseudophoenix sargentii*

This forest type was the first choice among all the different possibilities, because it is found only in and near Shipstern Nature Reserve and is therefore absolutely unique for mainland Belize (Bijleveld 1998). The palm tree *Pseudophoenix sargentii* and many other plant species grow only in this forest type and are unique for Belize (Bijleveld and McField 1998). Its area is usually very limited and by chance, almost half is found within the boundaries of the reserve. This neotropical dry forest has a patchy distribution through the Yucatan Peninsula. It is found in Mexico near Tulum, within the Sian Ka'an Biosphere Reserve near Cancun and as a small patch near Merida (Bijleveld 1998). In addition, this forest type seems only to establish itself when various factors combine, such as low rainfall, poor soils and proximity to the sea (Bijleveld and McField 1998).
Finally, two tracks cross the forest, providing access for sampling. Thus, for all these aspects, the low semi-deciduous forest represents a very interesting place to study.

3.1.2. Yucatecan medium-sized semi-evergreen forest

Once, the Yucatecan medium-sized semi-evergreen forest extended over the whole Corozal District (northern part of Belize), but since the extension of sugar cane fields and agricultural activities, it is now confined to the north-eastern part of the Corozal District (Bijleveld 1998). The future of this forest type in Belize is very threatened, because the reserve is its only protected area in Belize. Nonetheless, it corresponds to the typical kind of forest in this part of Belize and therefore has been chosen to be the second forest to study. The vegetation is higher than in the low semi-deciduous forest but the absence of brush and shrubs make it easier to walk through. In addition, tracks exist all around this forest (See Map 3, section 4.5.1).

Fig. 1 : The low semi-deciduous forest with the very rare palm *Pseudophoenix sargentii.*

Fig. 2 : The Yucatecan semi-evergreen forest in the area of Xo-Pol.

3.2. Establishment of plots

3.2.1. Quantity and designation of the plots

Ten plots were chosen in each forest type. These were sampled during the month of June and again from 6th July to 4th August. The traps were moved every 3 days from plot to plot.

The plots were numbered as a function of the forest type and the month of sampling:

100 to 109: plots of the low semi-deciduous forest in June.
200 to 209: plots of the Yucatecan semi-evergreen forest in June.
300 to 309: plots of the low semi-deciduous forest between 6th July and 4th August
400 to 409: plots of the Yucatecan forest between 6th July and 4th August.

3.2.2. Position of plots

The ideal method to set the 20 plots would have been to place them randomly on a map of vegetation divided in 100 m^2 squares (the smallest area necessary to set up all traps). In practice, the twenty plots were randomly chosen but near the existing tracks, trails, and survey lines of the reserve. Indeed, to go into the middle of the low semi-deciduous forest would require a new track with a machete, that is unthinkable in a nature reserve. All the plots were marked with orange flags in the field and their locations were saved with a Global Positioning System (GPS) (Garmin® E-Trex Summit™).

Plots of the Low semi-deciduous forest				Plots of the Yucatecan semi-evergreen forest			
Plot number	Altitude (m.)	Latitude N	Longitude W	Plot number	Altitude (m.)	Latitude N	Longitude W
100-300	13	18°18' 52.0"	88°11' 01.4"	200-400	15	18°15' 52.7"	88°14' 37.1"
101-301	13	18°18' 36.6"	88°11' 13.6"	201-401	16	18°14' 47.6"	88°14' 42.2"
102-302	10	18°18' 48.0"	88°11' 06.7"	202-402	9	18°15' 11.4"	88°15' 48.4"
103-303	10	18°18' 46.2"	88°11' 08.2"	203-403	18	18°15' 59.3"	88°15' 04.7"
104-304	12	18°18' 41.4"	88°11' 08.2"	204-404	17	18°14' 46.9"	88°15' 11.2"
105-305	16	18°18' 40.2"	88°11' 10.5"	205-405	11	18°15' 44.6"	88°16' 02.4"
106-306	12	18°18' 50.0"	88°11' 03.1"	206-406	12	18°15' 09.1"	88°15' 44.5"
107-307	12	18°18' 42.8"	88°11' 08.7"	207-407	10	18°15' 39.6"	88°14' 37.3"
108-308	14	18°18' 53.1"	88°11' 00.5"	208-408	18	18°14' 51.8"	88°15' 04.0"
109-309	15	18°18' 42.4"	88°11' 09.8"	209-409	16	18°16' 05.1"	88°15' 43.7"

Table 1 : GPS positions of the plots.

3.3. Choice of the season and sample organisation

3.3.1. The season

The choice of time of year was very important due to the strong seasonality of the climate (see section 2.2.3.). Indeed, in the Neotropical dry forest, the pattern of activity of Coleoptera is very seasonal and follow the rainfall pattern. Activity generally increases just at the end of the dry season (mid-May), with a maximum during the month of July (Noguera 1990), during the first good rains.

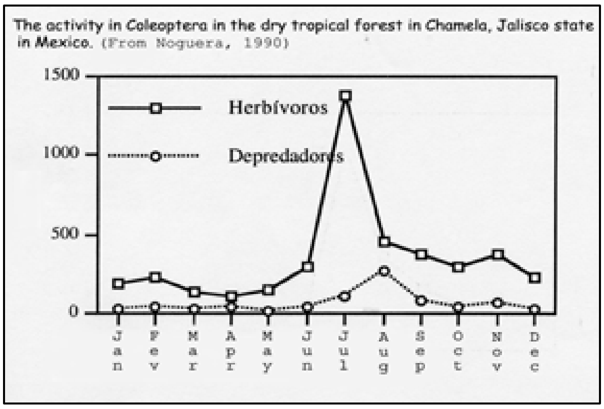


Fig. 3 : The very seasonal abundance of Coleoptera in a tropical dry forest.

Principally for this reason, the measures were collected between June and August. This season is called "the little rainy season" in Belize, because it is before the real rainy season (from September to December) (see section 2.2.3.).

3.3.2. Sampling timetable

The timetable was created to sample for each plot once per month for 3 days. As said before (section 3.2.1.), the traps were used from the 1st June to the 30th June 2002 and from the 6th July to the 4th August 2002. During these 60 days, all plots were visited twice.

In addition, insects were caught with a butterfly net once a week in each forest type, and nocturnal beetles were collected with a light trap once a week either in the Yucatecan semi-evergreen forest or in the low semi-deciduous forest.

Sampling schedule

Dates	Plots	Plots	Dates	Plots	Plots
01.06.02 - 03.06.02	100	202	06.07.02 - 08.07.02	300	402
04.06.02 - 06.06.02	106	205	09.07.02 - 11.07.02	306	405
07.06.02 - 09.06.02	102	209	12.07.02 - 14.07.02	302	409
10.06.02 - 12.06.02	103	203	15.07.02 - 17.07.02	303	403
13.06.02 - 15.06.02	107	200	18.07.02 - 20.07.02	307	400
16.06.02 - 18.06.02	104	207	21.07.02 - 23.07.02	304	407
19.06.02 - 21.06.02	109	201	24.07.02 - 26.07.02	309	401
22.06.02 - 24.06.02	105	208	27.07.02 - 29.07.02	305	408
25.06.02 - 27.06.02	101	204	30.07.02 - 01.08.02	301	404
28.06.02 - 30.06.02	108	206	02.08.02 - 04.08.02	308	406

Table 2 : Timetable of the studied plots.

3.4. Types and number of traps

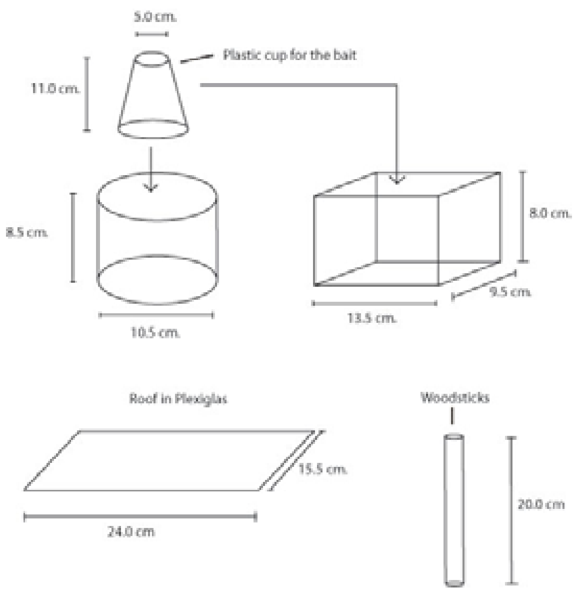
3.4.1. Dung-baited pitfalls, pitfall traps, sugar-baited pitfalls

This trap method involves a plastic cup that is buried up to the rim in the ground so that passing insects may fall in. Soapy water with alcohol can be put inside the cup to kill and conserve the insects, but the best method is to put antifreeze (ethylene glycol) as well, because antifreeze inhibits evaporation of the ethanol (that is crucial in tropical conditions). This allows the trap to be left for longer periods of time. Furthermore, a roof against the rain was necessary. A Plexiglas roof supported by sticks was used, because it does not stop the sunlight (a dark area during the day can influence the movement of a beetle (Greenslade 1964)).

To increase the catch and target specific insects it is possible to bait the trap. Dung, carrion, mushrooms or rotten fruit placed in a small cup near the rim are very attractive for many beetles. During the samples and for each plot, three types of pitfalls were used:

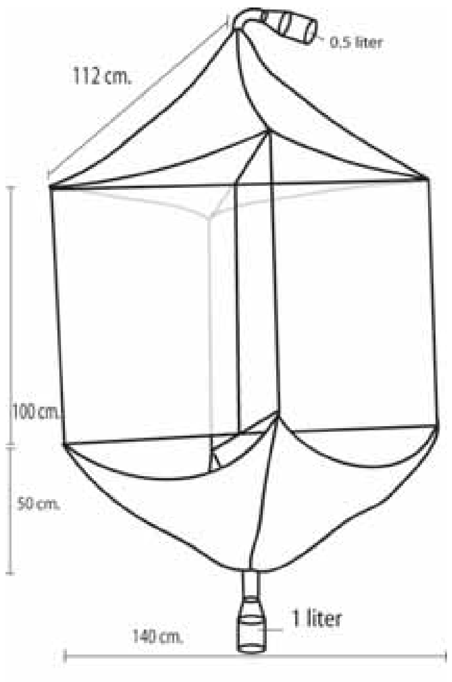
- 2 dung baited pitfalls with human dung.
- 2 sugar baited pitfalls with strawberry jam.
- 2 empty, classic pitfall traps.

In addition, two shapes were used for each type, one rectangular and one cylindrical, because the shape and the size can play a role in the efficiency of pitfall traps (Adis 1979).



3.4.2. Malaise traps and canopy Malaise trap

Invented by the Swedish entomologist Rene Malaise, the Malaise trap is based on the shape of a tent and is made from fine nets used to catch flying insects. A flying insect hits a vertical sheet of netting and instinctively flies up towards the light where a tilted, pitched roof guides it towards one end, where a hole in the netting allows it to pass into the collecting bottle. The collecting bottle can either be left dry or can be filled with a killing and preserving fluid, like alcohol or water and antifreeze.



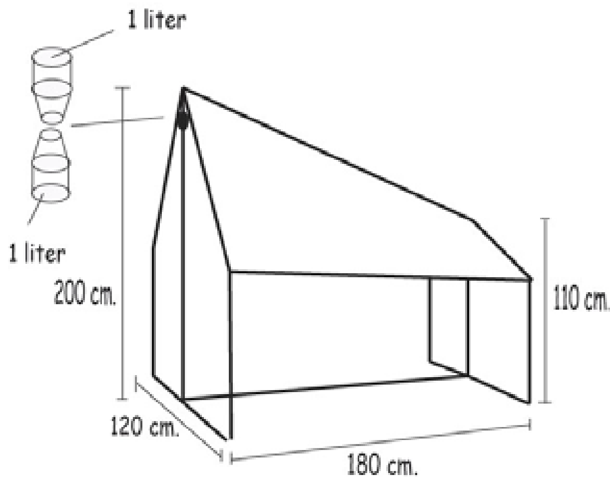


Fig. 7 : Ground Malaise trap.

Fig. 8 : Canopy Malaise trap.

A canopy malaise trap works on the same principle, but the form is clearly different and it is hung near the top of the trees in the canopy.

3.4.3. Flight intercept trap

This trap is designed to collect insects that drop when they encounter a barrier while flying. It is more suited to Coleoptera than the malaise trap (Godwin 1996). The net is erected at 90 degrees to a natural insect flight line like a hedge, a track or a clearing. When the insect reach the vertical blackish net, it drops into pans or a long pool containing soapy water and antifreeze.

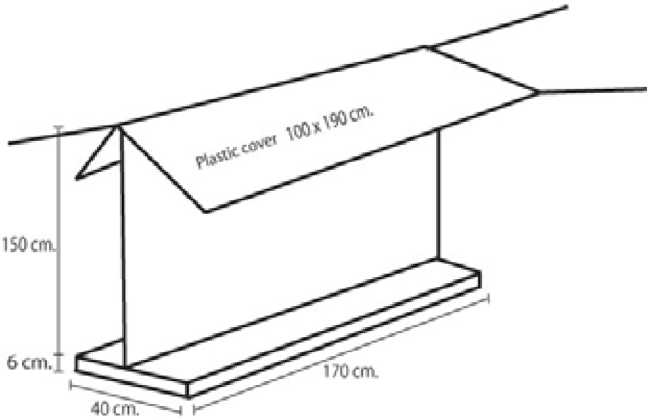


Fig. 9 : Dimensions of the flight intercept trap.

3.4.4. Light trap

Usually, this method attracts a great quantity of insects without great effort. A white sheet is suspended between two trees and a light is suspended so that it hangs a few centimetres away from the sheet. The sheet acts as a big reflector and as a substrate for attracted insects to land on. In Belize, a white sheet (115 cm.x 235 cm.) and a white light with a car battery were used once per week for this trap.

Generally black light (ultra-violet light) and white light (like mercury vapour light) are used together (Godwin 1996), but that was unfortunately not possible there.

3.4.5. Yellow pan trap

Two little yellow plastic bowls were putted out in each forest type. They were filled with slightly soapy water and a little ethylene glycol. Insects were attracted to the yellow colour and were drowned. This technique is usually directed at Hymenoptera, but Coleoptera and Diptera are also collected, sometime in abundance (Godwin 1996).

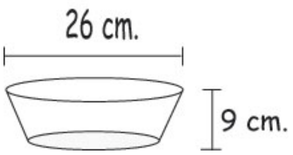


Fig. 10 : The yellow pan trap dimensions.

3.4.6. Butterfly net

As entomologists know, a simple walk through the vegetation with a butterfly net can be very efficient to catch a great diversity of insects. Thus, each forest was visited once a week for approximately two and a half hours. Naturally, the weather conditions and the period of the day played a key role in the efficiency of this method.

3.5. Environmental measures

3.5.1. Temperatures

Measures of temperature were taken for an uninterrupted stretch of 67 days, from 1st June to 6th August. The temperatures inside both forests were measured at 6h30 am and 13h00 pm each day.

3.5.2. Humidity

While measuring temperature, the electronic thermo-hygrometer (Oregon Scientific®) was also used to measure the relative humidity (in %).

3.5.3. Weather conditions

In addition, the weather conditions (rain, wind, cloud, sun) were recorded during all the sampling period. Some seasonal phenomena, such as the summer "little rainy season" or the "Belizean little dry" in the month of August (see the section 2.2.3.) can be demonstrated by these daily observations.

3.5.4. Canopy height

Above each plot, the height of the canopy Malaise trap in the top of the trees was measured with a graduate rope (the term canopy cannot be really used inside the low semi-deciduous forest, due to its vegetation structure). Thus, twenty heights were recorded for the purpose of determining the influence of the presence and the size of the trees on the distibution patterns of Coleoptera between the two forest types.

3.6. Geographic Information System (GIS)

Using a GPS computer, the positions and altitudes of the village of Sarteneja, the boundaries of the reserve, the roads, the trails and the plots were recorded to be mapping later. Together with an earlier vegetation study (Bijleveld 1998), these measures were used to draw a map of the vegetation of the Shipstern Nature Reserve (using Drawing Board II™ by Cal Comp and ArcGIS). Arcview 3.3. (by ESRI) was used to represent on the map the boundaries of the reserve, the plots and other objects (grid scale, tracks, roads, …) with explanatory legends.

3.7. Identification and statistical treatments

3.7.1. Identification

The purpose of this study is, for one part, to establish a first estimate of the biodiversity of Coleoptera within the Shipstern Nature Reserve. As mentioned above (section 2.5.), it was clearly impossible to work alone on the entire order due to its extraordinary diversity (more than 350'000 described species worldwide). Thus, the families of all the specimens were identified and the number of species in each family was determined by morphological criteria but without necessarily knowing the names of all these species.

Moreover, the second part of the study suggested that taxonomic level of the family would be inefficient for valuable statistical analyses. Thus, the family of the Scarabaeidae was chosen to be analysed more carefully. The species or at least the genera were identified for all the specimens (for more details, see "Scarabaeoidea of the Shipstern Nature Reserve, Belize" (Roeder 2003, unpublished)).

Recommended by numerous entomologists, the books American Beetles vol 1 & 2 (Arnett Jr., Thomas et al. 2002) were used as the principal book to identify families, subfamilies, genera and sometimes for the species taxonomic level. Nonetheless, many other identification keys as web sites and entomological articles were useful to identify the species and particularly for the Scarabaeidae specimens (Ratcliffe 2002). Finally, museum collections were visited to confirm some identifications such as Central Farm near San Ignacio in Belize and La Coleccion del Museo de Zoologia (Collegio de la frontiera sur) in Chetumal, Mexico.

3.7.2. Statistical treatments

The diversity data was examined graphically at the family and species level, and in more detail for the Scarabaeidae to compare trap efficiency.

Finally, for the comparative approach between the two forest types, statistical analyses were carried out with the software SPSS 11.0 for Windows.

4. Results

All the results have been presented with the same structure, with the general diversity data in first part, followed by the comparison between the two forest types. The two first sections present the results of the global diversity of Coleoptera and the richness of the Scarabaeidae family. The third section gives the details of the temperatures, humidity, and canopy height at each plot. The fourth section goes further in statistical analyses to describe the effect of these abiotic factors on the abundance of scarab beetles. Finally, the fifth section illustrates the result of the mapping of the Shipstern Nature Reserve as a tool for biodiversity estimation.

4.1. Coleoptera of Shipstern Nature Reserve

The general coleopteran diversity presented here is the result of two months sampling using all the trap types within the low semi-deciduous forest and the Yucatecan semi-evergreen forest only.

4.1.1. Global diversity - suborders and superfamilies

These taxa allow to present rapidly all the biodiversity of Coleoptera inside the reserve but are very poor in detailed informations about species and their environment.

Order	Suborder	Superfamily	Number total of species
Coleoptera	Polyphaga	Scarabaeoidea	39
		Chrysomeloidea	72
		Curculionoidea	39
		Elateroidea	32
		Scirtoidea	3
		Buprestoidea	10
		Cleroidea	7
		Tenebrionoidea	23
		Cucujoidea	10
		Bostrichoidea	9
		Hydrophiloidea	6
		Staphylinoidea	13
	Adephaga		9
			272 species

Table 3 : Superfamilies and their number of respective species caught inside the reserve.

In Table 3, we can notice that the superfamily taxonomic level does not exist in the suborder Adephaga, because this taxa is divided directly into families as the Carabidae (ground beetles) and Dytiscidae (water beetles) for example.

To clarify Table 3, a graph representing the proportions of these taxa can be made (see Fig. 11):

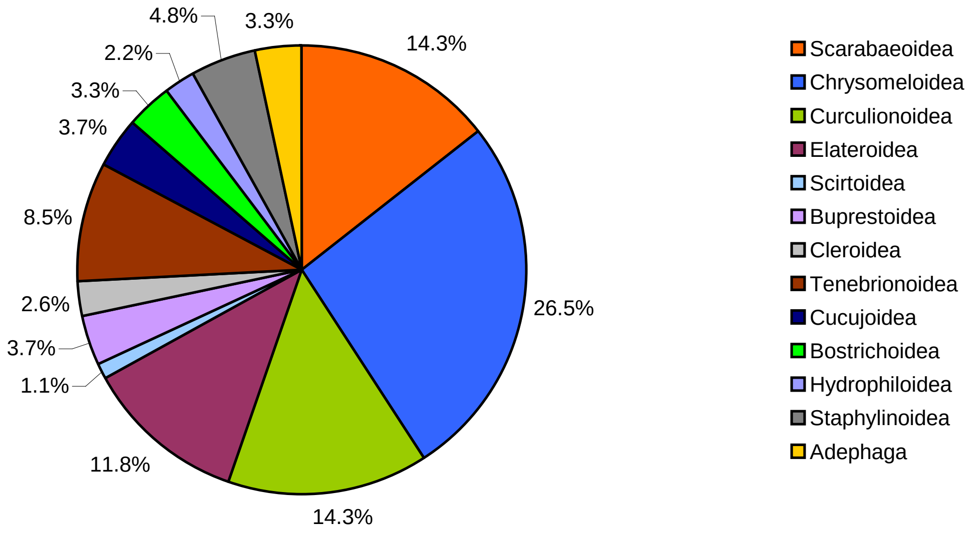


Fig. 11: Respective proportions of the superfamilies of the Polyphaga and the suborder Adephaga.

The same colours will be used in later graphs. For example, the longhorn beetles (Cerambycidae), the leaf beetles (Chrysomelidae) and the seed beetles (Bruchidae) belong to the same superfamily (Chrysomeloidea) and will always be represented in various blue colours.

4.1.2. Diversity of the families

Generally, each suborder or superfamily contains many families. This taxa is more specific and some families are typical to one region of the world and sometimes to one determined area. During the Belizean “little rainy season”, the 272 species found belonged to 38 families. It can appear quite poor, but many families like the leaf beetles (Chrysomelidae) are divided in numerous subfamilies (eleven for the Chrysomelidae, (Arnett Jr. & al. 2002)).

The 38 families are presented in Table 4, with detailed informations about their number of species occuring within the two forest types:

Coleoptera families of the Shipstern Nature Reserve, Belize

Family	Yucatecan forest	Low sem-d. forest	Both forests	TOTAL SPECIES
Scarabaeidae	16	5	14	35
Passalidae	1	0	1	2
Trogidae	0	1	0	1
Geotrupidae	1	0	0	1
Cerambycidae	16	16	5	37
Bruchidae	0	1	0	1
Chrysomelidae	19	7	8	34
Curculionidae	15	7	4	26
Brenthidae	4	0	0	4
Attelabidae	3	2	0	5
Anthribidae	2	1	1	4
Lampyridae	4	1	0	5
Phengodidae	0	0	1	1
Cantharidae	2	0	1	3
Lycidae	5	0	0	5
Omethidae	2	0	1	3
Elateridae	8	4	3	15
Clambidae	1	2	0	3
Buprestidae	4	5	1	10
Trogossitidae	2	1	0	3
Melyridae	2	0	0	2
Cleridae	1	1	0	2
Tenebrionidae	7	3	2	12
Mordellidae	4	5	1	10
Meloidae	1	0	0	1
Erotylidae	2	0	1	3
Nitidulidae	2	1	0	3
Coccinellidae	3	0	1	4
Bostrichidae	2	1	1	4
Anobiidae	2	2	1	5
Histeridae	3	0	1	4
Hydrophilidae	2	0	0	2
Staphylinidae	5	3	1	9
Silphidae	1	1	2	4
Carabidae	1	3	0	4
Rhysodidae	0	1	0	1
Cicindelidae	0	2	0	2
Dytiscidae	2	0	0	2
	145	76	51	272

Table 4 : Detailed table of the families present in the Shipstern Nature reserve, Belize.

Table 4 can be also be summarised graphically (Fig. 12), with the relative proportions in species of each family without comparison between the Yucatecan semi-evergreen forest and the low semi-deciduous.

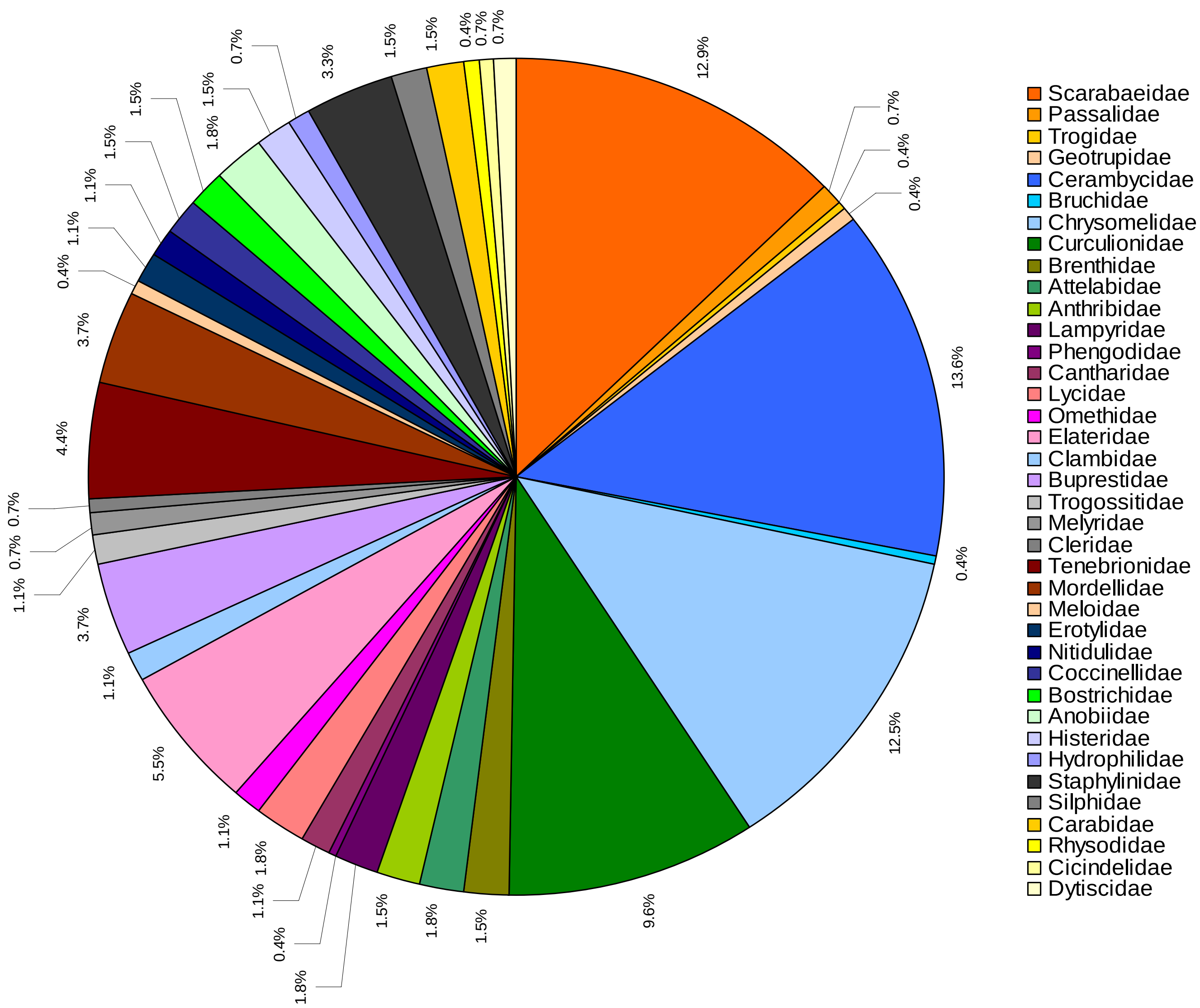


Fig. 12 : Proportions of each families in the total, without comparison between the both forests.

The discussion will explain later that these results have to be taken with cautions, because the traps are more efficient for some families than others (section 5.1.).

4.1.3. Comparison of the two forest types with the family taxonomic level

Fig. 13 represents the families and their respective number of species in each forest type.

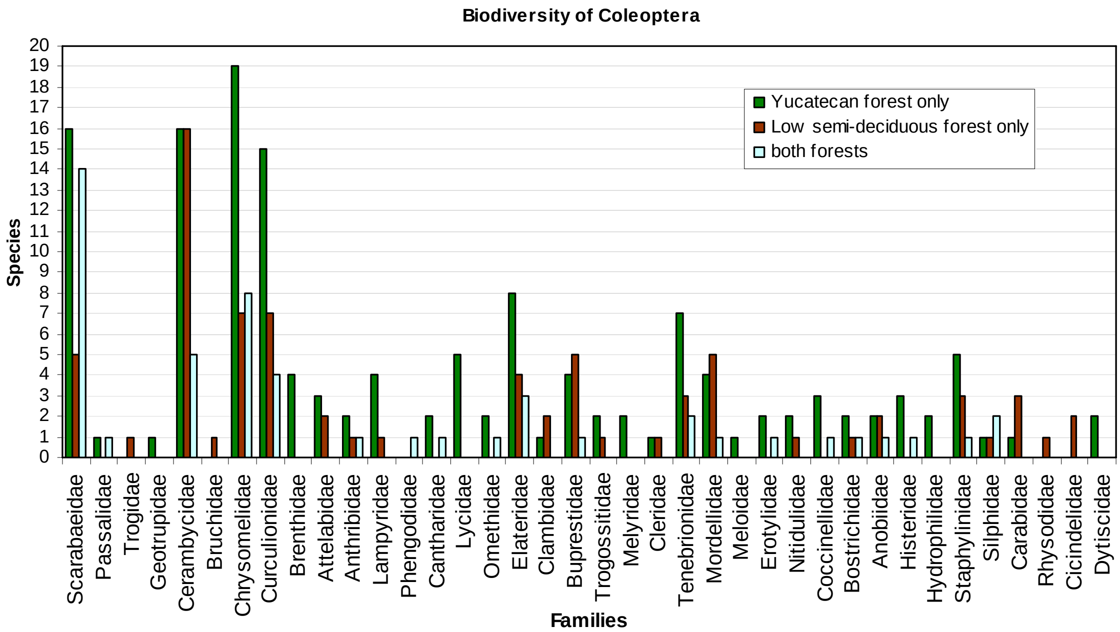


Fig. 13 : Biodiversity of Coleoptera, number of species per family and per forest type.

From Fig. 13 and considering the 272 species only, the richness in species of each type of forest can be compared (Fig. 14). For example, 145 species on the 272 caught can be found in the Yucatecan semi-evergreen forest only. The abundance of these species is not taken in consideration.

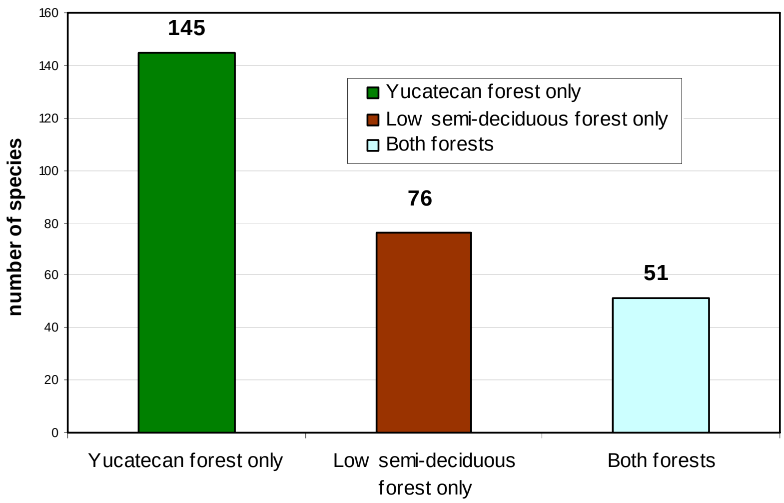


Fig. 14 : Complete diversity of species per type of forest.

4.2. Diversity of the Scarabaeidae family

4.2.1. General sampling

Overall, 4834 identified specimens of scarab beetles (Scarabaeidae) were caught in two months, but the efficiency of each kind of trap varied greatly. This point was crucial for the future data analyses.

Scarabaeidae of the Shipstern Nature Reserve	
Type of trap	beetles
Pitfall and bait traps	4202
Flight intercept traps	346
Malaise traps	72
Butterfly net	144
Light trap	70
Total	4834

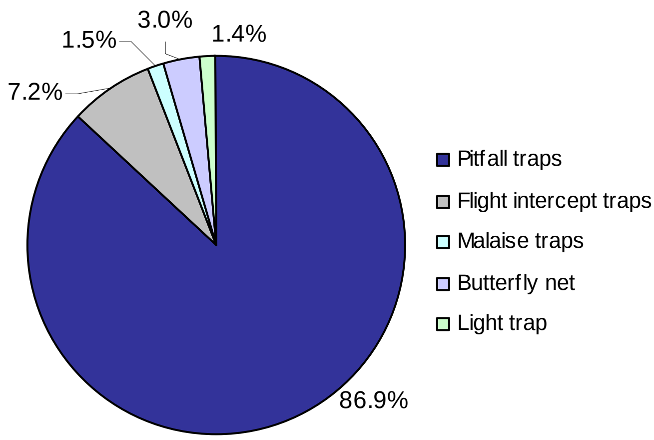


Table 5 & Fig. 15 : Effectiveness of the types of traps.

4.2.2. Diversity of the scarab beetles

Table 6 gives the 35 species of Scarabaeidae caught during two months, with all trap types. For more detailed information and pictures an annexe is available separately ("Scarabaeoidea of Shipstern Nature Reserve, Belize" (Roeder, 2003 unpublished)).

Scarabaeidae of Shipstern Nature Reserve

Species of Scarabaeidae		Yucatecan forest	Low semi-d. forest	Total specimens
Phanaeus pilatei	Harold, 1863	74	48	122
Phanaeus sp.		41	0	41
Deltochilum gibbosum sublaeve	Bates, 1887	46	31	77
Deltochilum lobipes	Bates, 1887	18	11	29
D. scabrisculum scabrisculum	Bates, 1887	47	0	47
Deltochilum sp.		0	3	3
Dichotomius centralis	Harold, 1869	75	23	98
Copris lugubris	Boheman, 1858	104	56	160
Coprophanaeus telamon corythus	(Harold, 1863)	1	2	3
Canthon cyanellus cyanellus	LeConte, 1859	388	472	860
Canthon viridis championi	Bates	748	880	1628
Sisyphus mexicanus	Harold, 1863	5	0	5
Canthidium sp.		17	106	123
Ateuchus illaesum	(Harold, 1868)	0	358	358
Onthophagus sp. 1		24	11	35
Onthophagus sp. 2		183	0	183
Onthophagus sp. 3		333	86	419
Ontherus sp. 1		157	0	157
Ontherus sp. 2		83	130	213
Euparia castanea	Serville, 1828	6	0	6
Euphoria sp.		4	0	4
Lissomelas sp.		4	0	4
Amithao cavifrons	(Burmeister, 1842)	11	0	11
Euphoria sp.		0	69	69
Euphoria sp.		0	17	17
Trigonopeltastes sp.		0	20	20
Strategus Aloeus	(Linnaeus, 1758)	5	0	5
Coelosis biloba	(Linnaeus, 1767)	7	0	7
Phileurus valgus	(Olivier, 1789)	4	0	4
Megasoma elephas	(Fabricius, 1775)	3	0	3
Pelidnota centroamericana	Ohaus, 1913	3	1	4
Pelidnota sp.		3	0	3
Phyllophaga yucateca	Bates, 1889	4	0	4
Phyllophaga parvisetis	(Bates)	31	73	104
Phyllophaga hondura	Saylor, 1943	8	0	8
Total		2437	2397	4834

Table 6 : Detailed data on scarab beetles of the Shiptern Nature Reserve.

Of course, these 35 species vary greatly in abundance and Fig. 16 shows that two species: *Canthon cyanellus cyanellus* LeConte and *Canthon viridis championi* Bates, represent more than the half of all the Scarabaeidae specimens caught during this study.

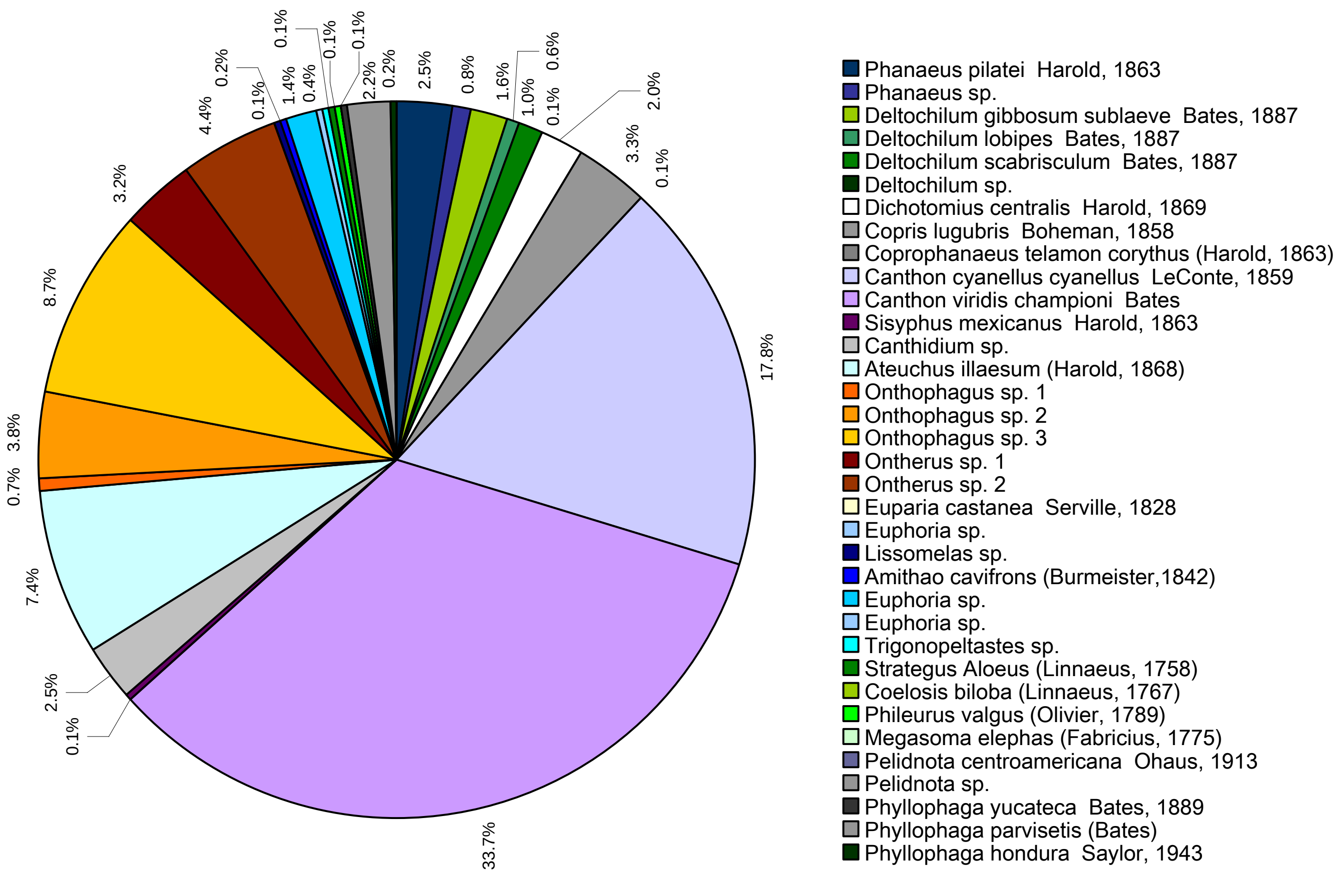


Fig. 16 : Relative proportions of all the species of the scarab beetles.

4.2.3. The scarab beetles used to compare the both forests

From the results above, some obvious comparisons can be made between the two forest types. In first part, some quantitative results :

The catchs of the Scarabaeidae during the sampling period

Traps	Low semi. June	Low semi. July	Yucatecan June	Yucataecan July
pitfall	798	1222	1170	1012
intercept	100	108	36	102
malaise	24	11	10	27
net	61	27	27	29
light	34	12	18	6
Total	1017	1380	1261	1176

Table 7 : Comparison of the catches of Scarabaeidae specimens between both forests.

Thus, over a period of two months, there was a difference between the two forests of just 40 individuals. However the species richness of each forest type is more interesting, because many species are specific to one kind of forest:

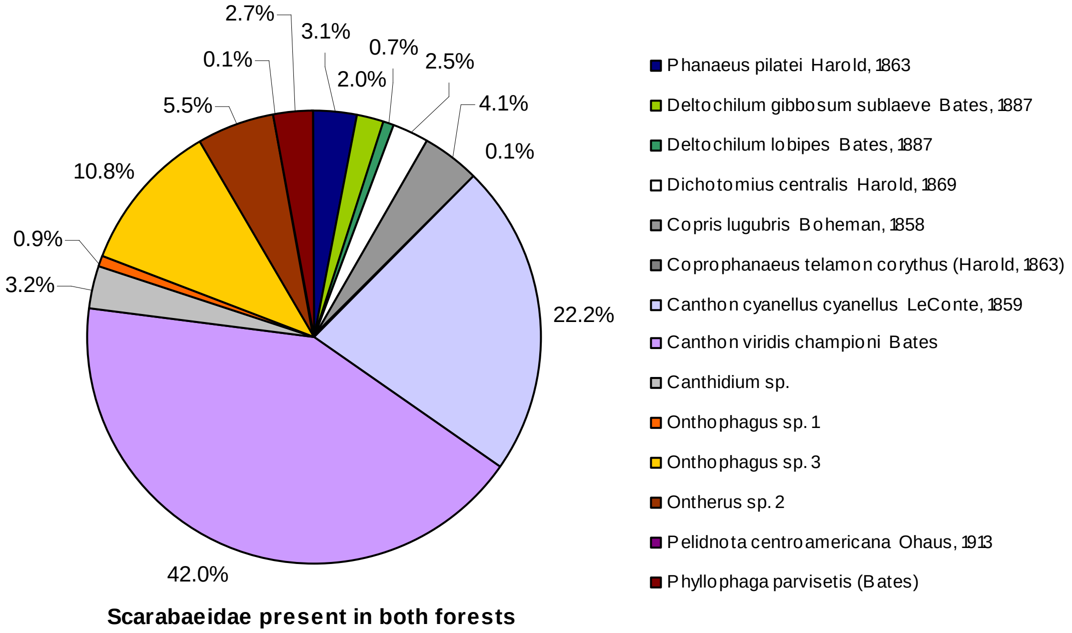


Fig. 17 : Species (Scarabaeidae) occuring in both forest types.

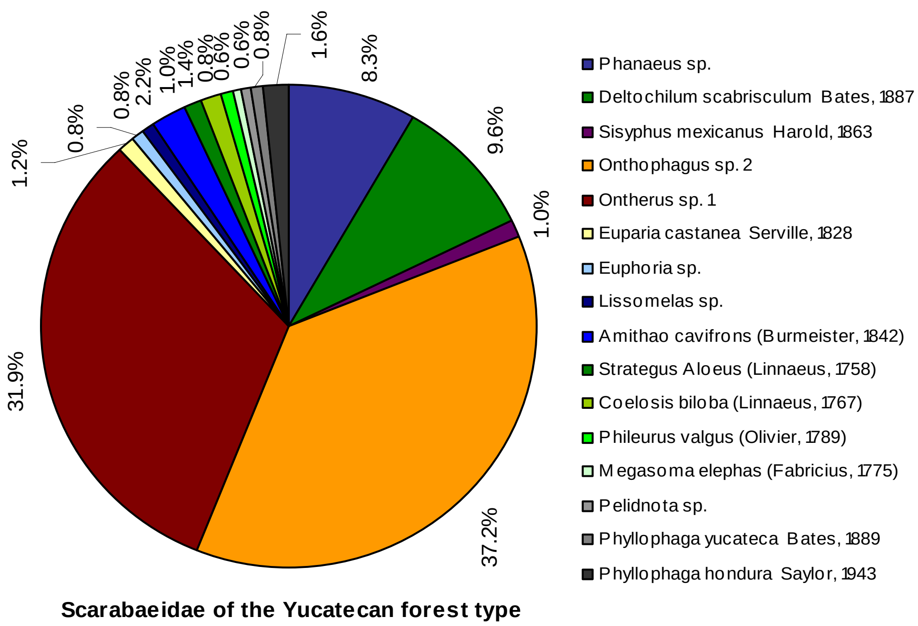


Fig. 18 : Species (Scarabaeidae) specific to the Yucatecan semi-evergreen forest.

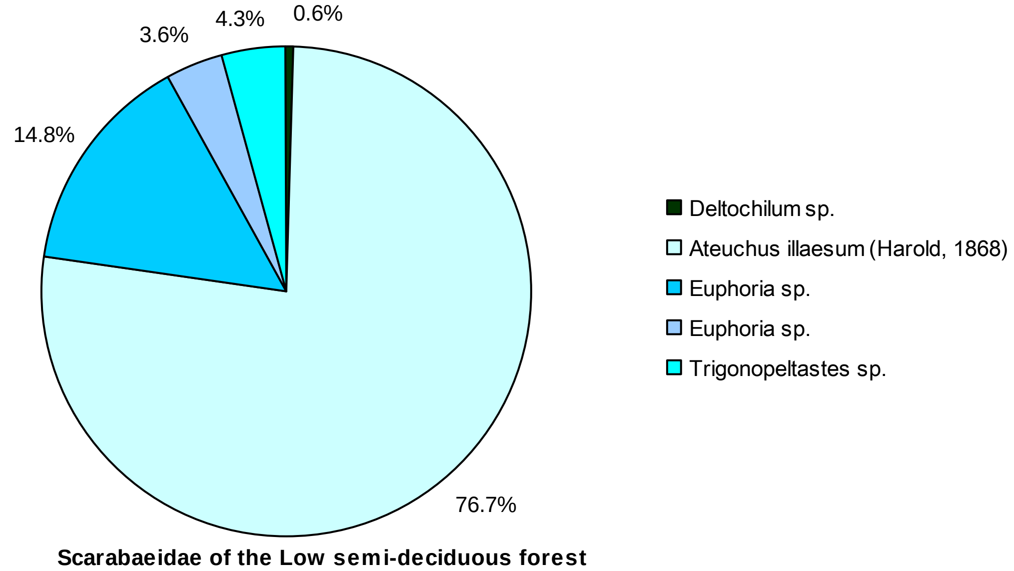


Fig. 19 : Species (Scarabaeidae) specific to the low semi-deciduous forest.

4.2.4. Dung baited traps and pitfall traps results

Due to the great effectiveness of the dung baited pitfall traps (section 4.2.1.), this was the only data used for the statistical treatments. Except in rare cases (two or three June beetles (Melolonthinae)), Fig. 20 & 21 concern dung beetles species (2 families, 20 species and 4202 specimens).

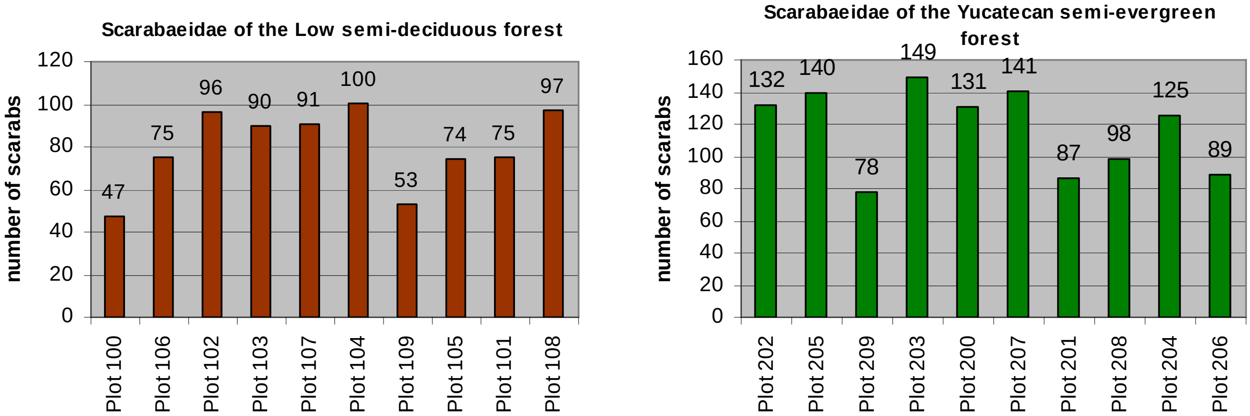


Fig. 20 : Specimens of Scarabaeidae caught per plot during the month of June.

In these histograms, the data are plotted in the same chronological order that they were collected.

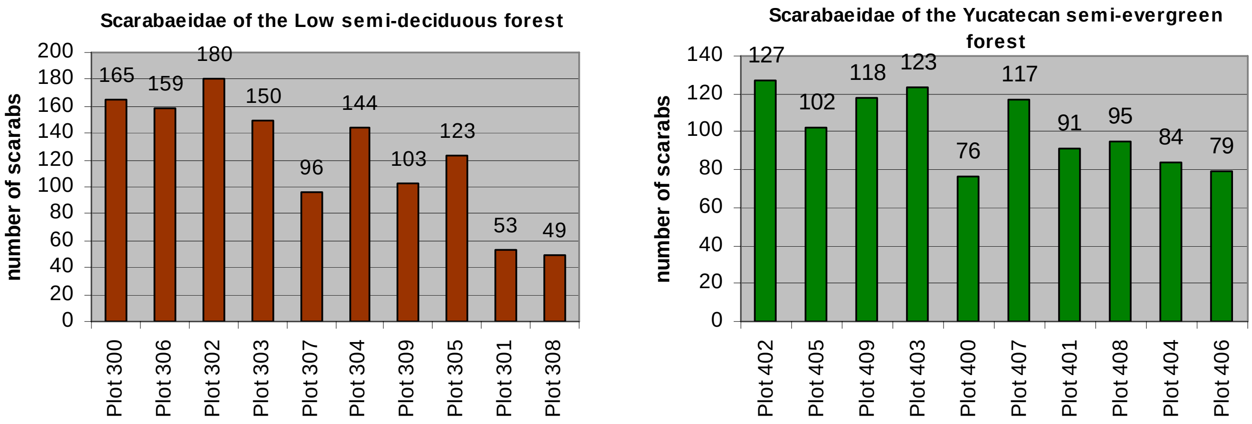


Fig. 21 : Specimens of Scarabaeidae caught per plot from 6th July to 4th August.

4.3. Measures of the non-biotic factors

4.3.1. Temperature

4.3.1.1. General data

67 temperatures were measured at 06h30 and at 13h00 in both forests. Nonetheless, each plot was visited during three days and thus, means of the temperatures for each three days were calculated to be able to compare with the amount of scarab beetles caught at the same time.

Fig. 22 & 23 show the mean temperatures at each sampling plot :

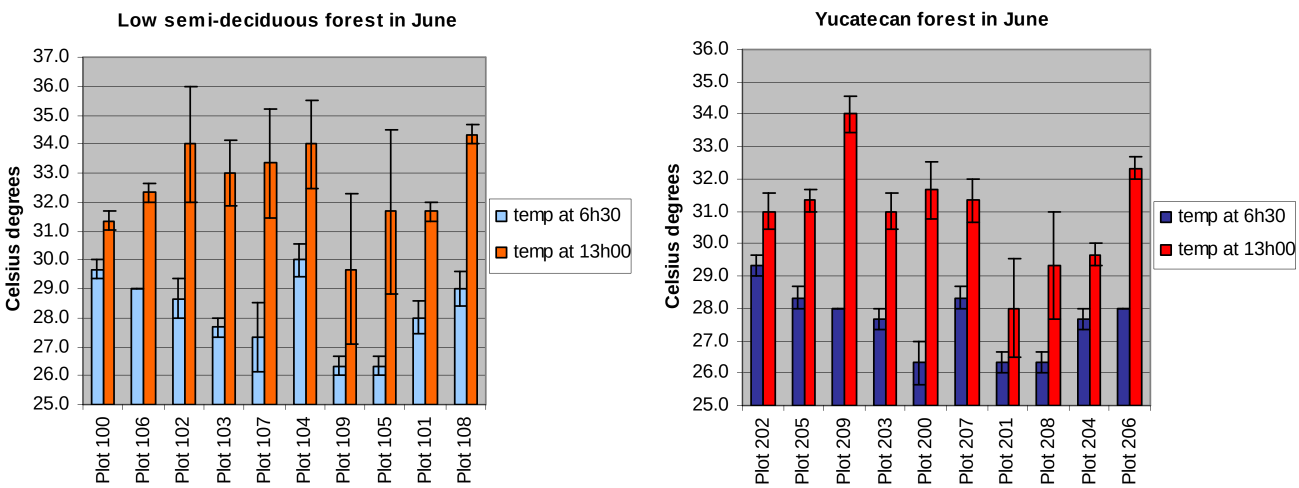


Fig. 22 : Mean temperatures with standard errors within the two forest types during the first sampling period.

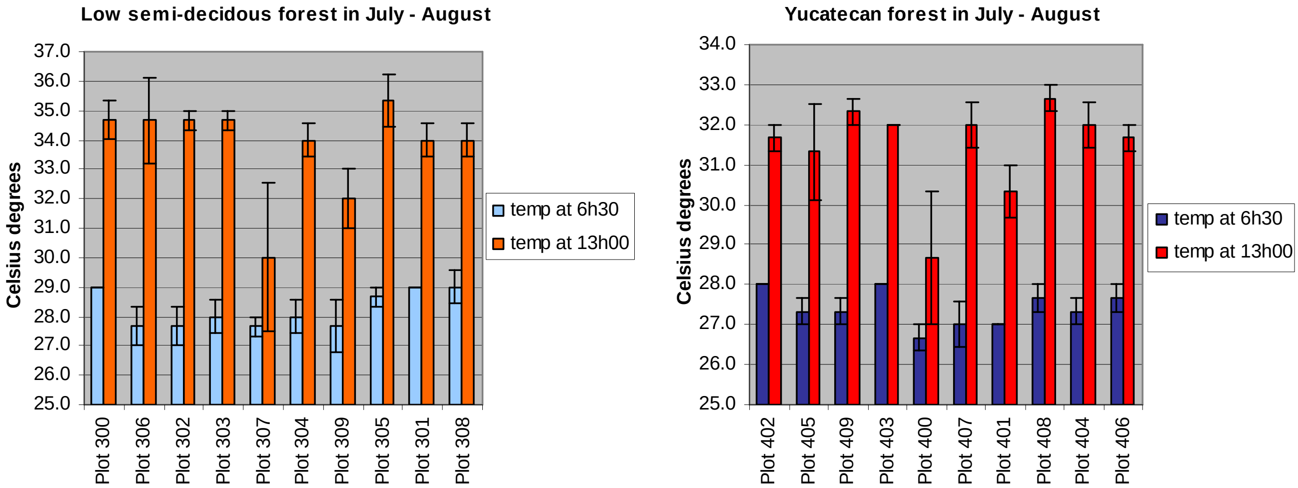


Fig. 23 : Mean temperatures with standard errors within the two forest types during the second sampling period.

4.3.1.2. The temperature in the two forest types

The areas of the two forest types are very close, but Table 8 shows a significant difference between their temperatures as illustrated by Fig. 24.

	t	df	P
temp. at 6h30	-3.915	132	0.000
temp. at 13h00	5.379	132	0.000

Table 8 : Two samples T-test comparing the temperatures between the two forest types in the morning and in the afternoon.

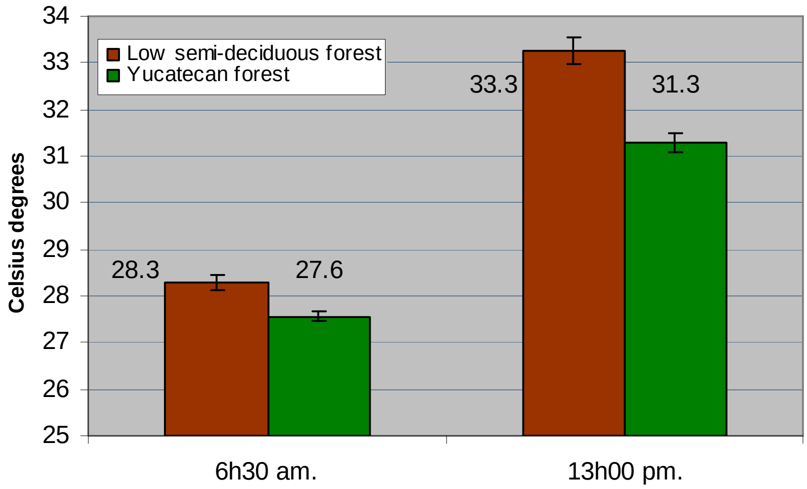


Fig. 24 : Mean temperatures in the morning and afternoon (on 67 days) in the two forest types.

The low semi-deciduous forest appears to be the hottest forest from the two.

In addition, Table 9 shows that the range of temperatures is greater in the low semi-deciduous forest.

		min	max
Low semi-d. forest	temp at 6h30	25	31
	temp at 13h00	25	38
Yucatecan forest	temp at 6h30	25	30
	temp at 13h00	25	35

Table 9 : Amplitude of the temperatures (in C°) in the two forests.

4.3.2. Humidity

4.3.2.1. General data

The exact same method was used to compare the means of relative humidity (in %) while the plots were sampled :

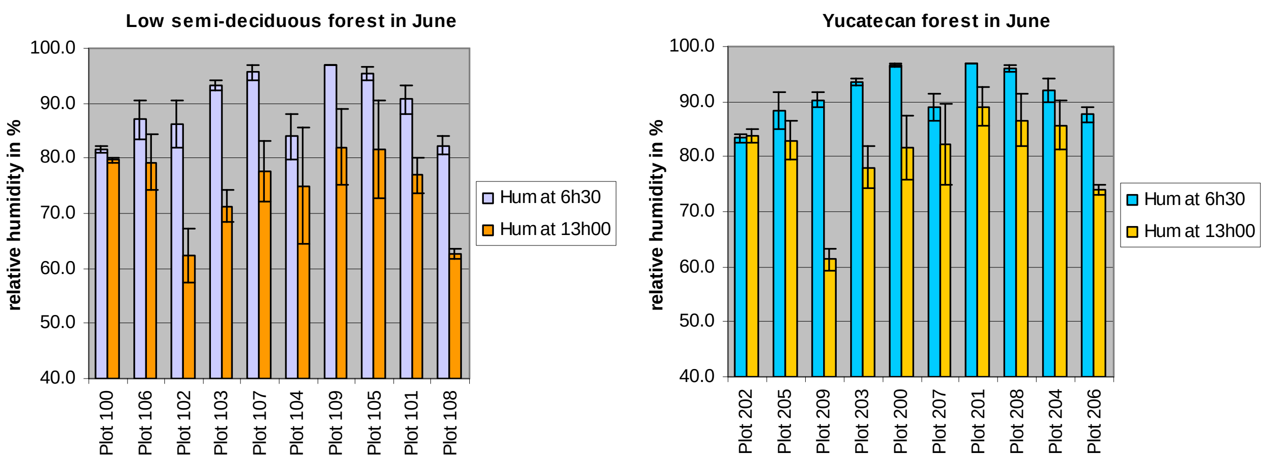


Fig. 25 : Mean of the relative humidity with standard errors within the two forest types during the first sampling period.

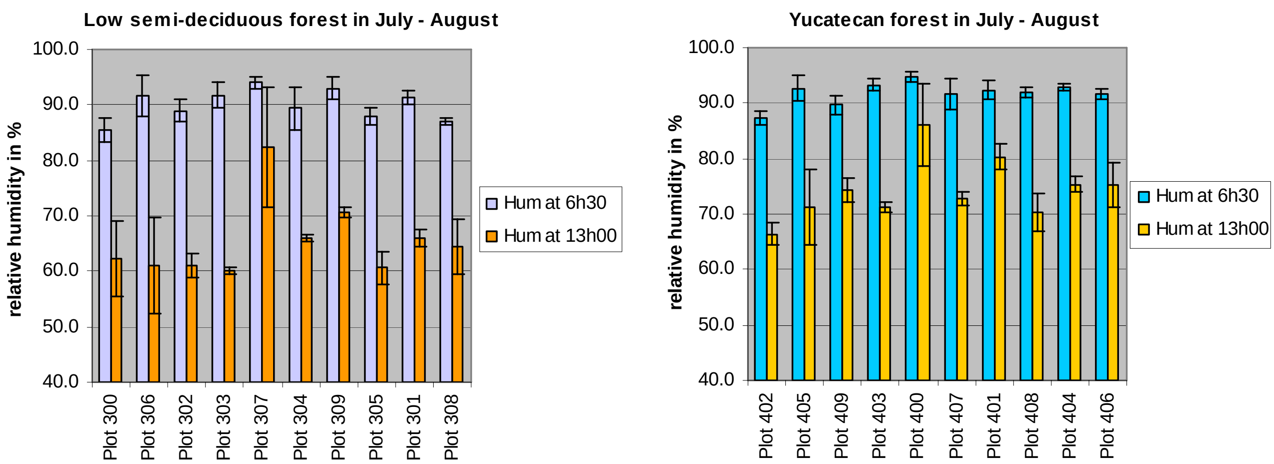


Fig. 26 : Mean of the relative humidity with standard errors within the two forest types during the second sampling period.

4.3.2.2. The relative humidity in the two forest types

Like temperature, relative humidity seems to differ between the two forests, and the low semi-decidous forest is effectively a Neotropical dry forest. Table 10 shows a significant difference between their temperatures as illustrated by Fig. 27.

	t	df	P
humidity at 6h30	2.329	132	0.021
humidity at 13h00	4.239	132	0.000

Table 10 : Two samples T-test comparing the relative humidity between the two forest types in the morning and in the afternoon.

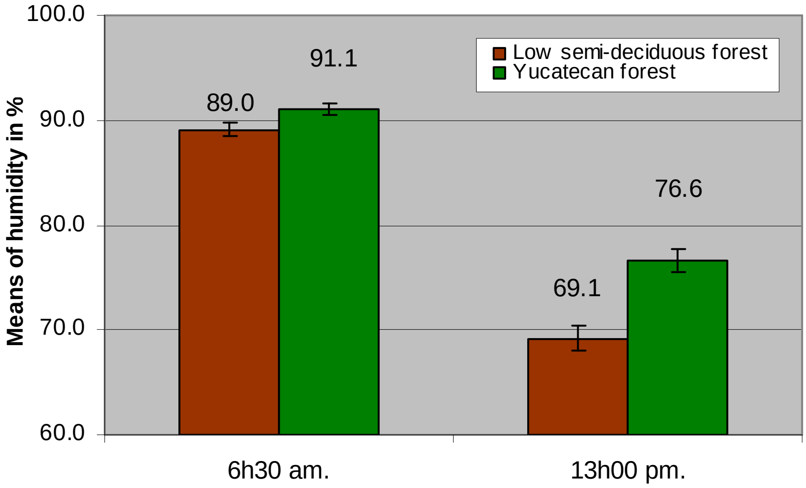


Fig. 27 : Mean of the relative humidity in the morning and afternoon (on 67 days) in the two forest types.

As shown in Table 11, the variation in humidity is also greater in the low semi-decidous forest, leading to a less stable environment for the Coleoptera.

		min	max
Low semi-d. forest	hum. at 6h30	77	97
	hum. at 13h00	51	97
Yucatecan forest	hum. at 6h30	82	97
	hum. at 13h00	58	97

Table 11 : Amplitude of the relative humidity (in %) in the two forests.

4.3.3. Height of the canopy Malaise trap

Does the height of the trees influence coleopteran abundance or the effectiveness of sampling? To answer to this question, all heights of the canopy Malaise trap were measured as shown in Table 12.

canopy Malaise trap Low semi-deciduous forest		canopy Malaise trap Yucatecan forest	
Plot number	height (m.)	Plot number	height (m.)
108-308	5.60	202-402	15.56
100-300	6.26	205-405	11.10
106-306	8.04	209-409	9.05
102-302	7.36	203-403	14.10
103-303	7.31	200-400	10.10
107-307	9.05	207-407	13.35
104-304	7.98	201-401	12.40
109-309	8.19	208-408	14.45
105-305	6.63	204-404	8.90
101-301	8.05	206-406	12.90

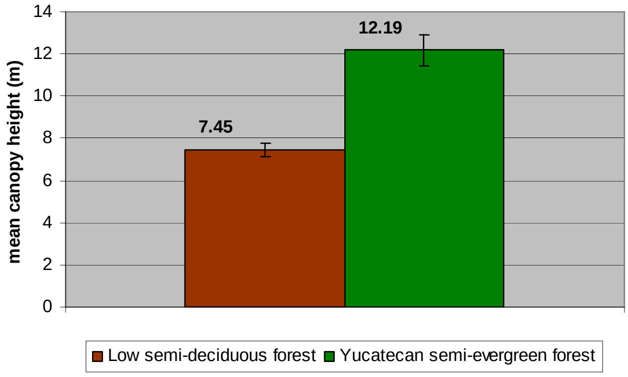


Table 12 & Fig. 28 : Positions and mean height of the canopy Malaise trap above the ground (m) in the two forests.

The means of the positions of the canopy Malaise trap show a great difference illustrated in Fig. 28. The canopy of the Yucatecan semi-evergreen forest is significantly higher (T-test, $t = -5.916$, $df = 18$, $P < 0.001$) and far more leafy than in the dry forest. In reality, we can say that the term canopy does not apply to the dry forest, due to its open and weakly organized structure.

4.4. Ecological study

All the results above show a clear difference in coleopteran biodiversity between the low semi-deciduous forest and the Yucatecan semi-evergreen forest. The abiotic factors reveal the same conclusions. What I have tried to do in this part of the study, is to understand how abiotic factors might influence the presence and abundance of dung beetles species (Scarabaeinae and Aphodiinae) inside these two very different kinds of forest.
The vegetation types certainly play a key role, but I have tried to correlate the quantity of captures in each plot with height of the canopy and weather conditions during the sampling period.

4.4.1. Further analyses on abiotic factors

The temperature and humidity are very different between the two forests (sections 4.3.1.2. & 4.3.2.2.), but other analyses were made and some interesting results were obtained.

4.4.1.1. Temperature

Morning and afternoon temperatures are very poorly correlated within the same forest :

- Inside the Yucatecan semi-evergreen forest

Pearson Correlation: R = 0.333 (N = 67, P < 0.01) (one-tailed)

Linear regression: R^2 = 0.111

- Inside the low semi-deciduous forest

Pearson Correlation: R = 0.260 (N = 67, P < 0.05) (one-tailed)

Linear regression: R^2 = 0.068

But temperatures at the same time of the day are strongly correlated between the two forests:

- At 6h30 am

Pearson Correlation: R = 0.773 (N = 67, P < 0.01) (one-tailed)

Linear regression: R^2 = 0.597

- At 13h00 pm

Pearson Correlation: R = 0.806 (N = 67, P < 0.01) (one-tailed)

Linear regression: R^2 = 0.650

4.4.1.2. Humidity

Morning and afternoon relative humidity is very poorly correlated within the same forest :

- Inside the Yucatecan semi-evergreen forest

Pearson Correlation: R = 0.395 (N = 67, P < 0.01) (one-tailed)

Linear regression: R^2 = 0.156

- Inside the low semi-deciduous forest

Pearson Correlation: R = 0.420 (N = 67, P < 0.01) (one-tailed)

Linear regression: R^2 = 0.176

But relative humidity at the same time of the day are strongly correlated between the two forests :

- At 6h30 am

Pearson Correlation: R = 0.902 (N = 67, P < 0.01) (one-tailed)

Linear regression: R^2 = 0.814

- At 13h00 pm

Pearson Correlation: R = 0.861 (N = 67, P < 0.01) (one-tailed)

Linear regression: R^2 = 0.741

4.4.1.3. Relation between temperature and humidity

Humidity and temperature are negatively correlated in both forest types as relative humidity depends on the temperature:

- Inside the Yucatecan semi-evergreen forest
  - At 6h30 : Pearson Correlation: R = -0.662 (N = 67, P < 0.01) (two-tailed)
    Linear regression: $R^2 = 0.438$
  - At 13h00 : Pearson Correlation: R = -0.826 (N = 67, P < 0.01) (two-tailed)
    Linear regression: $R^2 = 0.682$

- Inside the low semi-deciduous forest
  - At 6h30 : Pearson Correlation: R = -0.749 (N = 67, P < 0.01) (two-tailed)
    Linear regression: $R^2 = 0.561$
  - At 13h00 : Pearson Correlation: R = -0.839 (N = 67, P < 0.01) (two-tailed)
    Linear regression: $R^2 = 0.704$ (see Fig. 29)

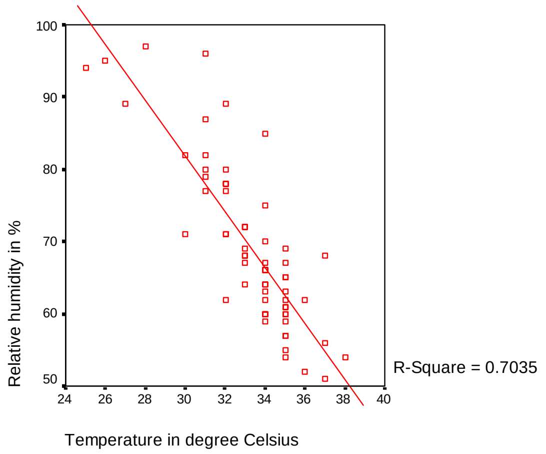


Fig. 29 : Humidity as a function of the temperature in the low semi-decidous forest at 13h00.

Fig. 29 demonstrates that if temperature rises then humidity drops. Thus, temperature alone was used for further statistical treatments, because it also includes the effects of humidity.

4.4.2. Behaviour of the dung beetles in relation to abiotic factors

The Scarabaeidae specimens caught during three days in each of the ten plots (Fig. 20 & 21) have been compared with the mean temperature of the same three days (Fig. 22 & 23) and with the height of the canopy Malaise trap (Table 12). The analyses were made in two parts, first sampling (during June) and second sampling (from 6th July to 4th August), except when comparison was made with canopy height, because these latter were exactly the same between the two sampling periods. In addition, during the month of August, the end of the sampling in both forests met the Belizean "little dry" (section 2.2.3.). Therefore, for the second period of sampling, the tests of correlation were made first with 10 means (temperatures and number of dung beetles caught) and then only with the first 7 values (the three last being influenced by the dryness) to prove the influence of this climatic phenomenon. By this method, I tried to understand the effects of the abiotic factors on the activity pattern of the dung beetles.

4.4.2.1. Effects of the temperature in the Yucatecan semi-evergreen forest

- Effect on the dung beetles, at 6h30 am :

		1st Sampling	2nd Sampling
		temp. at 6h30	temp. at 6h30
Scarabaeidae	Pearson Correlation (R)	0.339	0.472
	P (one-tailed)	0.169	0.084
	N	10	10
	Linear regression (R-Square)	0.115	0.222

Both correlations are not significant ($P > 0.05$)

Table 13 : The morning temperature does not affect the abundance of the dung beetles.

Obviously, the morning temperature does not influence the behaviour of the dung beetles.

- Effect on the dung beetles, at 13h00 pm :

The pattern of abundance of the dung beetles in this forest type shows a clear maximum when temperatures lie between 30° C. and 32° C.

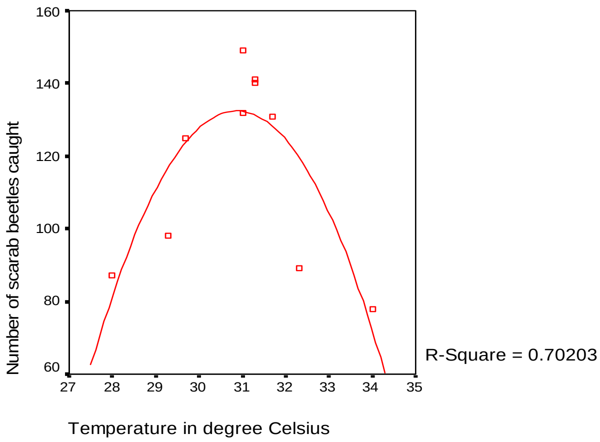


Fig. 30 : Abundance of dung beetles as a function of the temperature at 13h00 in the Yucatecan semi-evergreen forest, having for equation:

$$y = -6.170x^2 + 380.988x - 5748.550$$

Thus, a quadratic regression was executed to this part of the analyse:

- First Sampling (from 1st June to 30th June)

		1st Sampling
		temp. at 13h00
Scarabaeidae	Quadratic regression (R-Square)	0.70203
	P	0.0144
	N	10

Correlation is significant ($P < 0.05$)

Table 14 : Abundance of dung beetles as a function of the temperature at 13h00 in the Yucatecan semi-evergreen forest.

- Second sampling (from 6th July to 4th August)

The influence of the temperature on the abundance of dung beetles is exactly the same as in the first sampling, but the three last samples are unusual for the conditions, thus they were separated for the analyses. This method revealed a strong influence of the dryness on the dung beetles.

		With little dry	Without l. dry
		temp. at 13h00	temp. at 13h00
Scarabaeidae	Pearson Correlation (R)	0.500	0.933
	P (one-tailed)	0.070	0.001
	N	10	7
	Linear regression (R-Square)	0.250	0.870

Correlation is significant ($P<0.01$) for the values without the little dry effect

Table 15 : Correlation during the second sampling, with and without the effect of the Belizean "little dry".

Obviously, the dryness plays an important role in the abundance of the dung beetles.

4.4.2.2. Effects of the temperature in the low semi-deciduous forest

- **Effect on the dung beetles, at 6h30 am :**

		1st Sampling	2nd Sampling
		temp. at 6h30	temp. at 6h30
Scarabaeidae	Pearson Correlation (R)	0.244	-0.460
	P (one-tailed)	0.249	0.091
	N	10	10
	Linear regression (R-Square)	0.059	0.212

Both correlations are not significant ($P > 0.05$)

Table 16 : The morning temperature does not affect the abundance of the dung beetles.

- **Effect on the dung beetles, at 13h00 pm :**

The pattern of abundance of the dung beetles in this forest type shows a linear relation.

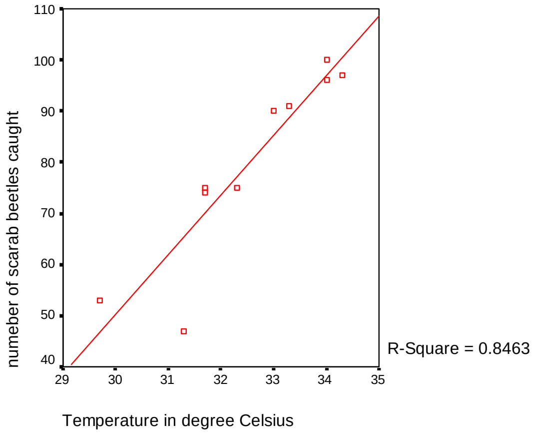


Fig. 31 : Abundance of dung beetles as a function of the temperature at 13h00 in the low semi-deciduous forest.

The behaviour of the dung beetles against the temperature is really different in the low semi-decidous forest. Appropriately, a linear regression was executed to this part of the analyse:

- First sampling (from 1st june to 30th June)

		1st Sampling
		temp. at 13h00
Scarabaeidae	Pearson Correlation (R)	0.920
	P (one-tailed)	0.000
	N	10
	Linear regression (R-Square)	0.846

Correlation is significant (P < 0.01)

Table 17 : Abundance of dung beetles as a function of the temperature at 13h00 in the low semi-deciduous forest.

- Second sampling (from 6th July to 4th August)

Temperature is a beneficial factor for the activity of the dung beetles, but the dryness causes difficulties in this Neotropical dry forest :

		With little dry	Without l. dry
		temp. at 13h00	temp. at 13h00
Scarabaeidae	Pearson Correlation (R)	0.391	0.925
	P (one-tailed)	0.132	0.001
	N	10	7
	Linear regression (R-Square)	0.153	0.856

Correlation is significant (P<0.01) for the values without the little dry effect

Table 18 : The "little dry" affect the abundance pattern of the dung beetles.

4.4.2.3. Effects of the canopy in the Yucatecan semi-evergreen forest

		Height of thetrap
Scarabaeidae	Pearson Correlation (R)	0.279
	P (one-tailed)	0.117
	N	20
	Linear regression (R-Square)	0.078

The correlation is not significant (P > 0.05)

Table 19 : The abundance of the dung beetles is independent of the height of the trees.

4.4.2.4. Effects of the canopy in the low semi-deciduous forest

		Height of thetrap
Scarabaeidae	Pearson Correlation (R)	0.067
	P (one-tailed)	0.389
	N	20
	Linear regression (R-Square)	0.005

The correlation is not significant (P > 0.05)

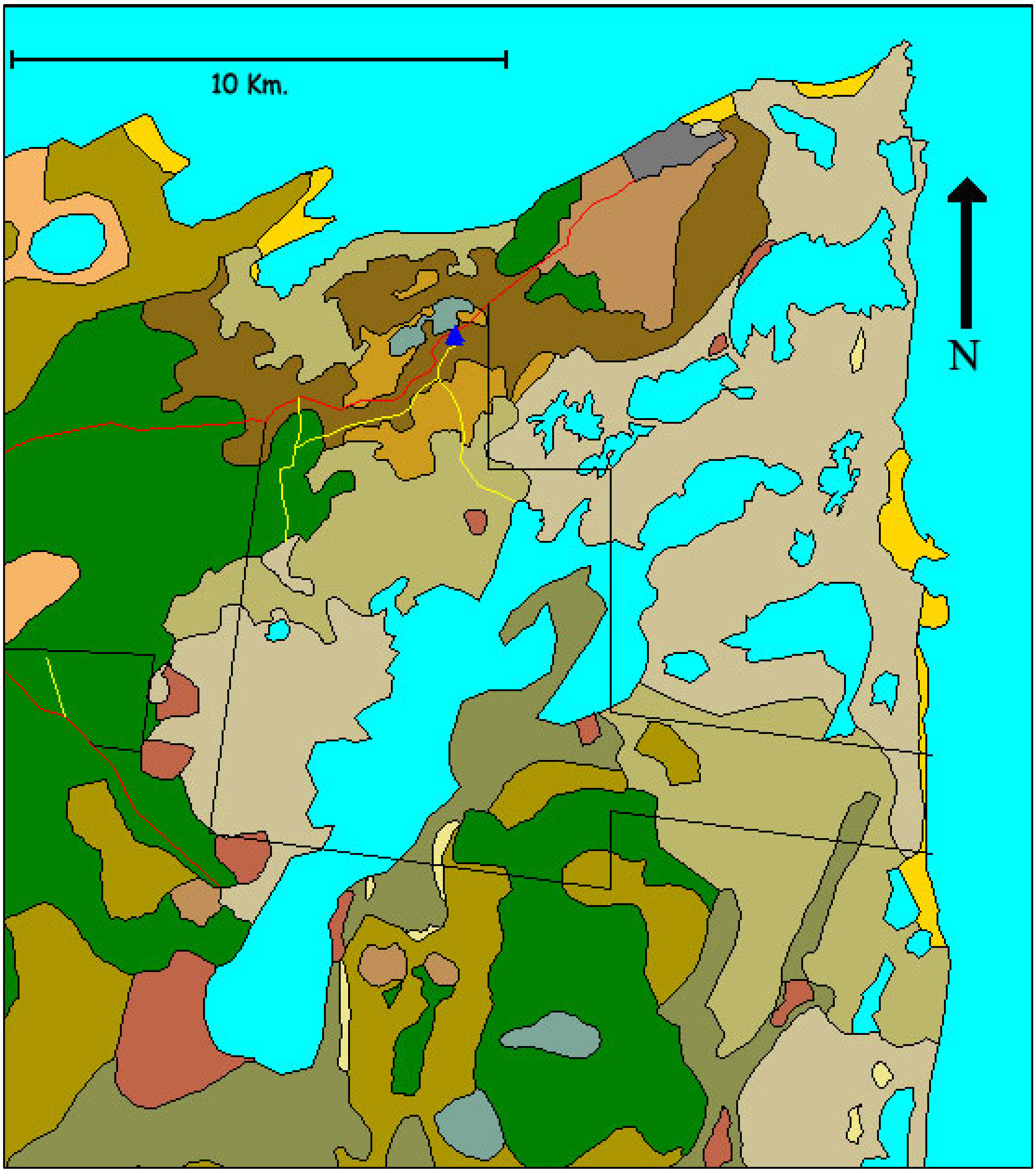
Table 20 : The abundance of the dung beetles is independent of the height of the trees.

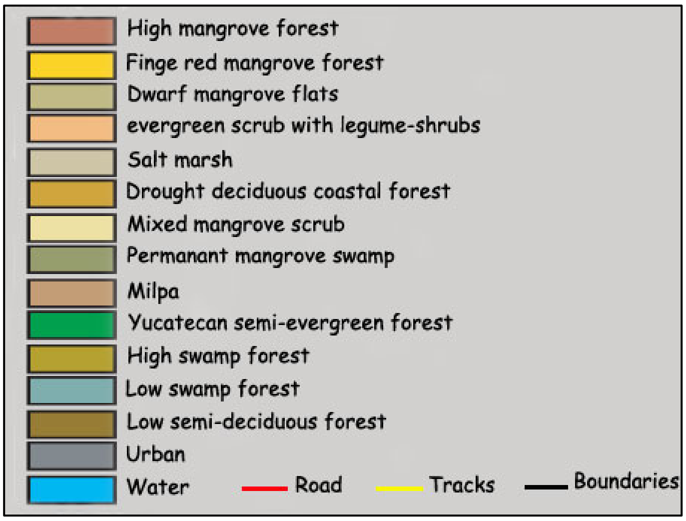
Remember that these statistics were made on the results of the dung baited traps only, principally on the Scarabaeinae subfamily with 20 species and 4202 specimens. Indeed, it is impossible to use the results coming from different types of traps since they differ in efficiency.

4.5. Biodiversity mapping with GIS

4.5.1. Map of the reserve

The measures obtained with the GPS computer were used to create a map of the Shipstern Nature Reserve (section 3.6.). This map is a very useful tool to visualize the positions of the plots, the distributions of the vegetation types and many other properties of the area. In addition, it can be used as a powerful tool to map general biodiversity and even for statistical research.

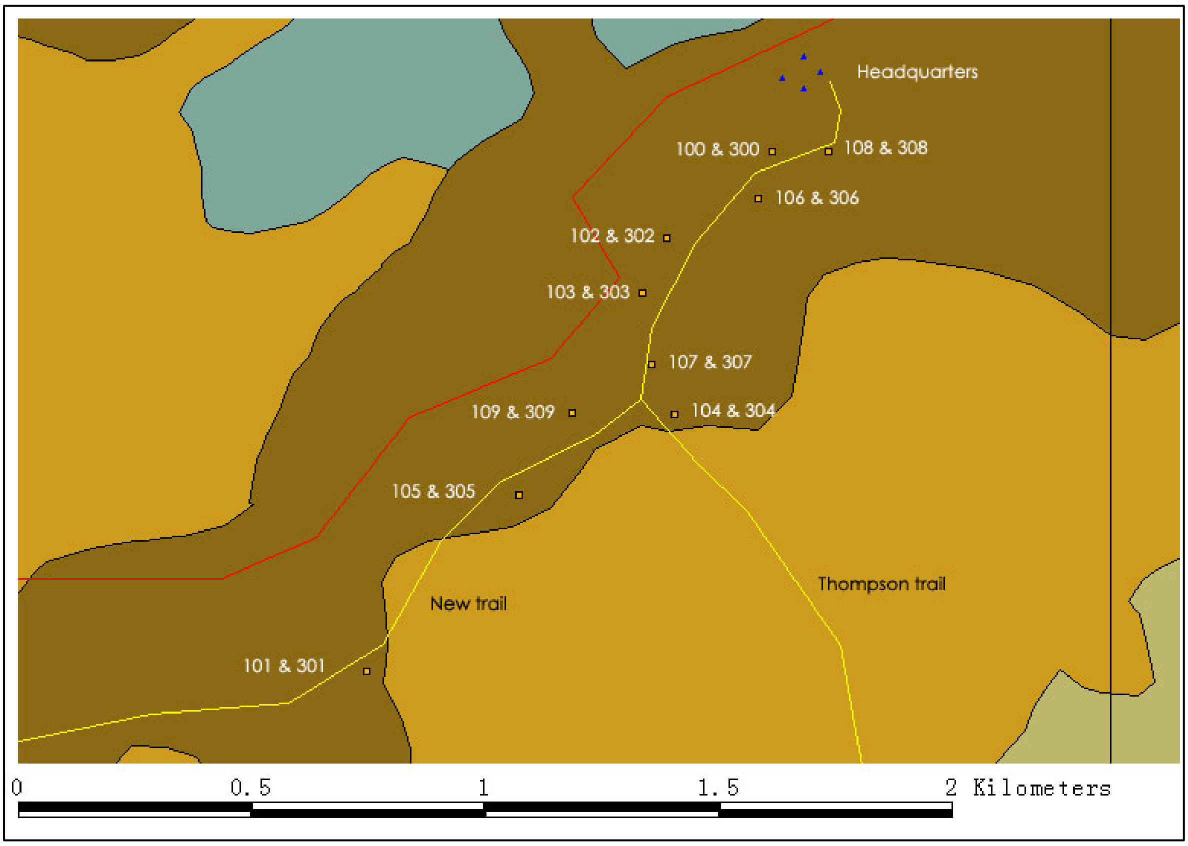




Map 3 & legend : Vegetation map of Shipstern Nature Reserve, with its roads, tracks and headquarter (dark blue).

4.5.2. Map of both forests and their plots

4.5.2.1. Low semi-deciduous forest

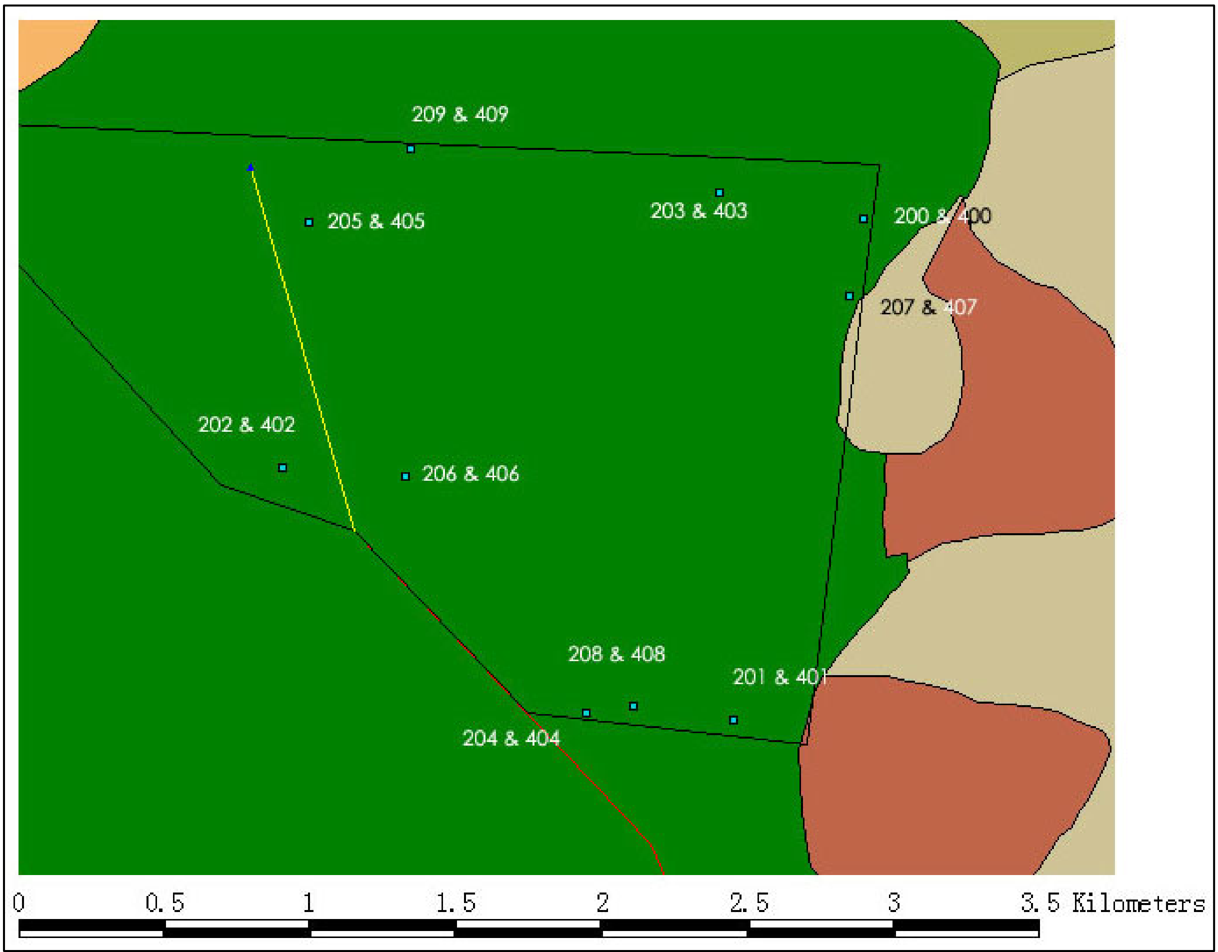


Map 4 : Position of the ten plots in the low semi-deciduous forest.

The low semi-deciduous forest is in deep brown on the map (see also Map 3) and is crossed by the Thompson trail and the New trail. The main road, in red, is also the northern boundary of the reserve.

4.5.2.2 Yucatecan semi-evergreen forest

Few kilometers from the western side of the The Shipstern Nature Reserve (see map 3), the parcel of Xo-Pol is mainly situated in a Yucatecan semi-evergreen vegetation type. The black lines represent the boundaries of the reserve and the yellow line is a trail leading to an observatory at the Xo-Pol ponds. In red, a track passes along the western boundaries of the parcel.



Map 5 : Position of the ten plots within the Yucatecan semi-evergreen forest

5. Discussion

5.1. Coleopteran biodiversity

In part, the purpose of this study was to make a first estimate of the coleopteran biodiversity of Shipstern Nature Reserve, Belize. During the “little rainy season”, the tropical Yucatecan semi-evergreen forest and the low semi-deciduous dry forest of the reserve were sampled for exactly 60 days, with five types of traps. From this method, 2 suborders, 12 superfamilies, 38 families, 272 species and over 7000 specimens were caught during this period (section 4.1. & 4.2.). These two forest types cover small areas inside the reserve, respectively 9 km^2 and 6 km^2, (see Map 3) but the results show a great diversity as well as a high density of Coleoptera. Of course, as often in the tropics, few species can be found in abundance and generally all the others are very rare but very diversified. This phenomenon also exists in the Shipstern Nature Reserve, where nearly 2500 individuals of two species of the genus *Canthon* (Scarabaeinae) were caught, even when many species were found only with one or two representatives, like the metallic wood boring beetle *Euchroma gigantea* (Linnaeus, 1764) and the rhinoceros beetle *Megasoma elephas* (Fabricius, 1775). Besides, the relative proportion in species of each family is interesting (Fig. 12, section 4.1.2.), but should be interpreted with caution, because it depends greatly on the trap efficiency. Indeed, the efficiency of the trap types is very unequal, because attractive traps and intercept traps were used together. For example, the classic pitfalls were surprisingly inefficient for the fauna of beetles living on the ground (Carabidae, Staphylinidae and Nitidulidae), even then the same kind of trap with a bait (dung baited pitfall traps) was the most efficient. Thus, there is a high probability of catching dung beetles (Scarabaeinae) with fresh dung, because the attractiveness is very strong and they can fly for considerable distances. This raises a question about the results for the subfamily Scarabaeinae, because if the low semi-deciduous forest is patchily distributed, we could suppose that the dung beetles caught there came from another forest type. Some species were probably caught “by accident” in this Neotropical dry forest, but the shortest distance between the Yucatecan semi-evergreen forest and a plot of the dry forest was over 2 km, and the number of repetitions (twenty times in each forests) permitted the specificity of species to be determined. In return, many species cannot be readily attracted, like the leaf beetles (Chrysomelidae). This is why, the coleopteran diversity in species was established principally thanks to the catches executed with the butterfly net. The canopy Malaise trap was useful to collect some longhorn beetles (Cerambycidae), flower beetles (Cetoniinae), minute beetles (Clambidae), metallic wood boring beetles (Buprestidae) and lighting bugs (Lampyridae). However, according to a study of the Diptera of the reserve (Rapp, 2003 unpublished), the coleopteran richness of the canopy was also very poor in both forest types, which could be explained by the hurricanes that regularly reach Belize between September and November (see section 2.2.3.). Hurricane Janet (in 1955) greatly affected the northern part of the country, the forests were completely flattened and suffered from severe fires (Bijleveld, 1998). Thus, the canopies of both forests are probably not highly developed and are still recovering, which could explain their lack of activity. Another obscure subject is the very poor efficiency of the light trap. Usually insects are very strongly attracted by light during the night and the tropical region is not an exception to that rule. Naturally, some bess beetles (Passalidae), June beetles (Melolonthinae) and longhorn beetles (Cerambycidae) were caught, but in very low quantities. The attraction effect is the principle of this method, but a white light cannot be seen further than one hundred meters in deep forest and the sessions took place for one hour at maximum. We are able to assume in these conditions, that all the specimens caught occur in the sampled forest and did not come from another part of the reserve. However, maybe a blacklight should have been tried to confirm the extraordinary poverty of the nocturnal beetles and insects in general (except for the mosquitoes).

In a second part of the project, the coleopteran diversity of the two forest types was compared and some remarkable differences resulted form this study : Of the 38 families found, 6 occur only in the Yucatecan forest and 4 are unique to the dry forest (Fig. 13, section 4.1.3.). The species richness is much higher in the humid forest with 145 of the 272 species occurring only in this forest type (Fig. 14, section 4.1.3.). This difference could be explained in part by the small area and patchy distribution of the low semi-deciduous forest of *Pseudophoenix sargentii*. The higher amplitude of variation in temperature and humidity (Tables 9 & 11) as well as a lower richness and protection of the vegetation could be a second explanation, based on the difficulties encountered by species in this environment. In all, these results show clearly the great differences in biodiversity of coleoptera that exists between these two forest types.

In addition, since their species composition is completely different, I also studied the behaviour of the dung beetles (Scarabaeinae and Aphodiinae) in both forest types, and related this to abiotic factors such as temperature and humidity.

5.2. Effects of abiotic factors on dung beetles

Dung beetles feed on many kind of dung and even carrion, but most species are specialists of one type of mammalian dung (Halffter & Favila, 1993). Thus, the number of different dung beetle species is strongly correlated with the number of animal species in the same ecosystem, so that they can be used as an indicator group for measuring biodiversity (Halffter, 1998). Therefore, the vegetation plays a key role in their distribution, because specific herbivores feed on and produce certain types of dung that permit the first settlement of coprophagous beetles communities, followed by species that feed on the dung of carnivores. Nonetheless, abiotic factors also influence the abundance of dung beetles (Scarabaeinae and Aphodiinae) inside the two forest types.

I proved that the communities of dung beetles behave differently as a function of temperature and humidity (which depends on temperature) in the two forest types.

Within the low semi-deciduous forest, hot temperatures increase the activity and thus the abundance of dung beetles. The hottest temperatures encountered (38° C.) do not seem to create difficulties for them, contrary to the effect of dryness. Indeed, periods without any rains, like the “Belizean little dry” in August, reduce captures. Cool temperatures, which are always due to rain (some tropical storms can last four days), are also detrimental. Finally, a maximum of abundance was recorded in July, as is typical for Coleoptera in Neotropical dry forest (Fig. 3, section 3.3.1.) (Noguera, 1990).

Within the Yucatecan semi-evergreen forest, the stability of the environment is greater (homogeneity of the vegetation, temperature and humidity) and the abundance peaks between 30°C and 32°C. Cooler and hotter temperatures have a negative impact on the community of dung beetles. Dry periods have the same effect as in the other forest type and the sampling is clearly less efficient in August. The maximum of abundance occurred in June but the difference with July is tiny, which suggests that the general activity of Coleoptera in this forest is less influenced by the rainfall pattern, certainly due to the stabilizing effect of the vegetation.

Finally, the height of the canopy Malaise traps do not seem to have any influence on the effectiveness of the catches. This result is almost obvious because I worked with coprophagous beetles which usually live and fly near the ground. Generally abundant in the air, flower beetles (Scarabaeidae: Cetoniinae) were also extremely rarely caught by this type of trap in the low semi-deciduous forest and never in the other, even when the flight intercept trap (1,50 m. high) caught a good diversity of flying insects. In conclusion, these results contribute to the observation that the activity is very poor in the tops of the trees. As said before, one biological explanation could be the phenomenon of the hurricanes that regularly hit this part of Belize destroying the forests -particularly the top of them- and leaving insufficient time for nature to produce a stable canopy.

5.3. Mapping of the biodiversity with GIS

The map of the Shipstern Nature Reserve was created to serve as a tool to map the vegetation and the biodiversity of the reserve and not only that of Coleoptera. In this study, it is used to show the positions of the plots and vegetation types inside the reserve. I did not collect enough data to begin further analyses of population density or to generalize my results to the whole reserve, but that in the future, this tool is likely to be appreciated by many researchers.

6. Conclusion

Coleopteran biodiversity is known to be very high in Central America as well as in the Neotropical biogeographic region (WRI, 2002). Shipstern Nature Reserve proves that it is not an exception, with 272 different species found in only two months, with modest methods. This number suggests the potential biodiversity in this part of Belize. Indeed, within the reserve, at least 13 other types of environment wait to be studied (see the Map 3, section 4.5.1.) and the other 10 months of the years could bring different species, because the climate and the vegetation are very seasonal in this part of Central America and some species can be found only during one period of the year, such as the *Euphoria sp*. (Cetoniinae) of the low semi-deciduous forest and the June beetles *Phyllophaga parvisetis* (Melolonthinae) in both forests. In addition, the biodiversity of this area presents one particular property: the encounter of species originating from South America (*Coelosis biloba*, *Euchroma gigantea*, the palm weevil *Rhynchophorus palmarum*) with those from the North of Mexico and the southern States of the USA (*Passalus punctiger*, *Euparia castanea*, *Phileurus valgus*). Naturally, many species are typical of Central America and Carribbean islands, such as the elephant beetle *Megasoma elephas* (Scarabaeidae : Dynastinae). This phenomenon creates an amazing richness and sometimes unexpected discoveries.
The dung beetles communities (Scarabaeidae) were used to make an ecological study, showing that the vegetation probably plays the main role in coleopteran distribution and activity. In the area covered by the reserve (9000 hectares), the general weather conditions are equivalent, but the temperature and the humidity are clearly different between the forest types, essentially due to the influence of the vegetation. For example, vegetation is more shaded, leafy and protective inside the Yucatecan semi-evergreen forest, lower and bushy with shrubs and open canopy in the low semi-deciduous forest. These differences are enough to exert pressures on certain Coleoptera and to lead to the specialization of the species to one of the two types of forest.

For all of these reasons, the Neotropical dry forest of *Pseudophoenix sargentii* in Shipstern Nature Reserve is a well defined type of forest possessing its own properties of vegetation, climatic conditions and coleopteran biodiversity. However, many coleopteran populations are very small and nobody can say what will happen to this diversity if the natural expansion of Yucatecan semi-evergreen forest and human encroachment upon this forest type continue to occur. We must remember that with regard to future conservation efforts in the northern part of Belize, the low semi-deciduous forest as well as the Yucatecan semi-evergreen forest of Shipstern Nature Reserve need a high conservation priority.

Canopy of Shipstern Nature Reserve.

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Annexe

Scarabaeoidea of Shipstern Nature Reserve
Belize, Central America

1. <u>The Scarabaeoid Beetles</u>

The superfamily Scarabaeoidea is a very large and diverse group of beetles. They are adapted to most habitats and can be coprophagous, saprophagous, fungivorous, herbivorous, necrophagous, and even carnivorous. They are widely distributed and even survive in the Arctic region in animal burrows. Some scarabs show parental care and sociality. Many possess huge and beautiful horns (Ratcliffe, 2002b). Some are agricultural pests that may have a strong impact on crops while others are very efficient in the biological control of dung and dung flies. Finally, they are familiar beetles due to their large size, extravagant forms and interesting natural histories. Early Egyptians revered the scarab as a god and Charles Darwin used observations of scarabs in his theory of sexual selection (Ratcliffe, 2002b).

2. <u>Main characteristics</u>

- Antennal club lamellate.
- Prothorax often highly modified for burrowing with large coxae.
- Protibiae usually dentate with a single spur.
- Wing venation reduced.
- Larvae scarabaeiform (c-shaped, cylindical):

- White Grub larva (Anonymous, 2001) -

3. <u>Scarabaeoidea Families and Subfamilies of the Shipstern Nature Reserve and their common names</u>

The samples collected during “the short rainy season” show that it is possible to find at least 4 families within the reserve:

3.1. Passalidae – The bess beetles
3.2. Trogidae – The skin or hide beetles
3.3. Geotrupidae – The earth-boring scarab beetles
3.4. Scarabaeidae:
   3.4.1. Aphodiinae – The aphodiine dung beetles
   3.4.2. Scarabaeinae – The dung beetles and tumblebugs
   3.4.3. Melolonthinae – The May beetles, June beetles, and chafers
   3.4.4. Rutelinae – The shining leaf chafers
   3.4.5. Dynastinae – The rhinoceros beetles
   3.4.6. Cetoniinae – The flower beetles

3.1 Passalidae

The bess beetle family is diverse in tropical regions and has a very limited distribution in temperate regions (Schuster, 1992). There are over 500 described species, nearly all of which are tropical. Individuals of this family are large beetles (20 to 70 mm long) with sublamellate antennal clubs. The form of the body (elongate and dorsoventrally depressed) and the form of the mentum (strongly emarginated apically) permit this family to be distinguished from other scarabaeoids.
Passalid adults live in well decayed logs and stumps with their larvae in subsocial family groups. All stages are found in galleries in wood that are excavated by the adults. Eggs are usually placed together in a "nest". Adults and larvae communicate by stridulating and can produce 14 different calls (Schuster, 1975).

Two genera and two species were found during "the little rainy season" (June-July) within the Shipstern Nature Reserve:

- *Odontotaenius striatopunctatus* (Percheron, 1835)
- *Passalus punctiger* LePeletier and Serville, 1825

(length: 40 mm)

- *Passalus punctiger* -

(length: 28 mm)

- *Odontotaenius striatopunctatus* -

P. punctiger was found only in the Yucatecan semi-evergreen forest whereas *O. striatopunctatus* seems to live in both types of forest (a map of Shipstern Nature Reserve is available on page 17).
It is interesting to notice that some *P. punctiger* were collected at the turn of the century in Arizona (U.S.A.) and have not been recorded in this part of the world since (Schuster, 1983).

3.2 Trogidae

The Trogidae is a small family (around 300 species) that can be found on all major continents. Members are easily recognized by the warts covering the body and their dirty appearance. They are generally brown, grey or black coloured.
Adults and larvae occur on the dry remains of dead animals because they are usually among the last of the succession of insects that invade carcasses. They have been also observed in the nests of mammals and birds in which they find hairs, feathers and skin.

Only one species was found:

- *Omorgus suberosus* (Fabricius, 1775)

<u>*Omorgus*</u> Erichson, 1847

The genus *Omorgus* occurs primarily in arid regions in the southern continents and *O. suberosus* (Fabricius, 1775) can be found in the low semi-deciduous forest of Shipstern Nature Reserve, a Neotropical dry forest.

(length: 13 mm)

- Omorgus suberosus -

3.3 Geotrupidae

The geotrupids are burrowers in the soil. They are oval or round with yellowish, brown, orange-brown, reddish-brown, purple or black colours. They have often tubercules and horns. Geotrupidae are predominantly adapted to cold temperature conditions and are mostly distributed in the Holoartic region (Lobo & Halffter, 2000), but in the New world, one subfamily occurs from Canada to El Salvador, the Bolboceratinae, well represented in Central America (Jameson, 2002). The adults of most species provision larvae in earthen burrows with dead leaves, cow and horse dung or humus.

Only one species within the reserve:

- *Neoathyreus fissicornis* (Harold, 1880)

<u>*Neoathyreus*</u> Howden and Martinez, 1963

The genus *Neoathyreus* is distributed in Neotropical and subtropical areas (it belongs to the Bolboceratinae subfamily) (Moron, 1996).

(length: 11 mm)

- Neoathyreus fissicornis -

This species was trapped only twice in the Yucatecan semi-evergreen forest with a "flight intercept trap".

3.4 Scarabaeidae

Scarab beetles comprise a diversified group. Adults of many scarab beetles are noticeable due to their relatively large size, bright colours, often elaborate ornamentation, and interesting life histories. The family includes the goliath beetle from Africa (G*oliathus goliathus* (L.)), known as one of the heaviest insects (up to 100 grams). It also contains the elephant beetle (*Megasoma elephas* (Fabricius, 1775)) and the hercules beetle (*Dynastes hercules* (L.)), both from the American tropics, which are known for their large size (up to 160 mm for the hercules beetle) and highly developed horns in the males. The group includes 27,800 species (91 % of all Scarabaeoidea).

Six subfamilies are present inside the Shipstern Nature Reserve:

3.4.1. Aphodiinae

Aphodiine beetles are present in numerous niches. There are approximately 1,850 species worldwide. Many species are generalist dung feeders, but others are highly specialized to feed on a specific type of dung or dung in specific situations. Other individuals are detritivorous, feeding on plant materials. Some species of aphodiines live in association with ants.

Only one species and only few specimens were found in the Yucatan semi-evergreen forest of the reserve:

- *Euparia castanea* Serville, 1828

Euparia LePeletier and Serville, 1828

Worldwide, the genus *Euparia* includes 18 species. *Euparia castanea* also occurs in the southeastern U.S. (Florida, Alabama, Louisiana), where it is myrmecophile and lives primarily with native fire ants (*Solenopsis* species) (Wojcik et al., 1977), (Wojcik et al., 1991).


(length: 4 mm)

- *Euparia castanea* -

3.4.2. Scarabaeinae

Members of this subfamily are commonly called dung beetles but while many species feed on mammalian dung, others specialize to varying degrees upon the dung of other vertebrates and invertebrates and even on carrion, mushrooms, rotting fruit and decomposing plant material.
The world fauna includes slightly over 5,000 described species with over to 2,000 of these species belonging to the genus *Onthophagus*.
Due to their relations with other organisms, their abundance and sometimes their specificities, Scarabaeinae can be used as a good bioindicator (Halffter, 1998) and are commonly considered as a strategy for measuring

biodiversity, for the inventory and the conservation of Neotropical ecosystems (Favila & Halffter, 1997), (Ceballos & Garcia, 1995).

Inside the Reserve you can find dung beetles in all kind of forest and even in the savannah near the mangroves (some dung of tapirs can be found there and specially in the dry or "little rainy season" where the water is shallow):

- *Phanaeus pilatei* Harold, 1863
- *Phanaeus sp*.
- *Coprophanaeus telamon corythus* (Harold, 1863)
- *Deltochilum gibbosum sublaeve* Bates, 1887
- *Deltochilum lobipes* Bates, 1887
- *Deltochilum scabrisculum scabrisculum* Bates, 1887
- *Deltochilum sp.*
- *Copris lugubris* Boheman, 1858
- *Canthon cyanellus cyanellus* LeConte, 1859
- *Canthon viridis championi* Bates
- *Sisyphus mexicanus* Harold, 1863
- *Dichotomius centralis* Harold, 1869
- *Canthidium sp*.
- *Ateuchus illaesum* (Harold, 1868)
- *Ontherus sp.*
- *Ontherus sp.*
- *Onthophagus sp.*
- *Onthophagus sp.*
- *Onthophagus sp.*

a) *Phanaeus* MacLeay, 1819

Nearly half of the 50 recognized species of *Phanaeus* are recorded from Mexico. Adults generally feed on mammalian dung and many species exhibit strong sexual dimorphism with males possessing long horns on the head and/or pronotum. Moreover, dimorphism exists as well among the males (in horn size) that lead to two different behaviours between the dominant males (stronger body and huge horn) and the others.

Within the region of Shipstern, they are diurnal and are among the first arrivals to fresh dung. They fly to the concerned area with a great precision and land directly into the dung. Usually they do not shape the dung and roll it into a ball. They go straight inside the dung and probably hollow galleries to leave eggs and food.

Phanaeus pilatei can be encountered in both Yucatecan and Low semi-deciduous forest whereas *Phanaeus sp*. lives exclusively in the more humid forest.


(length: 19 mm)

- Male of *Phanaeus pilatei* Harold, 1863 -


(length: 14-19 mm)

- Male of *Phanaeus sp.* -

b) Coprophanaeus d'Ousoufieff, 1924

Coprophanaeus is a Neotropical genus, which includes 32 species. It belongs to the tribe Phanaeini Kolbe, 1905, which is restricted to the New World with most of 9 genera and 150 species found in the Neotropics. Several species occur in Mexico. Many exhibit strong sexual dimorphism with males possessing long horns on the head and/or pronotum. Adults typically feed on carrion.


(length: 27 mm)

- *Coprophanaeus telamon corythus* (Harold, 1863) -

Coprophanaeus telamon corythus can be found in both types of forest but is rare. Probably those individuals are really specialized to feed upon carrion so that the "dung bait traps" are not really efficient.

c) Deltochilum Eschscholtz, 1822

Deltochilum is a New World genus with over 80 described species. Many species feed upon carrion although fresh dungs can be very attractive to these beetles.
All *Deltochilum* species within the Shipstern Nature Reserve are nocturnal and are attracted to "dung bait traps". However, it is very difficult to watch them and impossible to say if they search their food in flight or not.


(length: 25 mm)

- *Deltochilum gibbosum sublaeve* -


(length: 30 mm)

- *Deltochilum lobipes* -


(length: 25 mm)

- *D. scabrisculum scabrisculum* -


(length: 12 mm)

- *Deltochilum sp.* -

Deltochilum scabrisculum scabrisculum was caught only in the Yucatecan semi-evergreen forest whereas *Deltochilum sp*. was observed only in the low semi-deciduous forest. The other species live in both forests.

d) *Copris* Geoffrey, 1762

The genus *Copris* has nearly 200 species worldwide and 28 species recorded from the New World. *Copris* is the only representative of the tribe Coprini Leach, 1815 in the American continent.

C. lugubris Boheman, 1858 is present in both forest types. It is attracted by different kinds of dungs but also by the odours of carrion and is active only during the night.

 (length: 13 mm)

- Copris lugubris -

e) *Canthon* Hoffmansegg, 1817

Canthon is the most species-rich genus of the New World Canthonini (340 species in 27 genera) with nearly 150 species distributed from southern Canada to Argentina.
Adults of most species are ball-rollers, and they shape carrion or dung into balls that are rolled away and buried at a distance from the food source.
In the region of Shipstern nature Reserve, they are the first diurnal newcomers on new dung, and are the most abundant specimens inside the Yucatecan semi-evergreen forest as well as in the low semi-deciduous forest.

 (lenght: 6 mm)

- Canthon cyanellus cyanellus -

 (length: 8 mm)

- Canthon viridis championi -

f) *Sisyphus* Latreille, 1807

Most of the 30 species are found in Africa and Asia, with few representatives in Europe and the New World. Indeed, only two are native to the New World. This genus includes species of ball-rolling dung beetles.



(length: 4 mm)

- Sisyphus mexicanus -

Only five specimens of *S. mexicanus* Harold, 1863 were collected in the Yucatecan semi-evergreen forest.

g) *Dichotomius* Hope, 1838

Dichotomius is a New World genus with about 150 described species. The genus is in need of revision as the last complete study (Harold, 1869) is clearly out of date.
D. centralis can be found in both observed forests but is most common in the humid forest.


(length: 20 mm)

- Dichotomius centralis -

h) *Canthidium* Erichson, 1847

Canthidium is a Neotropical genus with over 150 described species and many more awaiting description. There is no modern taxonomic treatment for this group. The only revision (Harold, 1867) treated just 38 species.
This species can be found in both forests.


(length: 5 mm)

- Canthidium sp. -

i) <u>*Ateuchus*</u> Weber, 1801

This genus is very close to the *Canthidium*, *Dichotomius* and *Ontherus* genera (all in tribe Dichotominii) with their small and compact body. There are about 81 species in this New World genus.



(length: 5-6 mm)

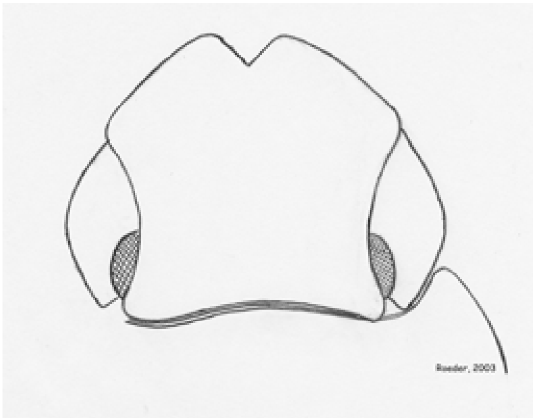
- *Ateuchus illaesum* -

A. illaesum (Harold, 1868) is quite abundant but can be observed only in the driest forest.

j) <u>*Ontherus*</u> Erichson, 1847

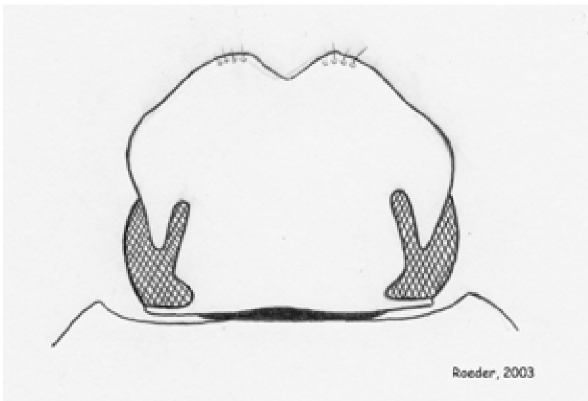
Ontherus is a Neotropical genus with 58 species described. Two species occur in the studied areas. They seem to be very similar but the size of the body and the shape of the clypeus are good criteria to distinguish themthem.

- *Ontherus sp.* - (length: 7 mm)



- Details of the head of *Ontherus sp*. -


- *Ontherus sp.* - (length: 4 mm)



- Details of the head of *Ontherus sp*. -

k) <u>Onthophagus</u> Latreille, 1807

Onthophagus is the largest genus of Scarabaeinae (over 2,200 species) with representatives in nearly all parts of the world. Approximately 130 species are known from the New World.
The body is generally small in length (2-12 mm.), oval and convex. Sexual dimorphism is well developed in most *Onthophagus* species (Child, 2001). Males typically have large horns on the head and/or pronotum (females with only rudimentary horns sometimes), which depend on the food quantity and quality during the larvae stages (Child, 2001) and also to the social context like absence of others males (Moczek, 1999).
Adults commonly feed on mammalian dung but some species feed upon carrion, fungi, rotting plant material and even live in association with ground-burrowing mammals or tortoises (Ratcliffe, 2002b).

  (length: 8mm)

- Male of *Onthophagus sp*. -

Onthophagus sp. were found in both studied types of forest.

 (length: 6 mm)

- *Onthophagus sp.* -

This species lives in the Yucatecan semi-evergreen forest and cannot be observed in the other studied place.

  (length: 7-8 mm)

- Male of *Onthophagus sp*. -

Like the first *Onthophagus* species, this beetle live in both humid and dry forest.

3.4.3. Melolonthinae

The cosmopolitan subfamily Melolonthinae Samouelle, 1819 is one of the largest and most diverse subfamilies in the Scarabaeiodea, with approximately 750 genera and nearly 11,000 species worldwide (W. W. K. Houston & Wier, 1992).
Adults and larvae of the Melolonthinae are generally phytophagous and some genera may be a considerable economic importance (*Phyllophaga*, *Polyphylla*), damaging a wide variety of crops and pastures (Evans, 2002), although some adults apparently do not feed.

Three species are present within the Shipstern Nature Reserve:

- *Phyllophaga parvisetis* (Bates)
- *Phyllophaga hondura* Saylor, 1943
- *Phyllophaga yucateca* Bates, 1889

Phyllophaga Harris, 1827

Its species include many of economic importance. The larvae (called the White grubs) may cause damage to pastures, lawns, grain, and legumes (Richter, 1966). Larvae considered to be serious crops and turf pests as a result of their root-feeding activities, while the nocturnal feeding activities of some adults *Phyllophaga* may result in the defoliation of deciduous trees.


(length: 18 mm)
(female)


(length: 9 mm)
(male)

- Phyllophaga parvisetis -

P. parvisetis (Bates) occurs from Mexico to northern part of Nicaragua. This is a very common and nocturnal species. However, it is quite rare to find it in the Yucatecan semi-evergreen forest. It typically lives during the "little rainy season" and it is impossible to find it in the Reserve after the end of July. The males, smaller than the females, appear a few days earlier in the season than the females.


(length: 9 mm)

- Phyllophaga hondura -


(length: 16 mm)

- Phyllophaga yucateca -

P. hondura Saylor, 1943 and *P. yucateca* Bates, 1889 are not present in the Low semi-deciduous forest.
P. hondura is more common in Honduras but is also recorded in Belize. *P. yucateca* is distributed in the more dry parts of Mexico, and as far south as Costa Rica. It has never been recorded above 1800 meters (Morán & Monterroso, 1997).
Both were caught with a "flight intercept trap", thus it is difficult to say if they have diurnal or nocturnal activities.

3.4.4. Rutelinae

The subfamily Rutelinae is composed of approximately 200 genera and 4,100 species that are widespread, but many taxa remain to be described.
Adult rutelines are phytophagous and feed on leaves, flowers or flower parts. Larvae feed on roots, compost and decaying vegetation. Some species are agricultural pests.
The common name of the subfamily (the shining leaf chafers) reflects the fact that members of the Rutelinae are brightly coloured, beautifully patterned, and often brilliantly metallic.

At least two different species occur during the "little rainy season":

- *Pelidnota centroamericana* Ohaus, 1913
- *Pelidnota sp.*

<u>*Pelidnota*</u> MacLeay, 1819

The genus *Pelidnota* includes about 100 species and is most diversified in South America. Adults feed on foliage and fruits of grapes. The larvae feed on decaying roots and tree stumps.


(length: 24 mm)


(length: 28 mm)

- *Pelidnota centroamericana* -

- *Pelidnota sp.*-

P. centroamericana Ohaus, 1913 is very rare in the Low semi-deciduous forest. It is most abundant in the other kind of forest and it is attracted by simple light in the night.
Pelidnota sp. does not live in the driest forest and appears only in mid-August.

3.4.5. Dynastinae

The Dynastinae are medium to very large beetles. The larvae mostly feed on dead vegetable material, from dead sugarcane plants to rotten logs. Because of their occasional abundance in cane fields several have well studied life histories, and a lot of common names have been given to this group. The largest beetle in the New World, and one of the largest in the World - *Dynastes hercules* (L.) - belongs to this group. The subfamily is worldwide in distribution, but nearly half of the species are from the Neotropical region. There are over 1350 species described. Endrödi (1985) divided the group into 8 tribes : the Cyclocephalini, Oryctoderini, Agaocephalini, Pentadontini, Oryctini, Dynastini, Hexadontini, and Phileurini. All but the Hexadontini (Madagascar) and Oryctoderini (Australasia) are represented in the New World.

Most species are sexually dimorphic, with males having either horns or enlarged tubercules or enlarged protarsi.

At least four species can be found in the Yucatecan semi-evergreen forest of Shipstern Nature Reserve, but none in the Low semi-deciduous forest. Nonetheless, it seems probable that other species occur in the southern part of the Reserve (Shipstern place).

- *Strategus aloeus* (Linnaeus, 1758)
- *Coelosis biloba* (Linnaeus, 1767)
- *Phileurus valgus* (Olivier, 1789)
- *Megasoma elephas* (Fabricius, 1775)

a) Strategus Kirby 1828

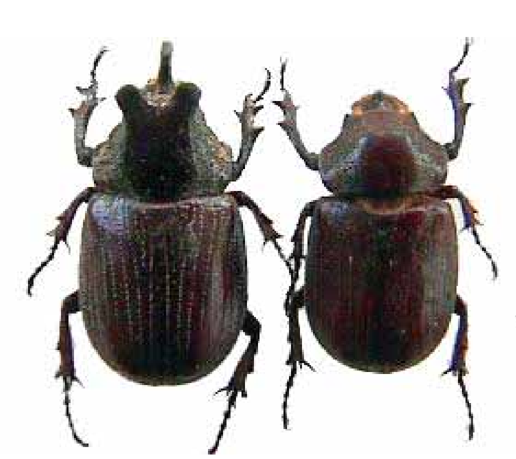
The genus *Strategus* contains 31 described species. The head and pronotum show tubercules and horns (especially in males).

(length: 40 mm)

- *Strategus aloeus* (Linnaeus, 1758) -

b) Coelosis

There is little known about this Neotropical genus. Species occur principally in South America, but the one species found at Shipstern, *C. biloba,* is distributed through Central America to French Guyana.



- *Coelosis biloba* (Linnaeus, 1767) - (length: 45 mm) - Male of *Coelosis biloba* (on the road of Xo-Pol) -

c) <u>Phileurus</u> Latreille, 1807

The tribe Phileurini Burmeister, 1847 is found in all regions of the world although most species are tropical. The genus *Phileurus* (Latreille, 1807) is one of the 21 genera of the New World and the 19 species in the genus are mostly Neotropical in distribution.

(length: 20 mm)

- *Phileurus valgus* -

P. valgus (Olivier, 1789) also occurs in the southern United State of America and Mexico.

d) <u>Megasoma</u> Kirby, 1825

Some members of the *Megasoma* are among the largest insects on Earth and males of some species possess very large horns. The head of the female has tubercules in most species.

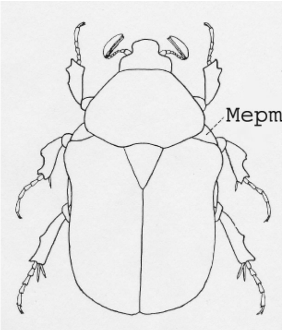
(male, 93 mm) (female, 65 mm)

- *Megasoma elephas* (Fabricius, 1775) -

3.4.6. Cetoniinae

The members of this group are principally pollen feeders and are common on flowers. The larvae feed on organic matter in the soil and some species damage the roots of plants. This subfamily includes the goliath beetles of Africa, which are among the largest and heaviest insects known.

Several genera in this subfamily have the mesepimera (mepm.) visible from above, which constitutes an easy way to recognize most flower beetles (Borror et al., 1992):



The subfamily Cetoniinae was redefined by Krikken (1984), but the taxa in this subfamily are in great need of further study.

However, six species at least can be recognizing during "the little rainy season" and these species are very specific to the kind of forest.

- *Euphoria sp.*
- *Lissomelas sp.*
- *Amithao cavifrons* (Burmeister, 1842)
- *Euphoria sp.*
- *Euphoria sp.*
- *Trigonopeltastes sp.*

The three first species come from the Yucatecan semi-evergreen forest, while the three others are found only in the low semi-deciduous forest, where they feed on different flower species showing a specialization to their environment (principally the kind of vegetation and weather conditions).

a) *Amithao* Thomson

Amithao is a genus belonging to the New World Gymnetini, which includes approximately 120 species and 25 genera, distributed from the southern United States to southern South America. They are associated with low and mid-elevation tropical forests and are also found in banana, cacao, and coffee plantations. Some species have been observed feeding on a wide variety of flowers, fruits, and plant saps, but they have not been associated with crop damage (Morón & Ratcliffe, 1984).
Adults are diurnal and can be attracted to fruit traps. Adults of *Amithao haematopus* Schaum are known to rest during the day in the axils of bromeliads (*Acmaea* spp.) where larvae (perhaps of the same species) were also encountered (Ratcliffe, 2002a).
At present, 15 described species belong to the *Amithao* genus.

During the months of June and July, *Amithao cavifrons* (Burmeister, 1842) was the most common flower beetles inside the Yucatecan semi-evergreen forest.

 (length: 21 mm)

- *Amithao cavifrons* (Burmeister, 1842) -

b) <u>*Euphoria*</u> Burmeister, 1842

The beetles in the genus *Euphoria* are somewhat bumblebee-like and are often called "bumble flower beetles". They are sometimes very pubescent and act much like bumblebees. More, these beetles do not extend their elytra in flight. The hind wings are extended through shallow emarginations at the sides of the elytra.
The genus *Euphoria* is badly in need of revision, and even some of the U.S. species cannot be reliably identified (Ratcliffe, 2002b). There are approximately described 73 species in the genus.

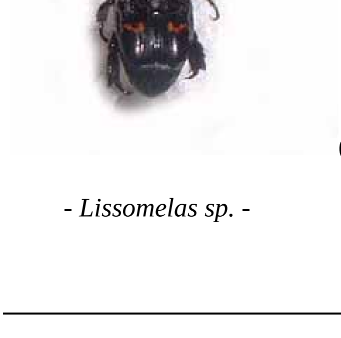
 (15 mm)  (16 mm)  (12 mm)

- *Euphoria sp* .- - *Euphoria sp* .- - *Euphoria sp* .-

Above, the left species of *Euphoria*, brownish and pubescent, occurs only in more humid forest, while the two others are found only in the driest forest and disappear almost completely at the end of July. Moreover, the greenish *Euphoria* (central picture) can be greenish to reddish coloured, without relation to sexual polymorphism. The size varies as well. Probably the quality and quantity of food during the larval stages play a key role.

c) <u>*Lissomelas*</u> Bates, 1889

This genus seems to be neotropically distributed, but one species (*L. flohri*) can be found in southern Arizona. There is very little information about the species of this genus, even in the best collections of the world.

 (length: 11 mm)

- *Lissomelas sp.* -

Lissomelas sp. was caught only four times in 12 weeks with a butterfly net in the Yucatecan forest.

d) Trigonopeltastes Burmeister, 1840

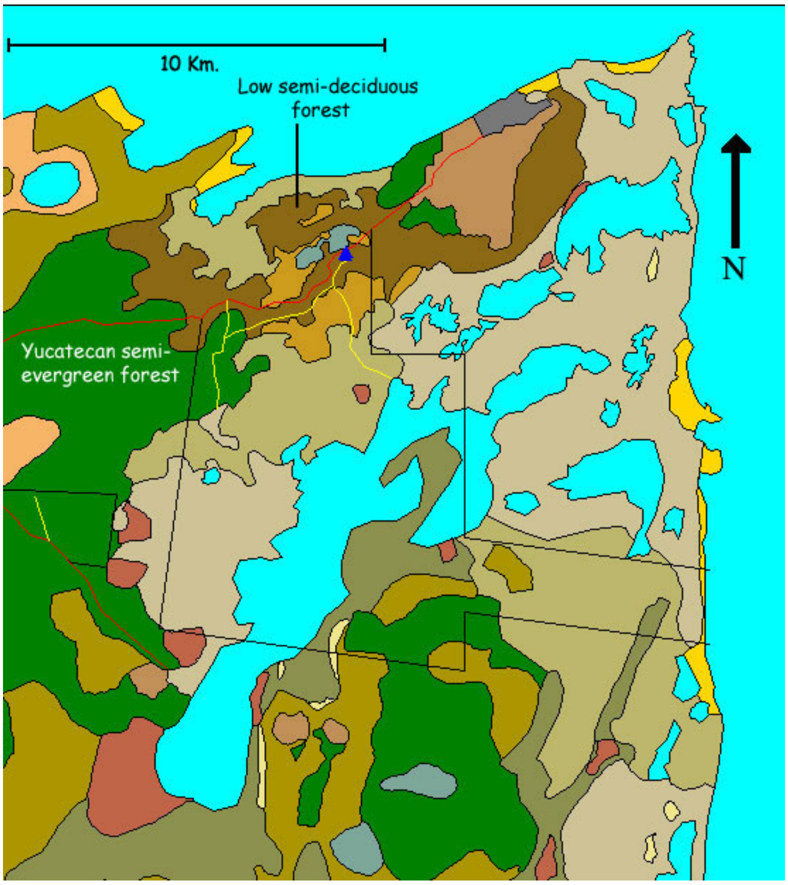
This genus has 15 species distributed in Mexico and Central America. They feed typically on flowers and easily recognizable by their pronotum with impression in form of triangle and marks on elytra.

(length: 8 mm)

- *Trigonopeltastes sp.* -

Trigonopeltastes sp. is present in the Low semi-deciduous forest of Shipstern Nature Reserve but almost only during "the little dry", which is a dry period (two or three weeks generally) in August.

4. Map of the Shipstern Nature Reserve



The main road, in red, cross the Low semi-deciduous forest (in brown) and one little part of the Yucatan semi-evergreen forest (in green). These two kinds of forest constitute the two studied areas. The black lines represent the limits of the Shipstern Nature Reserve, with the Xo-Pol area on the left of the map.

5. Checklist of Scarabaeoid Beetles

The arrangement of families, subfamilies, tribes and genera is taken from Ross (2002).

SERIES SCARABAEIFORMIA

Superfamily SCARABAEOIDEA

- **Family PASSALIDAE**
    - Tribe Proculini
        - Genus *Odontotaenius*
            - *Odontotaenius striatopunctatus* (Percheron, 1835)
    - Tribe Passalini
        - Genus *Passalus*
            - *Passalus punctiger* LePeletier and Serville, 1825
- **Family TROGIDAE**
    - Genus *Omorgus*
        - *Omorgus suberosus* (Fabricius, 1775)
- **Family GEOTRUPIDAE**
    - **Subfamily Bolboceratinae**
        - Genus *Neoathyreus*
            - *Neoathyreus fissicornis* (Harold, 1880)
- **Family SCARABAEIDAE**
    - **Subfamily Aphodiinae**
        - Tribe Eupariini
            - Genus *Euparia*
                - *Euparia castanea* Serville, 1828
    - **Subfamily Scarabaeinae**
        - Tribe Canthonini
            - Genus *Canthon*
                - *Canthon cyanellus cyanellus* LeConte, 1859
                - *Canthon viridis championi* Bates
            - Genus *Deltochilum*
                - *Deltochilum gibbosum sublaeve* Bates, 1887
                - *Deltochilum lobipes* Bates, 1887
                - *Deltochilum scabrisculum scabrisculum* Bates, 1887
                - *Deltochilum sp.*
        - Tribe Coprini
            - Genus *Copris*
                - *Copris lugubris* Boheman, 1858
        - Tribe Dichotomiini
            - Genus *Dichotomius*
                - *Dichotomius centralis* Harold, 1869
            - Genus *Ateuchus*
                - *Ateuchus illaesum* (Harold, 1868)
            - Genus *Canthidium*

        - *Canthidium sp.*
    - Genus *Ontherus*
        - *Ontherus sp.*
        - *Ontherus sp.*

- Tribe Onthophagini
    - Genus *Onthophagus*
        - *Onthophagus sp.*
        - *Onthophagus sp.*
        - *Onthophagus sp.*

- Tribe Phaneini
    - Genus *Phanaeus*
        - *Phanaeus pilatei* Harold, 1863
        - *Phanaeus sp.*
    - Genus *Coprophanaeus*
        - *Coprophanaeus telamon corythus* (Harold, 1863)

- Tribe Sisyphini
    - Genus *Sisyphus*
        - *Sisyphus mexicanus* Harold, 1863

- **Subfamily Melolonthinae**
    - Tribe Melolonthini
        - Genus *Phyllophaga*
            - *Phyllophaga parvisetis* (Bates)
            - *Phyllophaga hondura* Saylor, 1943
            - *Phyllophaga yucateca* Bates, 1889

- **Subfamily Rutelinae**
    - Tribe Rutelini
        - Genus *Pelidnota*
            - *Pelidnota centroamericana* Ohaus, 1913
            - *Pelidnota sp.*

- **Subfamily Dynastinae**
    - Tribe Oryctini
        - Genus *Strategus*
            - *Strategus aloeus* (Linnaeus, 1758)
        - Genus *Coelosis*
            - *Coelosis biloba* (Linnaeus, 1767)

    - Tribe Phileurini
        - Genus *Phileurus*
            - *Phileurus valgus* (Olivier, 1789)

    - Tribe Dynastini
        - Genus *Megasoma*
            - *Megasoma elephas* (Fabricius, 1775)

- **Subfamily Cetoniinae**
    - Tribe Gymnetini
        - Genus *Amithao*
            - *Amithao cavifrons* (Burmeister, 1842)

    - Tribe Cetoniini

- Genus *Euphoria*
  - *Euphoria sp.*
  - *Euphoria sp.*
  - *Euphoria sp.*

- Tribe Cremastocheilini
  - Genus *Lissomelas*
    - *Lissomelas sp.*

- Tribe Trichiini
  - Genus *Trigonopeltastes*
    - *Trigonopeltastes sp.*

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