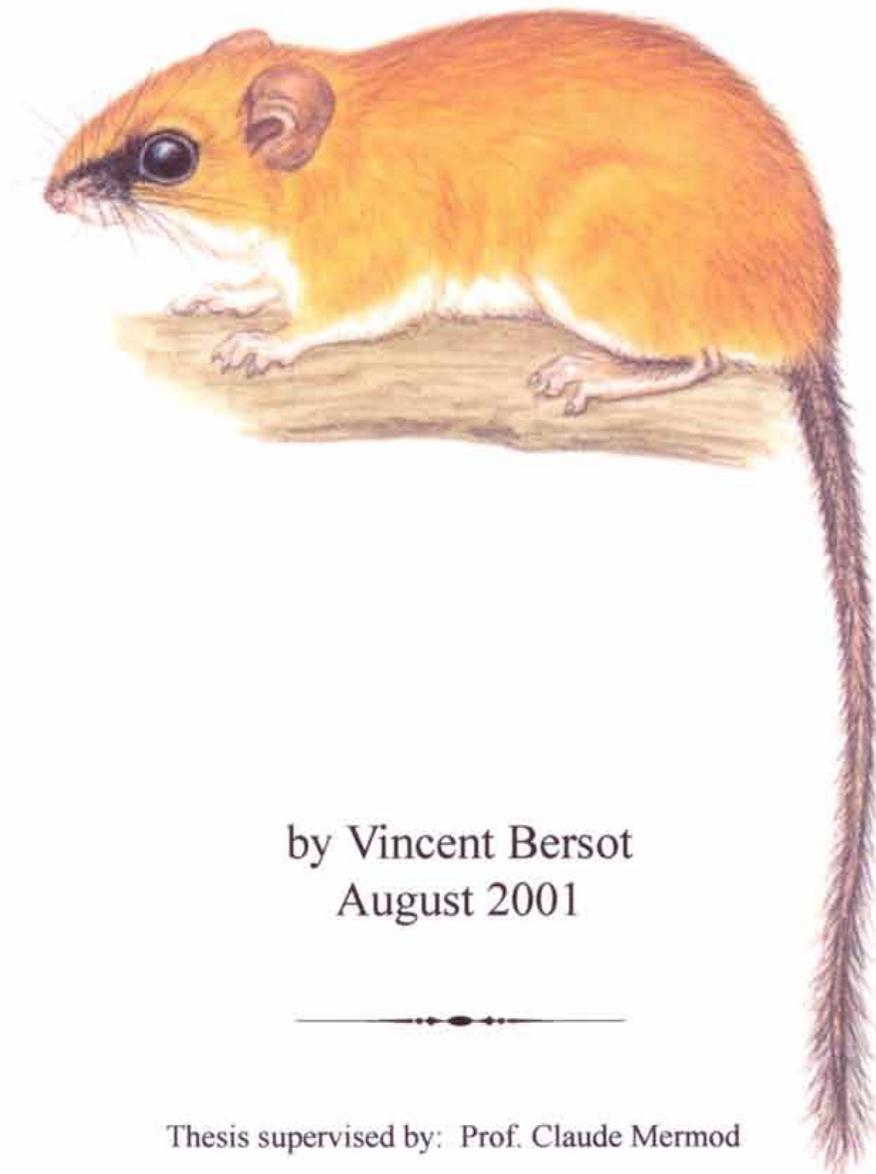


University of Neuchâtel
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Small Mammal Inventory
in the
Shipstern Nature Reserve
(Corozal District, Belize, Central America)
a preliminary assessment



by Vincent Bersot
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« The accelerating pace of deforestation in humid tropical lowlands worldwide threatens the continued existence of magnificent ecosystems whose biological diversity is still largely unexplored. Tragically, lowland rainforests are now only a memory in some regions where they were once extensive. Even where large tracts remain uncut, hunting has extirpated populations of key predators and large frugivores along roads and navigable rivers, compromising the long-term survival of natural communities in most accessible areas. Thus, opportunities to inventory the biotas of undisturbed rainforests, and to study the ecology of rainforest species under pristine conditions, are rapidly dwindling. »

R.S.Voss and L.H.Emmons, 1996.

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Chapter 1

Introduction :

1.1. Previous studies :

The information currently available to assess the magnitude and geographic distribution of mammalian diversity in Belize remains incomplete and unevenly representative. Indeed, Belize has only been briefly visited by collectors using inefficient or biased methods many years ago, and today, very few areas (if any) are characterized by a long history of field work on mammals. Among the most important mammalian surveys, Murie (1935) collected for several weeks in 1931 in the vicinity of Belize City and El Cayo (San Ignacio), British Honduras (today's Belize), on his way to Uxactun, Petén, Guatemala. In 1939 and 1940, after a brief survey in Jamaica and Haiti, I.T.Sanderson and A.Sanderson spent several months collecting along the coast of British Honduras, from Punta Gorda to the Bahía de Chetumal, prior to continuing their studies in Quintana Roo, Yucatán, and Chiapas, Mexico—part of their collection was studied by Hershkovitz (1951). Subsequently, additional lists of mammals arose from various research projects. Those include Disney (1968), Dieckman (1973), Kirkpatrick and Cartwright (1975), Burton et al. (1987), Rabinowitz and Nottingham (1989), and most recently Caro et al. (2001). However, few studies ever focused on the small mammal fauna of Belize. Consequently, methods used to trap marsupials and small rodents often remained adapted to common and generalist species, but proved to be unsuitable to catch specialists and/or rare species. In this context, recent accounts of mammalian diversity in Belize, such as the checklist proposed by McCarthy et al. (1998), still probably underestimate the number of small mammal species actually found in the country—this is especially true for the northeastern portion of the country (Corozal District) where studies on the mammalian fauna remain scarce.

In Shipstern Nature Reserve, as far as can be concluded from the available sources, non-volant small mammals were only briefly surveyed prior to the present study. This was done by Meerman (1993), and Miller et al. (1995), in a first attempt to survey the overall mammalian fauna of SNR. Apart from the latter, no other studies on mammals were reported from the reserve, with the exception of a bat inventory carried out by Bärtschi (1998). Nevertheless, other groups of vertebrates, but also invertebrates, were inventoried in SNR. Those include the following checklists : birds, reptiles, amphibians, and some miscellaneous invertebrates (Meerman, 1993); dragonflies and damselflies (Boomsma, 1993); butterflies (Meerman and Boomsma, 1993); and freshwater fishes (Bijleveld, 1990). In addition, beside a checklist of the flora proposed by Meerman (1993), two research projects focusing on the vegetation of SNR were recently carried out by Bijleveld (1998)—structure and floristic—and Sayer (2000)—phenology.

1.2. Goals :

The most important role for this project was to rapidly provide crucial diversity data for future research and conservation objectives implicating the Shipstern Nature Reserve and its surrounding areas. The study was therefore focused on a short-term inventory, that is combining the advantage of concreteness—listed species are definitely known to have occurred together at a particular place and time—with the disadvantage of incompleteness. The

usefulness of such a brief collecting was maximized by focusing on marsupials and rodents, that is taxa known to respond to ecological or zoogeographic gradients, and ignoring faunally uninformative groups. In this respect, the primary objective was to obtain fresh material—voucher specimens that are well preserved, complete, precisely labeled, and documented with exhaustive and informative data—to be subsequently added to the museum collections of the Natural History Museum, Geneva (NHMG), Switzerland. In turn, the liver was to be sampled, and saved for DNA preservation, from each of these voucher specimens, so as to constitute a precious tissue collection—to be completed with ear biopsies sampled from the specimens released in the field. These ear and liver samples were taken for inclusion into the Collection of Preserved Mammalian Tissues in Montpellier, France, where they are at the disposal of scientists. Finally, apart from recording the small mammals and preserving their DNA, the other objective of this study was to collect their ectoparasites, and list the endoparasites of their digestive tract, to be included in the NHMG museum collection.

Study area :

1.3. Shipstern Nature Reserve :

Previously owned by a British Limited Company, the area was partly managed as a private reserve during the eighties known as the Shipstern Wildlife Preserve. In 1989, it became the property of the International Tropical Conservation Foundation (ITCF), and the name Shipstern Nature Reserve was given. This newly created foundation followed the opening of the tropical butterfly garden Papiliorama of Marin-Neuchâtel in Switzerland, in 1988. Today a major tourist attraction, and further developed as the Papiliorama-Nocturama Tropical Gardens, it is actively concerned with the conservation of tropical biodiversity through two sister-foundations : the Papiliorama-Nocturama Foundation in Switzerland, and the ITCF in Belize.

Thus, beside numerous projects involving the local community, new protected areas were opened by the ITCF during the last few years : Xo-Pol area in 1994; and the Sarteneja National Tree Park in 1999. In parallel, the ITCF assisted the Belize Coastal Unit in the creation of the Bacalar Chico National Park & Marine Reserve, in 1996, which is part of the Belizean network of the UNESCO World Heritage Sites. In Shipstern Nature Reserve, scientific work has been and is being further developed by the ITCF in conjunction with the universities of Bern, Neuchâtel, and Fribourg—several studies were completed between 1998 and 2001 (see paragraph 1.1).

Located at the northeastern limit of Belize in the Corozal District (see figs. 1 and 4), the Shipstern Nature Reserve covers an area of approximately 9000 hectares (22000 acres). It encompasses part of the Shipstern Lagoon, which is in direct contact with the southern waters of Chetumal Bay, and it also includes the separate surface of Xo-Pol (600 hectares). By land, the only means of access to the area is an all-weather road starting at Orange Walk, and ending at the fishermen village of Sarteneja. This road marks the northern boundary of the reserve, which is otherwise delimited by extensive survey lines that are used both as boundaries and trails. Further trails allow an easy access to most of the areas situated north of the lagoon, whereas the Xo-Pol area is best accessed by the dirt road of Cowpen. Concerning the areas situated south of the lagoon, the main and most direct means of access is by boat. Indeed, when going from the channel of Cowpen, both Iguana Camp and Shipstern Landing, as well as the village of Fireburn, are easily accessible.

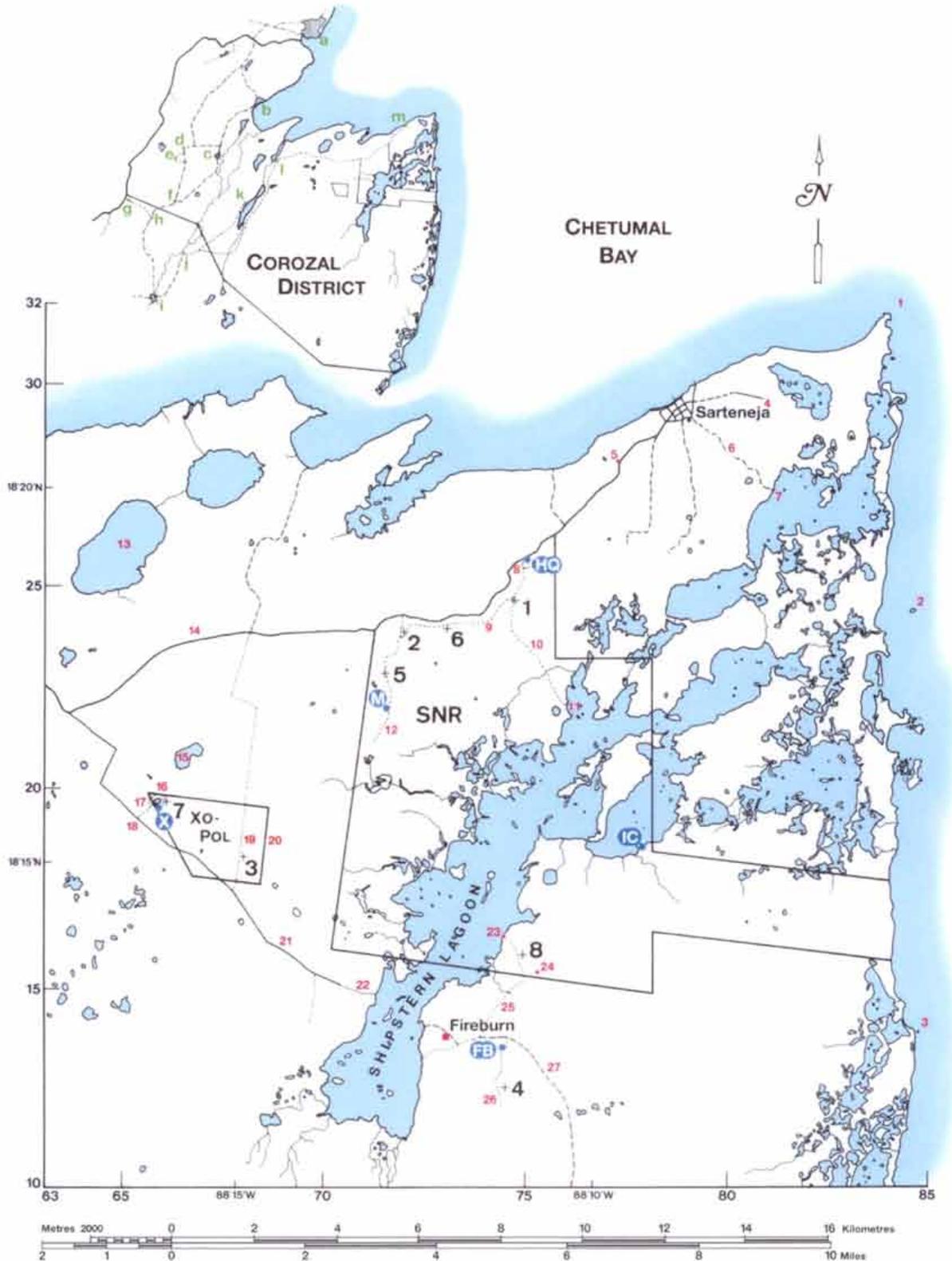


Figure 1. Map of Corozal District (above) and Shipstern Nature Reserve (below). **a**, Chetumal; **b**, Corozal; **c**, Libertad; **d**, Louisville; **e**, San Narciso; **f**, Buena Vista; **g**, Douglas; **h**, San Pablo; **i**, Orange Walk; **j**, San Estevan; **k**, Progreso; **l**, Chunox; **m**, Sarteneja; **FB**, Fieldbase; **HQ**, Headquarters; **IC**, Iguana Camp; **M**, Main Trail Treetop; **X**, Xo-Pol Treetop; **1-8**, trapping sites; **1**, Rocky Point; **2**, Shipstern Cay; **3**, Condemned Point; **4**, Sarteneja Airstrip; **5**, Museum of the Sarteneja National Tree Park; **6**, Wildtracks; **7**, La Isla; **8**, Botanical Trail; **9**, New Trail; **10**, Thomson Trail; **11**, Cayo Verde; **12**, Main Trail; **13**, Barracouta Pond; **14**, Main Road; **15**, Chacan Chac Mol; **16**, Xo-Pol Pond; **17**, Pond Trail; **18**, Treetop Road; **19**, Tiger Road; **20**, Tiger Trail; **21**, Cowpen Road; **22**, Cowpen Channel; **23**, Shipstern Landing; **24**, Shipstern Old Village; **25**, Shipstern Trail; **26**, Fieldbase Trail; **27**, Fireburn Road. Grid : Universal Transverse Mercator and WGS 84.

With about a third of the surface being occupied by the Shipstern Lagoon, habitats in the reserve appear to be diverse and patchily distributed. Indeed, the lagoon constitutes an intricate system of shallow waters (1-3 feet) bordered by dwarf mangroves and other saline wetlands—listed in the Directory of Neotropical Wetlands (IUCN/IWRB, 1986)—, and dotted with numerous small mangrove islands. Besides, so called « forest islands » are randomly distributed in the transitional areas with true forest. The latter tends to vary considerably in its structural and floristic characteristics, thus creating a complicated mosaic of various forest types—the patches of which are sometimes less than 50 ft wide—that are not always clearly delimited. Aiming for a better understanding of its vegetation, Bijleveld (1998) listed seven main vegetation types within Shipstern Nature Reserve (see fig. 2) :

1. Yucatecan medium-sized semi-evergreen forest.

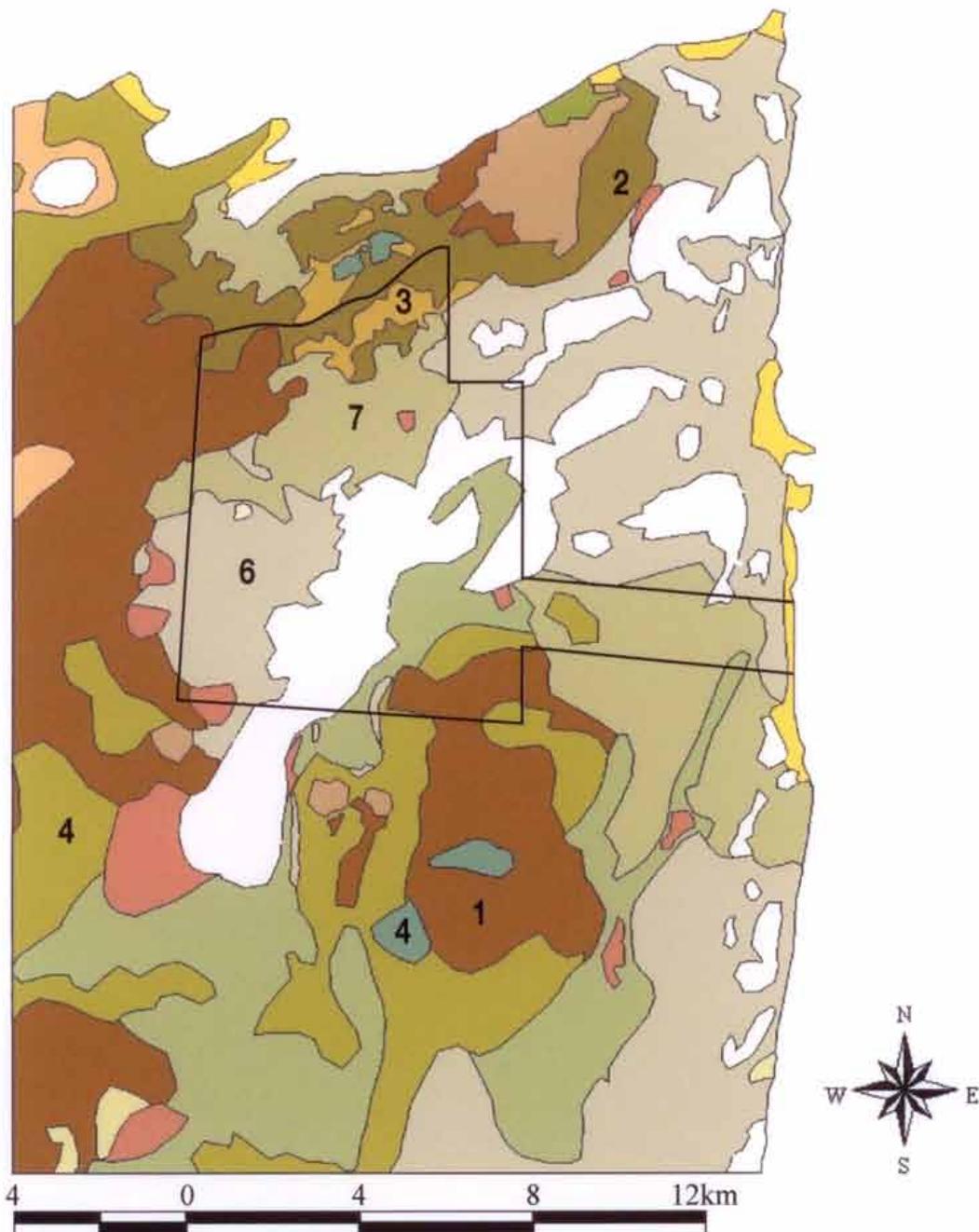
This forest type (30-50 ft) covers most of the land situated to the west of the reserve, including the Xo-Pol area (see fig. 1), as well as the land situated to the south of Shipstern Lagoon, including the Shipstern area. But, whereas it alternates with extensive Cohune forests in the latter, such is not the case in the Xo-Pol area where Cohune trees are virtually absent. Dominant species composing its canopy are : *Brosimum alicastrum*, *Hampea trilobata*, *Coccoloba reflexiflora*, *Bursera simaruba*, *Metopium brownei*, and *Manilkara zapota* (emergent tree). Dominant understory species are : *Pithecellobium stevensonii*, *Coccoloba schiedeana*, *Ouratea lucens*, *Randia aculeata*, and *Croton reflexifolius*. Beside *Brosimum alicastrum*, differential species for this vegetation type are : *Dendropanax arboreus*, *Nectandra salicifolia*, *Pouteria campechiana*, *Protium copal*, *Quararibea funebris*, *Sabal yapa*, *Swartzia cubensis*, *Tetrapteris schiedeana*, *Talisia olivaeformis*, and *Nectandra coriacea*. An additional differential species, *Cryosophila stauracantha*, is found in the Xo-Pol area.

2. Yucatecan medium-sized semi-deciduous forest.

This forest type (30-45 ft) covers part of the land situated north of the reserve, where it alternates with Low semi-deciduous *Pseudophoenix s.sargentii* forests. In the Main Trail area (see fig. 1), it is transitioning to vegetation type 1. Dominant species composing its canopy and its understory are similar to the Yucatecan medium-sized semi-evergreen forests, therefore it is very difficult to differentiate between the two. Besides, no differential species for it have been clearly brought out yet. Hence, it is mainly characterized by the absence of species such as *Brosimum alicastrum*, or *Pseudophoenix s.sargentii* that are distinguishing vegetation types 1 and 3 respectively.

3. Low semi-deciduous *Pseudophoenix s.sargentii* forest.

This forest type (20-40 ft) covers part of the land situated north of the reserve, including the New Trail area, where it alternates with Yucatecan medium-sized semi-deciduous forests. Some patches of it—coinciding with previously disturbed areas, after the passage of hurricane Janet in 1955 (see below)—are dominated by *Lysiloma latisiliquum*, and can be considered as a structural variant called *Lysiloma*-dominated *Pseudophoenix s.sargentii* forest. In the latter, the canopy is almost exclusively composed of *L.latisiliquum*, which will be gradually replaced by the usual canopy species yet confined to the understory. Otherwise, dominant species composing its canopy and its understory are fairly the same as in vegetation types 1 and 2, with commonly associated species such as *Agave augustifolia* and *Diphysa carthagenensis*.



- | | | | |
|---|---|---|--|
|  | Basin mangrove forest |  | Shifting cultivation including unimproved pasture |
|  | Coastal fringe <i>Rhizophora</i> mangle dominated forest |  | Yucatecan medium-sized semi-evergreen forest (1) |
|  | Discontinuous dwarf mangal interrupted by bare salt flats (7) |  | Low periodically inundated forest - Pucteal and Tintal (4) |
|  | Evergreen broadleaf scrub dominated by leguminous shrubs |  | Low periodically inundated forest - Mucal and Tasistal (4) |
|  | Discontinuous dwarf mangal interrupted by bare salt flats mixed with <i>Cladium jamaicense</i> -dominated herbaceous wetlands (6) |  | Yucatecan medium-sized semi-deciduous forest (2) |
|  | Low semi-deciduous <i>Pseudophoenix s.sargentii</i> forest (3) |  | Urban |
|  | Mixed mangrove scrub |  | Water bodies |
|  | Permanently waterlogged freshwater mangrove scrubs | | |

Figure 2. Vegetation types of Shipstern Nature Reserve and its vicinity. Modified from Meerman (2000, unpublished). Vegetation types 5 and 8 are not represented (see paragraph 1.3).

Differential species from this forest type are : *Pseudophoenix s.sargentii*, *Ceiba aesculifolia*, *Coccothrinax argentata*, *Erythroxylum rotundifolium*, *Gymnopodium floribundum*, *Hintonia octomera*, *Lysiloma latisiliquum*, *Neomillspaughia emarginata*, *Plumeria obtusa*, *Eugenia buxifolia*, *Randia truncata*, and *Beaucarnea ameliae*.

4. Low periodically inundated forest.

This heterogeneous type of low forest (10-20 ft) is represented by four closely related vegetation types called Pucteal, Tintal, Mucal and Tasistal. Often growing in a complicated mosaic, locally called « Bajo forest », these plant communities are patchily scattered all over the reserve, and only part of them have yet been localized. Whereas the elevation and duration of inundation are gradually decreasing from the Mucal to the Pucteal, the Tasistal forms an open habitat (Tasiste marsh) close to being permanently inundated. It is dominated and differentiated by the palm *Accoelorrhapha wrightii*, which is typically found with *Erythroxylum areolatum*, *Eugenia acapulcensis*, and *Jacquinia aurantiaca*, along with occasional species such as *Crescentia cujete*, *Borreria verticillata*, *Eustoma exaltatum*, and *Cladium jamaicense*. The Mucal forms a shrub forest (Muc marsh) dominated by *Dalbergia glabra*, which is typically found with species such as *Cameraria latifolia* and *Malpighia lundellii*. The Tintal forms a semi-open habitat (Tinta marsh) dominated by *Haematoxylon campechianum* and *Byrsonima bucidaefolia*. The Pucteal forms a low forest dominated by *Bucida buceras*.

5. *Bravaisia tubiflora*-dominated transitional zone.

This type of low forest (10-25 ft) is mainly found in the surroundings of Shipstern Lagoon, where true forest is transitioning to open wetlands—in most cases, *Cladium jamaicense*-dominated herbaceous wetlands. Such transitional zones are inundated at the peak of the rainy season, whereas their soils remain water-saturated for most of the year. However, it can also be present in forest areas bordering more permanent bodies of water. It is dominated and differentiated by *Bravaisia tubiflora*, which is typically found with *Croton reflexifolius*, *Sabal yapa*, *Metopium brownei*, *Eugenia rhombea*, and *Eugenia acapulcensis*, along with occasional species such as *Ouratea nitida*, *Cameraria latifolia*, and *Dalbergia glabra*.

6. *Cladium jamaicense*-dominated herbaceous wetlands.

This type of wetland (3-5 ft) is found in the surroundings of Shipstern Lagoon, where it forms a transitional belt between true forest and mangal flats. Often preceded by a *Bravaisia tubiflora*-dominated transitional zone, the belt varies in width from nearly nothing to about 350 ft (100m). It is dominated and differentiated by *Cladium jamaicense*, which is normally found with species such as *Conocarpus erectus* and *Solanum blodgettii*. Assimilated to this vegetation type, an omnipresent variant dominated by *Distichlis spicata* forms another transitional belt between the *Cladium jamaicense*-dominated belt and the mangal flats.

7. Discontinuous dwarf mangal interrupted by bare salt flats.

This type of mangal association (3-6 ft) covers most of the periodically inundated surface bordering Shipstern Lagoon, and extending to areas of transition with true forest. Also along the coast, it represents the dominant vegetation type within the reserve. It is fairly intermittent, with large patches of ground being completely bare of vegetation, sometimes interrupted by so-called « forest islands »—punctual change in ecological conditions allowing various

vegetation types to establish, including *Thrinax radiata*-dominated low forests (not considered as a distinct vegetation type). It is dominated by the red mangrove (*Rhizophora mangle*), which constitutes well-developed communities along the lagoon, but is otherwise found in patches of its dwarf counterpart. Typical associated species are the white (*Laguncularia racemosa*) and the black (*Avicennia germinans*) mangroves, only found in dwarf form. Occasionally, species such as *Distichlis spicata*, *Fimbristylis spadicea*, *Batis maritima*, and *Salicornia perennis* are also found in this vegetation type.

One more vegetation type can be added to this list (Wright et al., 1959) :

8. Cohune forest.

With the exception of a few small patches localized in the Xo-Pol area (see fig. 1), this forest type (50-70 ft) is exclusively found in the deep soils of the land situated south of the lagoon, including the Shipstern area. It alternates with Yucatecan medium-sized semi-evergreen forests, and patches of Low periodically inundated forests. The dominant and differential species composing the canopy is the cohune palm : *Orbignya cohune*. Associated canopy and understory species are otherwise similar to vegetation type 1.

The Shipstern Nature Reserve plays an important role in Belize representing one of the very few protected areas in the northern lowlands. As a consequence, as far as Belize is concerned, the Yucatecan medium-sized semi-evergreen forests situated in the north of the country—well represented over most of the Yucatan Peninsula, this forest type was probably covering the whole Corozal District before the expansion of sugar cane fields—as well as the very rare Yucatecan medium-sized semi-deciduous forests, are almost exclusively found in and around the reserve. Furthermore, the latter protects the unique patch of Low semi-deciduous *Pseudophoenix s.sargentii* forest distributed on mainland Belize, other patches being localized in the Bacalar Chico National Park & Marine Reserve, and in the Yucatan Peninsula mainly.

The fishermen village of Sarteneja (over 1500 inhabitants) as well as the Shipstern Lagoon, and its surrounding forested areas have long been fairly isolated from the rest of the country. This is mainly due to the fact that the present all-weather road (see fig. 1) was nothing more than a dirt track before 1980. As a consequence, the pressure that was exerted on the area remained relatively low until recently, coming down to low-scale logging, and occasional hunting carried out by the villagers of Sarteneja, Chunox, and Fireburn. Hence, the flora (Bijleveld, 1998, and Sayer, 2000) and fauna are still particularly rich. For example, among mammals, all five cat species occurring in Belize are present in the reserve (Miller, 1995), as well as commonly hunted species such as the White-tailed Deer, the Red Brocket, or even the Baird's Tapir (see appendix 2). Besides, healthy populations of the endangered Morelet Crocodile (*Crocodylus moreleti*) live in the few freshwater ponds of the Xo-Pol area, whereas the other Belizean crocodile species, namely the Saltwater Crocodile (*Crocodylus acutus*), has already been observed in the Shipstern Lagoon. Furthermore, among birds, two expanding colonies of the otherwise declining American Woodstork (*Mycteria americana*) breed on two mangrove islands of the lagoon nearby Iguana Camp.

Nowadays, however, an increased demography in Belize coincides with an increased pressure on the forest areas and on the fauna. Of primary concern is the rapid expansion of cultivated lands. In the surroundings of the Shipstern Nature Reserve, slash and burn cultivation—locally named « milpas »—principally owned by the villagers of Chunox is more and more common in

the vicinity of Xo-Pol. Whereas a worrying increase in agricultural activities carried on by Mennonites—community of settlers of dutch, german, and swiss origin who arrived in Belize from neighbouring countries during the sixties—is observed from Little Belize towards Shipstern Lagoon. In addition, selective logging aimed at species such as Santa Maria (*Callophyllum brasiliense*), Ciricote (*Cordia dodecandra*), and Mahogany (*Swietenia macrophylla*) is expanding throughout the eastern forests of Corozal District, and in particular those around Fireburn which are virtually empty of their large trees.

Occasionally, extensive destructions of forests is caused by natural phenomena. Such is the case during the so-called « hurricane season », which is usually any time from September to November. Thus, as far as the Shipstern Nature Reserve is concerned, two hurricanes have led to serious damages. The first one, hurricane Janet, hit Belize in 1955, and greatly affected the northern part of the country. As a result, the villages of Sarteneja and Shipstern, as well as Corozal Town were completely destroyed, whereas the forests in and around the present reserve were almost entirely flattened and burnt by subsequent fires. Because of this, the vegetation of Shipstern Nature Reserve can be considered as being 46 years old, and most of its vegetation types have not yet reached a structural climax. The second one, hurricane Keith, hit the country during the course of the present study, in early October. Apart from the fact that San Pedro and Cay Caulker were partially destroyed, damages caused directly by the wind remained unextensive in the Corozal District—the reserve still suffered from localized falls of large trees. However, unusual fluctuations of the water level caused by extreme rainfalls and inland accumulation of water carried in by the wind, led to serious floods. As a result, the water depth in the Shipstern lagoon was estimated at 4-6 feet, and the village of Chunox, as well as Orange Walk remained surrounded by floods for weeks.

Rainfall at the reserve was measured over a period of four years, between October 1989 and October 1993 (Meerman and Boomsma, 1993, in Bijleveld, 1998). An average annual rainfall of 1260mm (49.6 inches) was recorded, with a minimum at 1029mm (40.5 in.), and a maximum at 1610mm (63.4 in.). Such results suggest that Shipstern Nature Reserve is in one of the driest areas in Belize (see fig. 5), with a pronounced dry season—in the year of the present study, the months of February and March appeared to be exceptionally dry, with no rainfall and 10mm (0.4 in.) respectively (Sayer, 2000). As a consequence, the water level of the Shipstern Lagoon fluctuates on a yearly cycle, and areas close to the lagoon are temporarily flooded during the wet season.

A small scale karst topography with elevations not exceeding 4-5m (17ft) exists in and around the reserve (Bijleveld, 1998). This is mainly due to the sequence of limestone composing the underground, the most recent layer of which being the Buena Vista formation (see paragraph 1.6), a dense and highly fossiliferous limestone. Thus, numerous sinkholes, caves, and natural wells are found in the area, but there is virtually no stream and river system on the surface. Regarding the soils, they are believed to belong to mainly four categories in the reserve (King et al., 1992, in : Bijleveld, 1998) :

1. Pembroke suite - Xaibe subsuite — with Chromic Cambisols (FAO/UNESCO international system of classification) when shallow, or Chromic Luvisols when deep, these soils are mostly underlying the vegetation type 1 (see above), and occasionally 2, 3 and 4.
2. Bahia suite - Remate subsuite — with Leptosols, these soils are mostly underlying the vegetation type 3, and occasionally 2.

3. Yaxa suite — with deep Chromic Luvisols, these soils are mostly underlying the vegetation type 8, and occasionally 4.
4. Tintal suite - Chucum, Sibal, and Ycaco subsuites — with Gleysols when partly organic, or Histosols when mineral, these soils are found in most seasonally or permanently inundated areas underlying the vegetation types 4, 5, 6 and 7.

1.4. General locality :

Situated south of the Tropic of Cancer ($23^{\circ}26'45''\text{N}$), Belize is in the Neotropics between $15^{\circ}50'\text{N}$ and $18^{\circ}30'\text{N}$. It lies on the Atlantic side of Central America, and its eastern coast is further north extended by the Yucatan Peninsula, Mexico. Also, it shares its western and southern boundaries with the Guatemalan departments of El Petén and Izabal respectively, and its northern boundary with the Mexican state of Quintana Roo. Apart from the mainland, Belize comprises a range of islands spreading all along the coast, starting with Ambergris Cay at the north, and ending with Lime Cay at the south. Most of these islands are bordered with coral reefs, thus constituting the most important barrier reef (about 290km) of the Western Hemisphere.



Figure 3. Political map of Central America. Reproduced from Reid's (1997) plate 49.

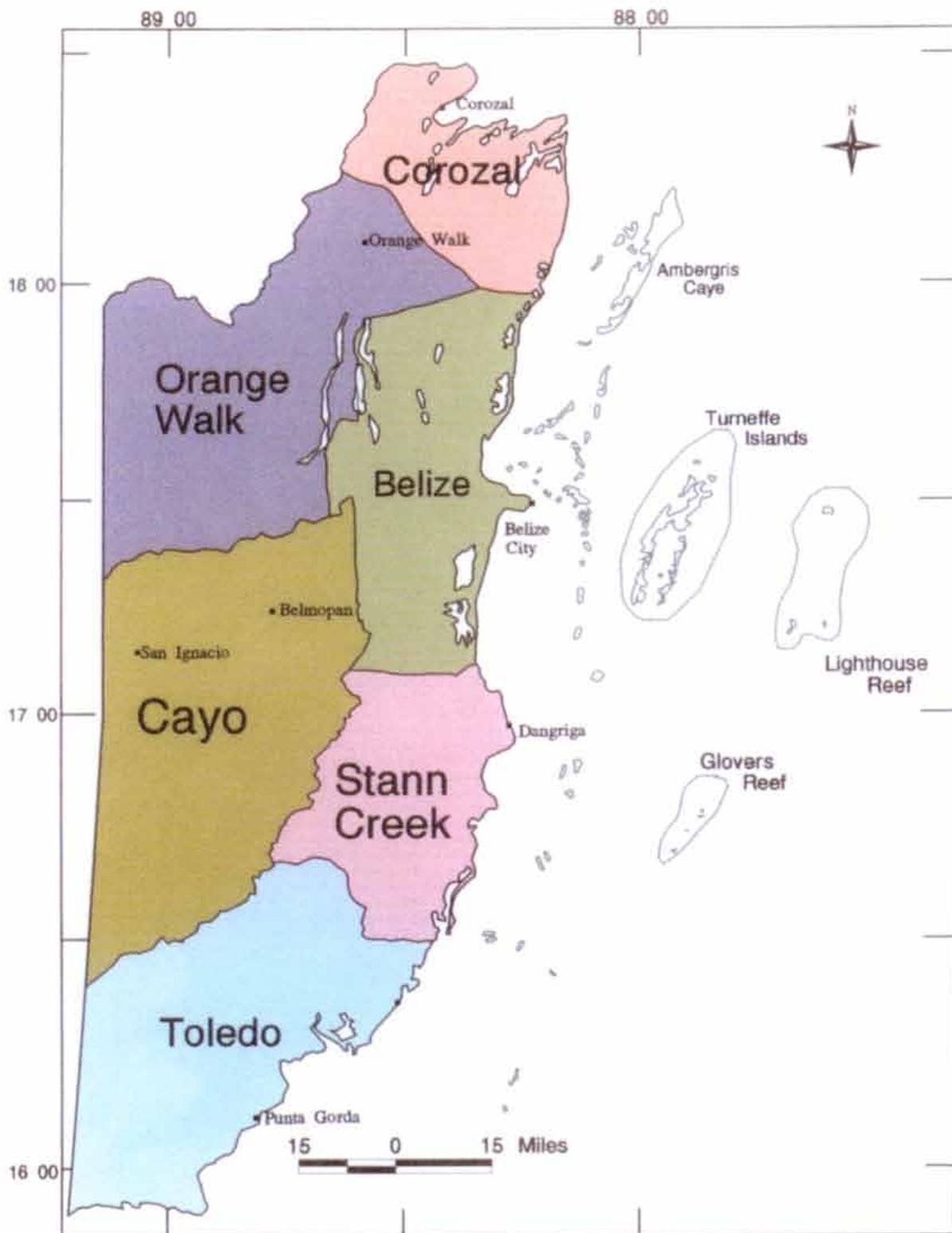


Figure 4. District boundaries of Belize. Reproduced from Stafford and Meyer (2000).

1.5. General climate :

Its position in the northern Tropics, gives Belize a greater annual range of temperatures than further south in Central America. Thus, whereas King et al. (1992, in : Bijleveld, 1998) found an annual mean temperature of 26°C (78.8°F), temperatures exceeding 40°C (104°F) have already been measured in the country (Walker, 1973, *in* Bijleveld, 1998). And, it is not uncommon to see the temperatures dropping as low as 10°C (50°F) between the months of November and December, when cold air masses enter the country from the north-east. Concerning the mean monthly temperatures, minima range from 16°C (60.8°F) in winter to 24°C (75.2°F) in summer, and maxima from 28°C (82.4°F) to 33°C (91.4°F).

On a yearly cycle, rainfall tends to vary markedly in Belize. It starts with a pronounced dry season between the months of January and May—February and March being the driest months. And, even if wet weather often occurs in late April or May, only 10% of the annual rainfall may be received during the overall period (Stafford and Meyer, 2000). Then, from June to December, rainfall increases gradually to reach a maximum in September, following a dry spell in August. And some years, this is precisely in September just as in October and November that the wet season turns to a hurricane season. However, if Belize is frequently facing tropical storms, few hurricanes ever reach the country. And among those that did in the past, only four are known to have caused serious damages : one in 1931, Janet in 1955, Hattie in 1961, and Keith in 2000.

From south to north in Belize, the mean annual rainfall decreases considerably (see fig. 5). Furthermore, rainfall tends to be higher and seasonality less severe on the southeastern slopes of the Maya Mountains exposed to the southeast tradewinds than on the northwestern side, where a rain shadow effect reduces the precipitations while reinforcing seasonality (Stafford and Meyer, 2000). Thus, annual rainfall averages 1347mm (53 inches) at Libertad (Corozal District), 1550mm (61 in.) at Orange Walk (Orange Walk District), 1500mm (59 in.) at Gallon Jug (Orange Walk District), 1650mm (65 in.) at Douglas Da Silva (Cayo District), 1850mm (73 in.) at Belize City (Belize District), and 4526mm (178 in.) at Barranco (Toledo District).

1.6. General geology :

The dominant physical feature in Belize is the Maya Mountain massif (see fig. 6). Starting from Mount Margaret (940m)—situated halfway between Belmopan, capital of Belize, and Dangriga—it forms an arc-shaped range extending southwesterly to Victoria Peak (1120m), to Richardson Peak (1000m), and then to the vicinity of Poptún in the department of El Petén, Guatemala. On the south-eastern side of the range, mountain slopes rise steeply from the coastal plain. Whereas on the leeward side (see above), they descend more gradually westerly in direction of the Vaca Plateau, but rise again northerly at Mount Baldy (1020m). According to Stafford and Meyer (2000), the ridge-top plateau Doyle's Delight culminating at 1160m (3805ft) is the highest point in Belize.

Beside these highlands, the remaining part of the country is essentially flat (below 100m). It includes a coastal plain stretching all along the Belizean coast, and lowlands covering the whole remaining area between Belmopan and Corozal, and further extending northward from Chetumal to Cancún on the eastern side of the Yucatan Peninsula, Mexico. In northern Belize, only Yalbac Hills (237m) along with isolated hills at the Guatemalan border give a little topographical relief.

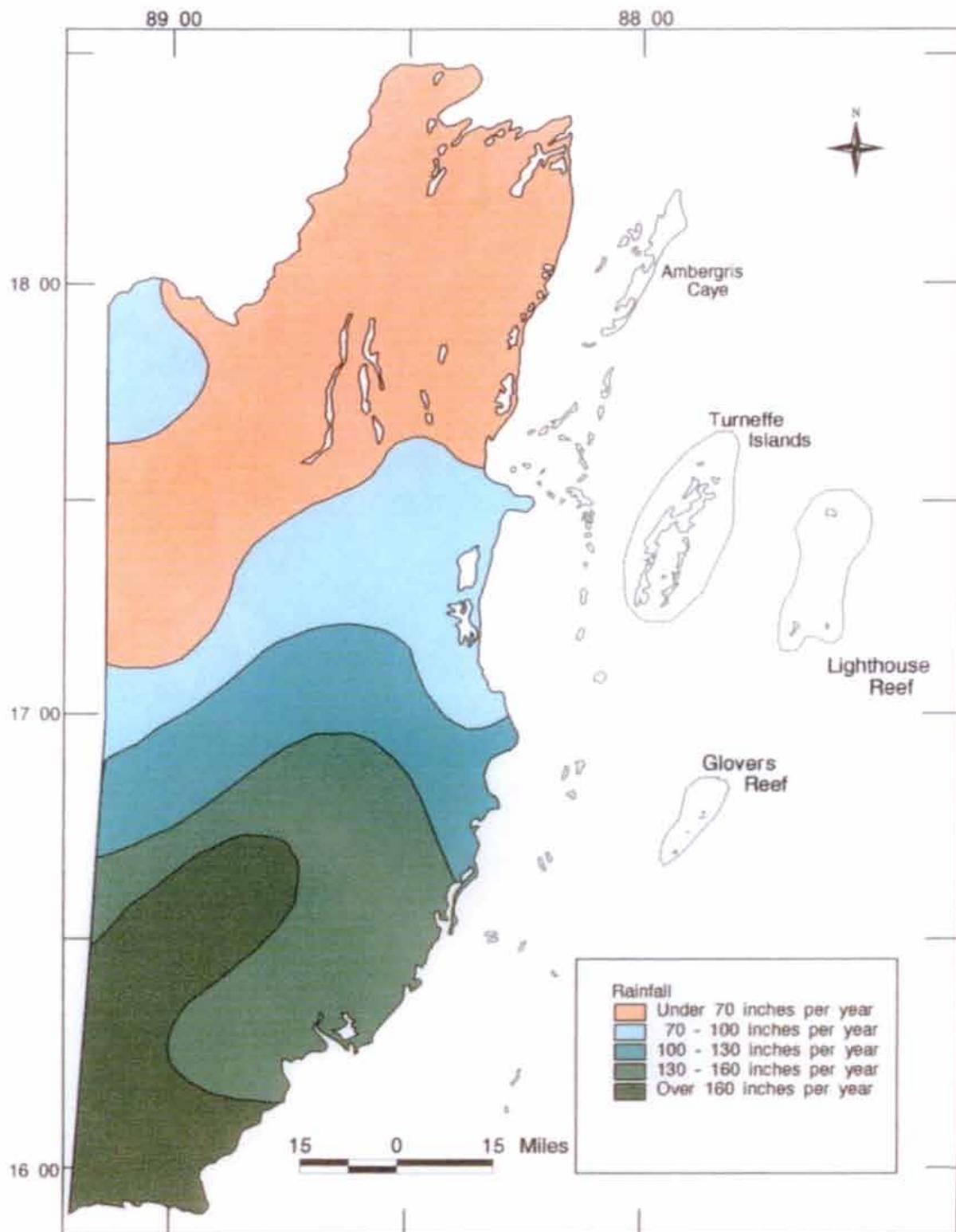


Figure 5. Rainfall in Belize. Reproduced from Stafford and Meyer (2000).

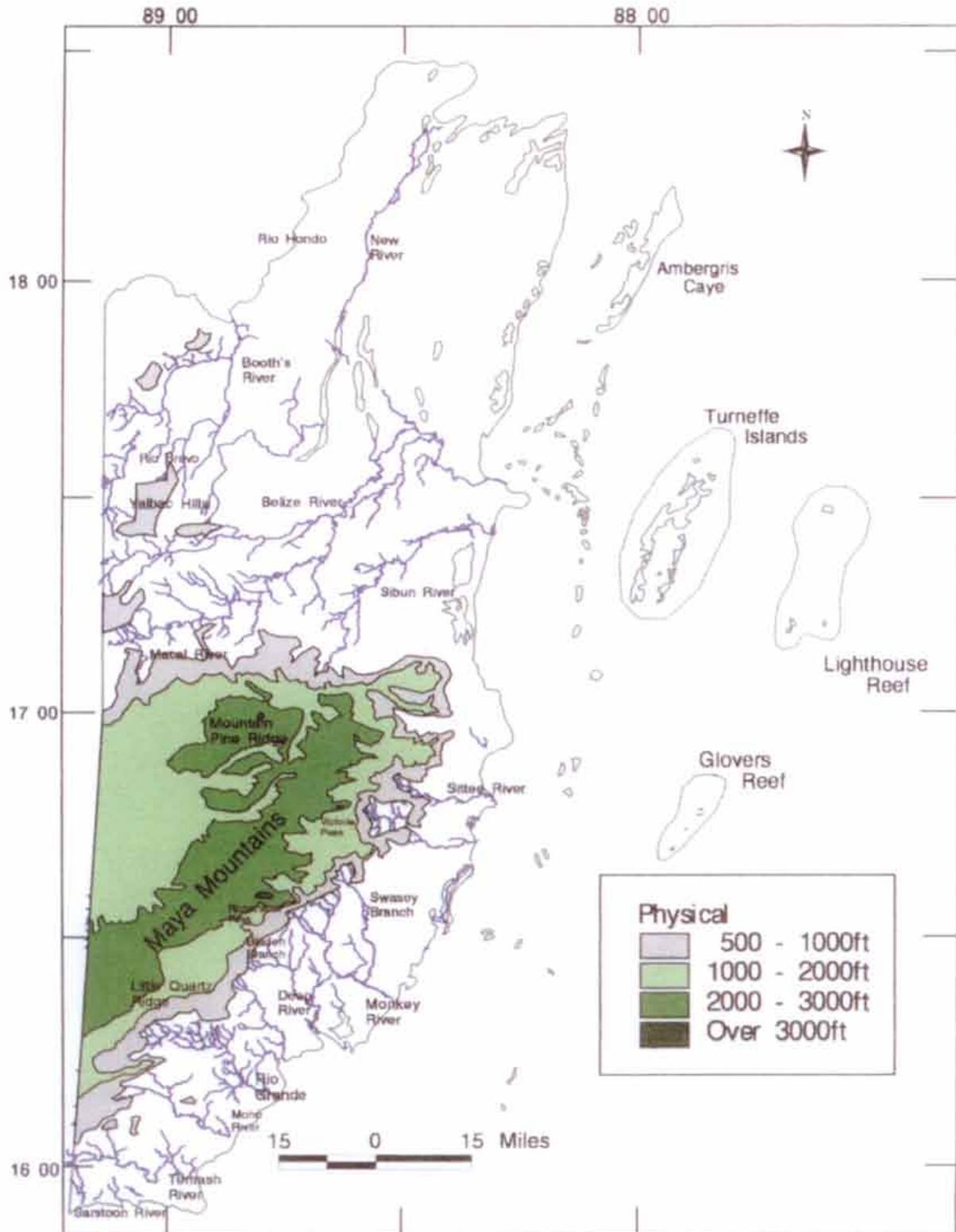


Figure 6. Physical map of Belize. Reproduced from Stafford and Meyer (2000).

Following the retreat of the sea, which inundated much of the country during the Cretaceous, all but the highest parts remain covered by a thick deposit of limestone, dolomite, and evaporites (see fig. 8). Named Coban limestone (Hartshorn et al., 1984), this deposit has successively been covered by two other cretaceous limestones, the Campur limestone—partially porous, it develops prominent karst topography whenever exposed in outcrops, and is probably the major aquifer in Belize—and the Lacandon formation. In turn, during the Tertiary, they have been covered by the Santa Amelia formation in Orange Walk District and Cayo District (north), by the Buena Vista formation in Belize District and Corozal District, and by the Toledo formation in Toledo District (south). Moreover, during the quaternary, extensive deposits of detrital materials eroded from the highlands and quartz sand deposits have accumulated along the coast and around some lagoons, from which are derived the present coastal plain sediments.

In this way, the Maya Mountain massif is the only area of Belize where large upfaulted blocks of intrusive (mainly granite) and associated metamorphic sedimentary (mainly talc and white mica) rocks are preponderant (Hartshorn et al., 1984, *in* Bijleveld, 1998). Such a substrata with only a thin soil cover means that water is essentially drained on the surface, thus constituting an extensive system of streams and rivers. By contrast, karst topography with jagged limestone peaks, caves, sinkholes, and underground rivers lies around the northern and southern edges of the massif (Stafford and Meyer, 2000) in areas where cretaceous limestones are exposed in outcrops (see fig. 8). To a lesser extent, a modest karst topography is also developed in the northern lowlands covered by tertiary limestones.

1.7. Phytogeography :

Despite a long-established timber industry, and a history of successive destructions due to natural phenomena (see Shipstern Nature Reserve), Belize remains covered by substantial areas of natural vegetation. However, most of its forests are secondary in nature.

The majority of plants growing in the country have a wider distribution, often ranging from Southern Mexico to the north of South America (Bijleveld, 1998). The very few endemic species found in Belize lead to consider its flora on a larger scale. Thus, it is commonly divided in two phytogeographic regions (Gentry, *in* Bullock et al., 1995) :

1. Caribbean region

In Belize, it extends over the Corozal District, including Shipstern Nature Reserve. It is otherwise comprising the whole Yucatan Peninsula, along with the Greater and Lesser Antilles, and the coastal plains of the southern United States (Florida and Texas).

2. Central American region

It extends over the remaining part of the country, so that the northern boundaries of Orange Walk District and Belize District lie in a transitional zone between the two phytogeographic regions. It also covers the Guatemalan departments of El Petén and Izabal, and most of the central american continent.

Based on the Holdridge (1967) classification of life zones combining the effects of latitude, altitude, evapotranspiration, and precipitation, Hartshorn et al. (1984) listed six major ecological life zones in Belize (see fig. 7) : the Subtropical Moist forest, Subtropical Lower

Montane Moist forest, Subtropical Lower Montane Wet forest, Subtropical Wet forest, Tropical Moist forest, and Tropical Wet forest life zones. According to these authors, most of the northern lowlands, along with the Yucatan Peninsula, are included in the Subtropical Moist forest life zone, whereas Murphy and Lugo (*in* Bullock et al., 1995) classified this same area as a Tropical Dry forest life zone. However, the dry climate prevailing in the Corozal District is more typical of a Subtropical Dry forest life zone, so that Shipstern Nature Reserve is probably situated at a transitional position in the Holdridge life zone system.

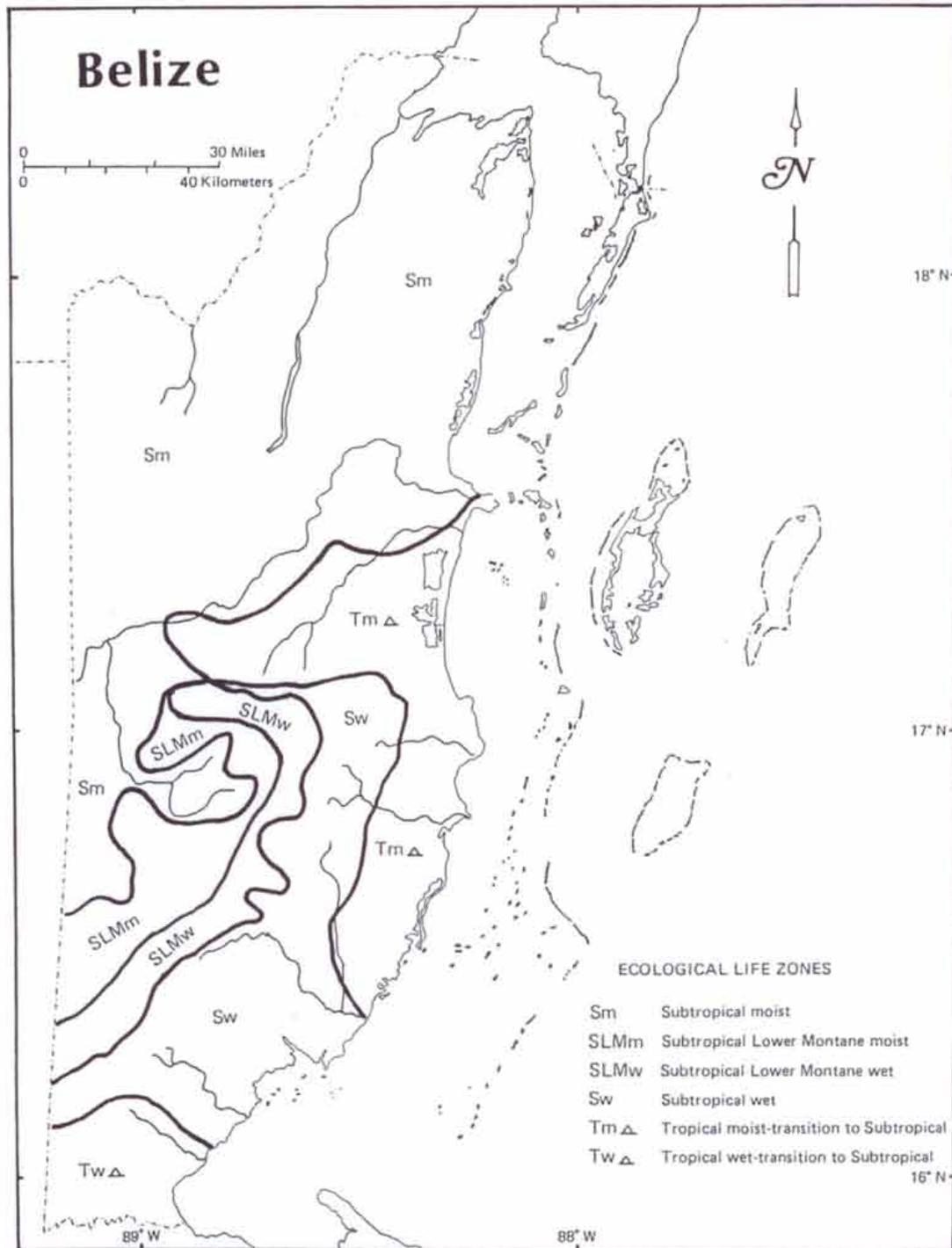


Figure 7. Ecological Life Zones of Belize. Reproduced from Hartshorn et al. (1984).

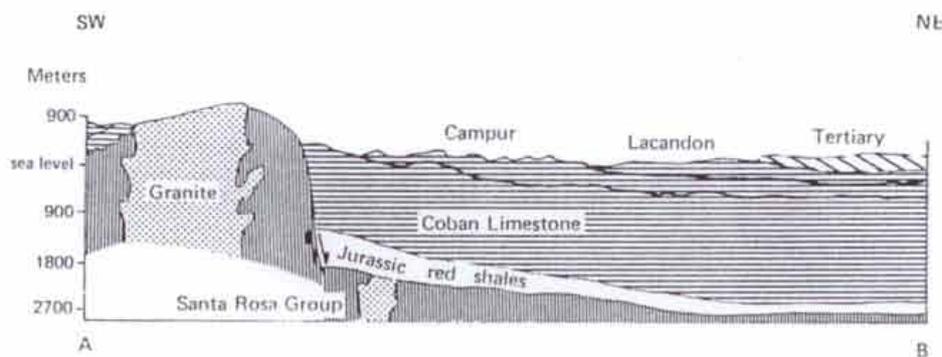
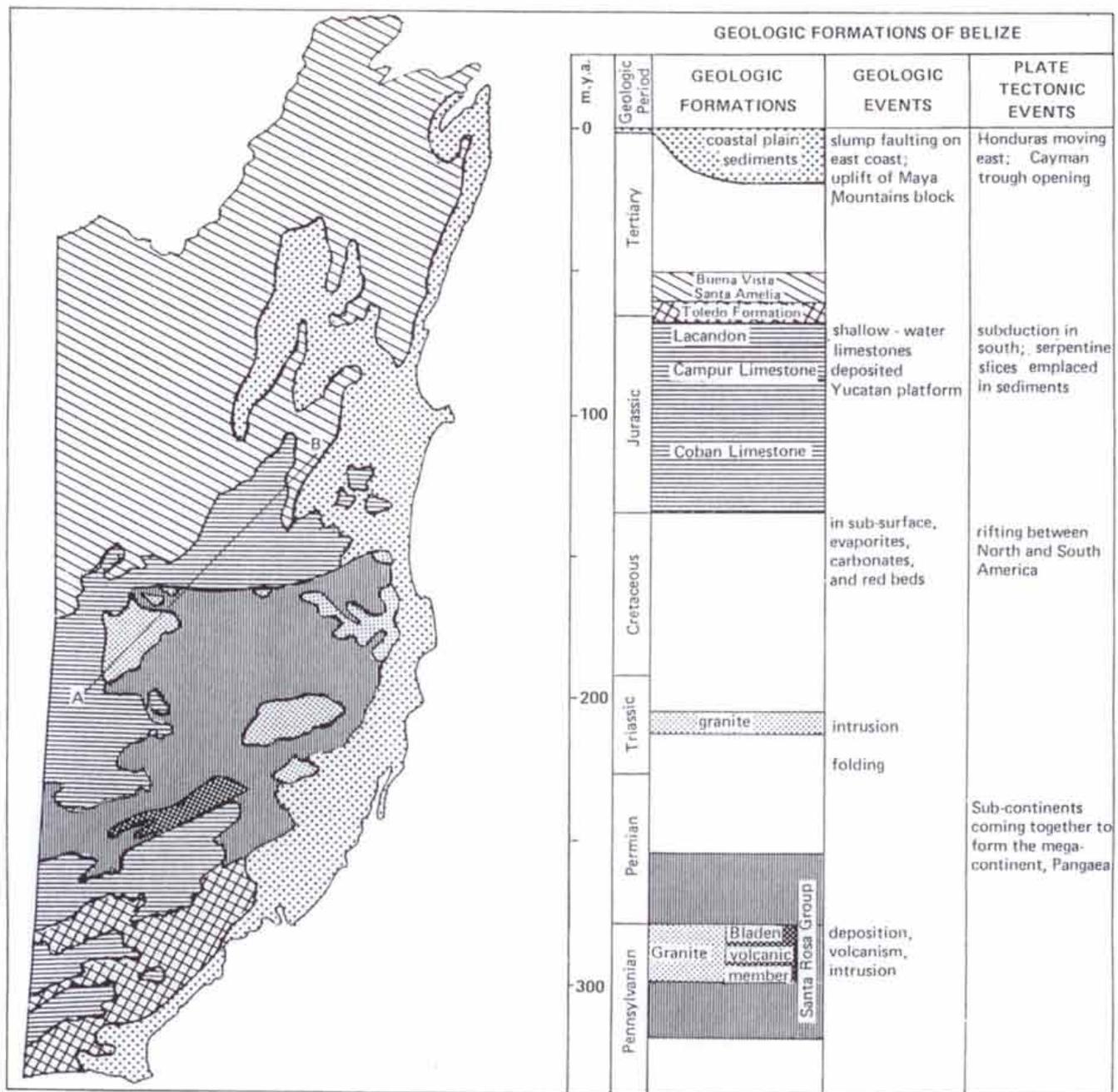


Figure 8. Geologic formations of Belize. Reproduced from Hartshorn et al. (1984).

Chapter 2

Materials and Methods :

2.1. Trapping sites :

Referring to the geographic distribution of the vegetation types listed above (see fig. 2), four areas were selected in and around Shipstern Nature Reserve : the New Trail, Main Trail, Xo-Pol, and Shipstern areas (see fig. 1). Being representative of characteristic habitats, two trapping sites were attributed to different localities—selected on the basis of their accessibility and the presence of ecotones—within each of these areas. Data related to the resulting eight trapping sites are summarized in table 1.

2.2. Transects :

Each of the eight trapping sites were identically built by reproducing a standardized trap design (Patton et al., 2000). It consisted of two parallel transects separated by a distance of 500 ft (150m). Each trapping line was 940 ft (285m) in length and subdivided into 20 trap stations at 50 ft (15m) intervals. In turn, four traps (see below) were positioned at each trap station, for a total number of 160 traps per trapping site. Transects were set either in a north-south, or a west-east direction by using a compass along with a 500 ft long red line marked every 17 ft (5m). Marking of the trapping lines was based upon the latter, so that a fluorescent orange tape was fastened to a trunk, a vine, or a shrub at 17 ft intervals. Every 50 ft, a number from 1 to 20 was attributed to these marks, thus giving the position of each trap station. Both trapping lines were numbered the same way, that is with trap station (1) at *north* (northern end of the line) and (20) at *south*, or conversely *west* and *east* depending on the trapping site—with the exception of trapping site n°2, where (1) is at *south*, and (20) at *north*. To differentiate the transects, the letters A and B were attributed to the lines with traps 1 to 80 (see below), and 81 to 160 respectively. Forest trails—discreet paths opened by the author—were set so as to facilitate the moves along each trapping line, from one transect to the other, and from the trail of access (see table 1) to the overall trapping site.

2.3. Traps :

One folding Sherman (23 x 7.5 x 7.5 cm) and three folding BTS—Besançon Techniques Services, Besançon, France—mesh (28 x 10.5 x 10.5 cm) live traps were set at each trap station (see fig. 9). Traps were placed in the most likely microhabitat—along logs, next to dens, at converging branches, on connecting vines, etc...—within 7 to 17 ft (2-5m) of the station marker. Wherever possible, two BTS mesh live traps were positioned from a height of 4 to 14 ft (1-4m), whereas the third one remained terrestrial. The Sherman live trap was always set on the ground. In this way, each trap was attributed to one of the following trap types (see table 5) : S=Sherman; T=terrestrial BTS; A1=arboreal BTS (<1m); A2=arboreal BTS (1-3m); and A3=arboreal BTS (>3m).

All traps were anchored to their support by using wire for fastening them to a root or a branch, for example. Each trap was marked with blue tape bearing a number between 1 and 160. The number allowed any trap to be precisely positioned along transect A or B by following the numeration of trap stations. For example, traps 1 to 4 were attributed to trap station (1) of transect A, traps 5 to 8 to (2) of A, traps 81 to 84 to (1) of B, and traps 157 to 160 to (20) of B. In addition, the highest number at each trap station was always given to the Sherman live trap, that is number 4, 8, 12,..., 156, 160. For bait, the dried fruit of Guaya trees (*Talisia olivaeformis*) was fixed on the hook of BTS mesh live traps, and coated with peanut butter—no baits were used for Sherman live traps.



Figure 9. BTS mesh wire live trap. Reproduced from Besançon Techniques Services' brochure.

2.4. Calendar :

From the transportation of the overall equipment to the base camp and the trapping site, to the construction of the transects and the activation of the traps, four days were usually necessary to prepare a trapping session. All traps were left open for 10 consecutive nights, thus totalling 1600 "trap nights" (see paragraph 2.7) per locality (Wilson et al., 1996). Whereas the transects were checked daily at sunrise for captures, BTS mesh live traps were rebaited at 48 hours intervals. Eight trapping sessions were scheduled over a 6 month time interval in the year 2000, and effective trapping periods took place at the dates presented in table 4. The last trapping session (site n°8) totalled only 640 trap nights, having been brutally interrupted under

the threat of hurricane Keith (see paragraph 1.3). Therefore, trapping effort for all 8 trapping sessions together totalled 11840 trap nights.

2.5. Data collection :

In the field, each capture was recorded on a Small Mammal Catalogue sheet (see fig. 10). A field number including the initials of the author (VB) was attributed to every newly captured specimen. This number combined to the site and trap numbers allowed each capture to be precisely positioned along the transects (see paragraph 2.3). Weight was measured in grams, using a Pesola 100g or 600g. External measurements were obtained using a simple rule, and are expressed in millimeters as follows (Nagorsen and Peterson, 1980, Catzeflis et al., 1997, and Musser et al., 1998) :

TL	Total length—straight-line distance from the tip of the nose to the end of the last tail vertebra, exclusive of hair.
TV	Tail vertebrae—distance from the base of the tail to the tip of the last vertebra, exclusive of hair.
HF	Hind foot—distance from the end of the heel bone (calcaneum) to the end of the longest toe, exclusive of the claw.
E	Ear length—distance from the base of the notch of the lower part of the ear to the uppermost margin of the ear.
NEB	Nose-ear basis—distance from the tip of the nose to the base of the notch of the lower part of the ear.
NEC	Nose-eye corner—distance from the tip of the nose to the anterior corner of the eye.
V	Vibrissae—length of longest mystacial vibrissae.

In addition, two external measurements related to the genitals, and one to the tail—added to the remarks—were obtained from each capture :

PA	Penis-anus—distance from the posterior margin of the base of the penis to the centre of the anus.
VA	Vulva-anus—distance from the posterior margin of the base of the vulva to the centre of the anus.
SR	Scale rows—number of scale rows in a centimeter section of the tail about one-third from the body.

The age class of each captured specimen was determined from the five following categories (Wilson et al., 1996) : juvenile, immature, subadult, adult, and old adult. Reproductive data

was obtained from each animal to be released, along with the sex. For males, the penis was described as protruded or retracted, and the scrotum as visible or not. For females, the vagina was described as perforate or not, and the vulva like the urethra as visible or not. Further information on the breeding condition of females was included in the remarks : the abdomen and the teats of the mammary glands were described as swollen or not, the number and position of the latter were determined, and on this basis females were described as pregnant, lactating, or both.

Particular data related to some captures were also recorded in the remarks, and include : an intraspecific variation of pelage coloration; a local depigmentation of the skin on naked parts, such as the tail, the feet, the ears or the muzzle; wet fur when measuring weight; an abnormality in the external morphology (e.g. a part of the tail or a toe amputated, an ear partly torn off, a scar on the forehead, etc...); an unhealed injury (e.g. caused by the animal forcing its way out of the trap); an obvious parasitosis (e.g. myiasis, eggs in the fur or on the ear pinna, ticks, etc...); the death of a specimen in or around the trap (e.g. successive to a predation); the presence of a predator next to the trap (e.g. a snake, a colony of army ants, etc...); the capture of several individuals together in the trap (e.g. a male and a female, a female with juveniles); the capture of unexpected animals (e.g. snake, tortoise, toad, spider, etc...); the behavior in the trap; the behavior after release (e.g. flight on the ground, up the vegetation, or into a den); a photograph.

First captures of newly encountered species were systematically brought back to the base camp for a first identification and further sampling (see below). Then, after collection of several male and female adults within one species, the specimens collected successively and satisfactorily identified as belonging to the same species were only then released—their distinctive external characters being briefly summarized in the remarks.

Before release, each individual was plunged into a transparent plastic bag where it was observed in more detail, sexed, weighed, and attributed an age. Then, a wad of cotton containing a few drops of ether was introduced into the bag to anaesthetize the animal before taking hold of it. After the external measurements, an ear sample—a triangular incision of 4-5mm in the ear pinna—along with an occasional hair sample were finally collected. Complemented with a drawing of the sampled ear on the Small Mammal Catalogue sheet, the animal was thus marked and recognized if recaptured. The ear sample was directly placed in a labeled screw-cap vial filled with a large volume of 95% ethanol for DNA preservation (see below).

Recaptures were systematically recorded in a notebook with the field number of the identified individual, the date, and the trap number. Additionally, the following data was taken from each trap subject to a capture or a recapture : terrestrial or arboreal (with its approximate height above the ground), position relative to its microhabitat (e.g. along a log, next to a den, at the convergence of two branches, on a connecting vine, etc...), forest cover at the trap station (portion of the sky occluded by vegetation expressed in percentage), and dominant plant species in the vicinity of the trap.

In the notebook, the climatic conditions prevailing during each trapping night were also recorded—the resulting data is not presented in this study. At the same time, any track or associated sign related to a known mammalian species, along with direct sightings in the area of the trapping site were carefully listed (see appendix 2).

At the base camp, all data mentioned above was also recorded, and complemented by a detailed description of the external morphology of each specimen and further reproductive data, whereas ectoparasites and endoparasites along with liver samples were collected.

SMALL MAMMAL CATALOGUE

Field n°.....
Museum n°.....

Collector : Vincent Bersot

General area : Shipstern Nature Reserve, Corozal District, Belize

Site n°.....

Date.....2000

Trap n°.....

Time.....

Species..... Sex..... Age..... Weight.....

Measurements

TL.....

TV.....

HF.....

E.....

NEB.....

NEC.....

V.....

--

Reproductive Data

MALES		
PA		
Penis	Pro	
	Ret	
Scrotum	Vis	
	No	
Testes	L	
	W	
Epididymes	Vis	
	No	

Remarks :

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FEMALES		
VA		
Vagina	Per	
	No	
Vulva	Vis	
	No	
Urethra	Vis	
	No	
Normal Embryos	L	
	R	
	CR	
Resorbed Embryos	L	
	R	
	CR	
Placental Scars	L	
	R	
	Sets	
Mammary Tissue	Y/N	
	Milk	

Figure 10. Small Mammal Catalogue Sheet. Abbreviations are defined in text.

Following a period of observation, data on behavior was recorded, and the animal was sacrificed by plunging it into an airtight transparent plastic bag provided with a wad of highly etherified cotton. The dead animal was then brushed above a white surface to extricate the ectoparasites from the fur, which were recovered along with the ones fallen into the plastic bag—ticks were collected with dissection forceps. These dead ectoparasites were directly placed in a labelled screw-cap vial filled with a large volume of 95% ethanol. The weight was measured before starting the dissection with an abdominal incision extending from the sternum to the genitalia. Once in the peritoneal cavity, the digestive tract was immediately cleared from its surrounding organs, and severed at its rectal and pyloric ends. The intestine thus sampled was transferred into a plastic petri dish where the small intestine (duodenum, jejunum, and ileum) was separated from its large counterpart (caecum, colon, and rectum). The caecum was further separated from the remaining colon (if present) and rectum. In turn, the resulting three sections were incised longitudinally all over their length, so as to open the organ and expose its content for the fixation. The presence of any visible parasite was then recorded, prior to fixing each of the three sections of intestine by placing them in separate screw-cap vials (25ml) labelled and filled with boiling 4% formalin. The liver was also sampled and directly placed in small pieces in labelled vials filled with a large volume of 95% ethanol for DNA preservation (see below).

At this point, the remaining organs in the peritoneal cavity were carefully observed, and any visible parasitosis were described under the remarks of the Small Mammal Catalogue sheet. Then, all of the previously mentioned data was recorded on the latter. However, the animal was sexed by referring to the urogenital system, from which further data was obtained. In males, the length (L) and the width (W) of the testes, whenever accessible, were measured in millimeters using a parallel-jawed caliper. Also, the tubules in the cauda epididymis were described as visible or not. In females, the uterus was examined to reveal the presence of normal and/or resorbed embryos in the right (R) and left (L) horns. There, they were counted, and an approximation of their size was given after the following measurement in millimeters (Nagorsen and Peterson, 1980) :

CR Crown-rump length—straight-line distance from the top of the head to the end of the rump with the embryo in situ (i.e. not straightened).

In addition, the presence of one or several sets of placental scars on the inside of the uterus, and of heavy deposits of mammary tissue that contain milk were recorded. On this basis, females were classified as nulliparous, primiparous, or multiparous (Nagorsen and Peterson, 1980).

In a first attempt to identify the dissected specimens, their external morphology was carefully described and compared to the species accounts in Reid (1997). The coloration and texture of fur on upperparts and underparts of head, body and limbs were first examined. Any particularity in the pelage—e.g. a blackish median line on forehead, a patch of white fur at the ear basis, a conspicuous black eye ring, a coloration on tops of forelegs discontinuous with the one on back and sides, a bright orange stripe on sides, dark brown spines on back and rump, etc...—was recorded, and hairs were checked for a change in coloration from base to tip. The hair distribution and skin pigmentation on feet (manus and pes), along with the pads on their respective soles were then examined and complemented with a drawing (plantar view). Drawings were also obtained from the head profile, the vibrissae, the ears, the hairs and scale rows on the tail, the external genitalia, and particular structures such as cheek pouches, or sensorial hairs on the body appendages. Furthermore, the pigmentation and the hair distribution on the tail, on the ear pinnae, and on the rhinarium were examined. Mystacial,

superciliary, and genal vibrissae (Brown, 1971, *in* Musser et al., 1998) were checked for a change in coloration from base to tip and/or from one position to another on the head. Sensorial hairs were recorded when present under the chin, the wrists, and/or on top of claws. Finally, morphological specializations such as swivelling ankle joints, opposable hallux, prehensile tail, and interdigital webbing were described whenever present.

Prior to the fixation, a field tag was tied securely to each specimen. Then, the latter was carefully rinsed, and placed into an airtight plastic container filled with 4% formalin.

The voucher specimens, the preserved ectoparasites, and the intestine samples were incorporated in the collections of the Natural History Museum, Geneva (NHMG), Switzerland. The ear and liver samples were included in the Collection of Preserved Mammalian Tissues (Catzeflis, 1991) held at Montpellier, France.

At NHMG, further data was collected from the voucher specimens, prior to the analysis. The skin was removed from the head of adult males and females by peeling it off backwards without damaging the lips, eyelids, ears, and skull, starting from the muzzle. The skull was then separated from the carcass by severing muscles in the region of the neck and rotating the head until it came away from the first vertebra. After cleaning by dermestid beetle colonies, and marking by the museum number attributed to each specimen, the cranium and dentary were drawn and measured. Skull measurements (see figs. 11 and 12) were obtained using a profile projector (5X) coupled to a photoelectric digital micrometer graduated to 0.001mm. In murid rodents, they are expressed as follows (Patton et al., 2000, Musser et al., 1998, and Voss, 1988) :

ONL	Occipitonasal length
CBL	Condylobasal length
CIL	Condyloincisive length
NL	Nasal length
PL	Palatal length
PPL	Postpalatal length
LD	Length of diastema
RL	Rostral length
BR	Breadth of rostrum
LIF	Length of incisive foramina
BIF	Breadth of incisive foramina
BZP	Breadth of zygomatic plate
OL	Orbital length
LBP	Length of bony palate
BBP	Breadth of bony palate
MPFL	Mesopterygoid fossa length
MPFW	Mesopterygoid fossa width
BOL	Basioccipital length
BL	Length of auditory bulla
BW	Breadth of auditory bulla
MB	Mastoid breadth
OCB	Occipital condyle breadth
LB	Lambdoidal breadth
BB	Braincase breadth
ZB	Zygomatic breadth
IB	Interorbital breadth
CD	Cranial depth
BM1	Breadth of first upper molar
CLM1-3	Crown length of maxillary toothrow

DI	Depth of incisor
HI	Height of incisor
CLMT	Crown length of mandibular tooththrow
LM	Length of mandible

In addition, these skull measurements were complemented with the followings, depending on the species :

LR	Length of rostrum
IPL	Interparietal length
IPW	Interparietal width
ORB	Breadth of supraorbital ridges
BPB	Breadth of palatal bridge
LBC	Length of braincase
HBC	Height of braincase
BIT	Breadth of incisor tips

In marsupials, skull measurements are expressed as follows (Patton et al., 2000, and Gardner, 1973) :

ONL	Occipitonasal length
CBL	Condylbasal length
CIL	Condylincisive length
NL	Nasal length
BN	Greatest breadth of nasals
PL	Palatal length
PW	Palatal width
PPL	Postpalatal length
BPS	Breadth of palatal shelf
RL	Rostral length
RW	Rostral width
BRJ	Breadth of rostrum across jugals
BRF	Breadth of rostrum across frontals
LIF	Length of incisive foramina
BIF	Breadth of incisive foramina
OL	Orbital length
LBP	Length of bony palate
MPFL	Mesopterygoid fossa length
MPFW	Mesopterygoid fossa width
BOL	Basioccipital length
MB	Mastoid breadth
OCB	Occipital condyle breadth
BB	Braincase breadth
ZB	Zygomatic breadth
IB	Interorbital breadth
IOC2	Postorbital constriction
CD	Cranial depth
BCT	Breadth across canine tips
BM1	Breadth of first upper molar
C-M4	Maxillary tooththrow length
M1-M4	Molar tooththrow length (maxillary)
CLMT	Molar tooththrow length (mandible)
LM	Length of mandible

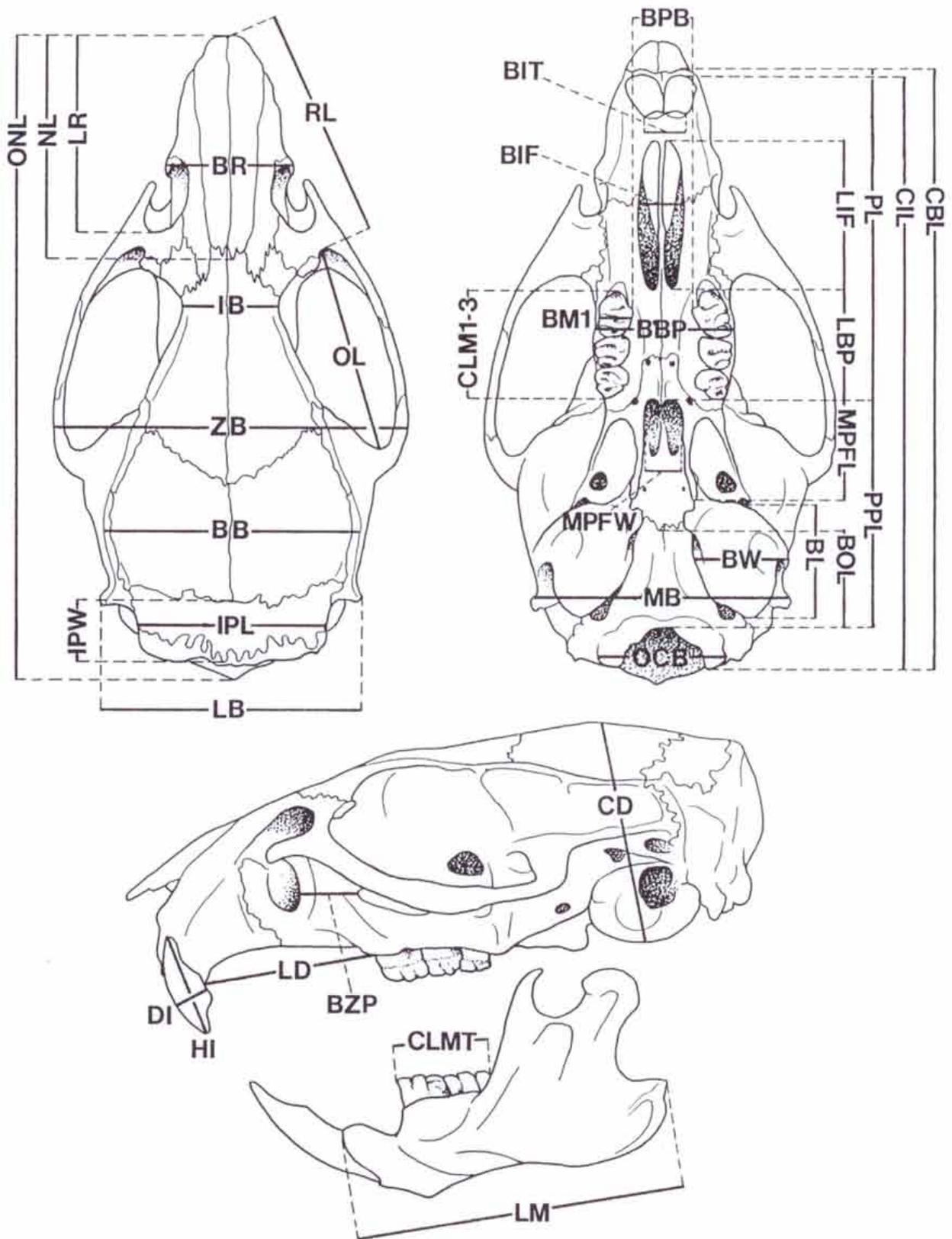


Figure 11. Rodents, limits of 38 cranial and dental dimensions. The following measurements are not represented : **ORB**, minimal breadth across the roof of the skull above the orbits (=IB); **LBC**, distance in the midventral line of the skull from the supraoccipital posterior margin to the frontal transverse depression; **HBC**, vertical distance between the basioccipital surface and top of cranium. Abbreviations are defined in text.

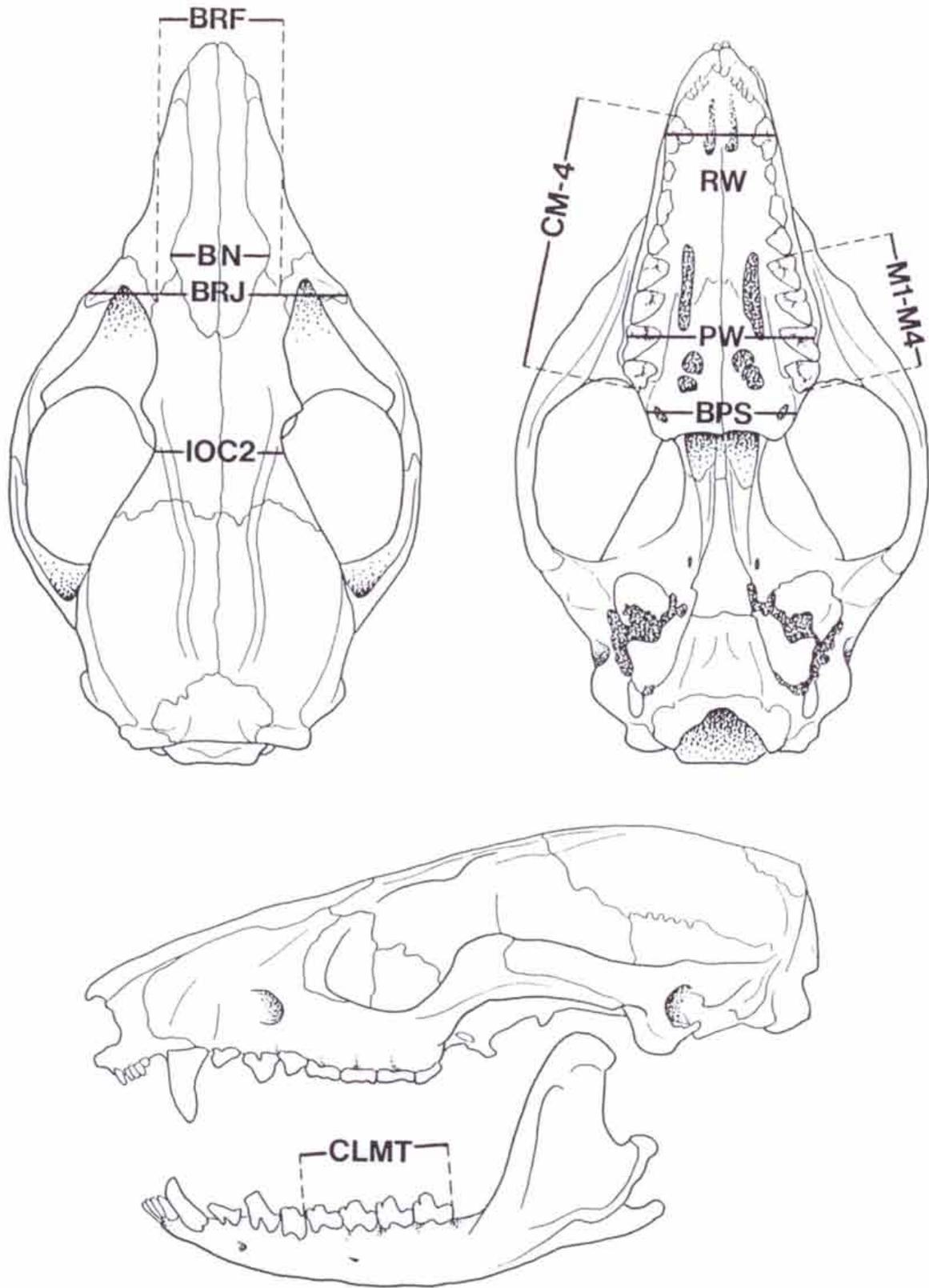


Figure 12. Marsupials, limits of 10 cranial and dental dimensions. The following measurement is not represented : **BCT**, breadth between the tips of the upper canines (=RW). Abbreviations are defined in text. Other measurements, see figure 11.

2.6. Data analysis :

The voucher specimens were analysed primarily so as to confirm their first field identification. Then, attention was given to the intestine samples and their endoparasites. However, the ear samples, the liver samples, and the reproductive data were not analysed within the framework of the present study, whereas the ectoparasites were mentioned only to indicate to which main groups they belong.

At NHMG, the voucher specimens were essentially re-identified by referring to their corresponding skull measurements and cranial characters. The latter data was compared to that found in available literature by first assigning age classes based on tooth eruption and wear to each specimens. Then, whenever a set of skull measurements was not clearly affiliated to one species, distinctive cranial characters were considered as reliable. In addition, the data obtained in the field was finally reexamined, along with the known distribution of the diagnosed species. As a result, the final identification of each specimen was based on the following data : external morphology, external and skull measurements, cranial characters, and distribution.

Each of the three sections of intestine—small intestine, caecum, and (colon-) rectum—being examined separately, the intestine samples were first analysed by sorting out their content in alimentary residues. The latter was emptied in glassy petri dishes, and diluted with 75% ethanol. In parallel, the inside of the remaining gut was thoroughly examined and cleaned using a dissecting microscope (0.63X-5X) and jeweler's forceps—when parasites were observed in the mucosa, the gut was conserved in alcohol. Prior to being sorted, the dilution was cleared by partly transferring it from one petri dish to another, and further diluting it with alcohol. Both parasites collected from the gut and the resulting dilutions were counted and directly placed in labelled vials (4ml) filled with 75% ethanol. At the same time, round worms (nematodes), tape worms (cestodes), and flukes (trematodes) were separated, so that each section of intestine was typified by a known number of endoparasites belonging to one of these three taxa.

Within the framework of this study, priority was given to the classes Trematoda and Cestoidea (see paragraph 3.2). The collected parasites were transferred from their respective vials to glassy petri dishes, and thoroughly examined using a dissecting microscope. At this point, the most representative specimens were sampled, stained, and mounted as permanent preparations in Canada balsam after the method described in De Chambrier (2001). In turn, the field number of the host and the corresponding section of intestine were recorded on the resulting microscope slides using a diamond pencil. Each stained specimen was then carefully observed by microscope, and subsequently described and drawn. In the case of *Railletina sigmodontis* (see paragraph 3.2), the latter data was complemented with a set of measurements taken from Smith (1954), and its rostellar hooks were counted by mounting the crushed scolex as a temporary preparation in a drop of Dantoin. This information was finally compared to that found in available literature, so as to obtain a first identification. Whenever a specimen was not fully identifiable but observed as a distinct species, it was still mentioned for its presence. However, the resulting identification remains to be confirmed, and deeper analyses will be carried out within the framework of a subsequent study. In this way, no attempts were made to identify to the species the specimens belonging to the phylum Nemata; by observing transverse sections of two specimens male and female, one sample was nevertheless identified to the genus in order to situate the overall collection.

2.7. Calculations :

A first capture (see table 2) was defined as the first occasion that an individual was trapped and marked (Stallings, 1989). The first capture plus subsequent captures of each specimen were considered total captures. Recapture indices were calculated by dividing total captures by first captures, thus indicating the average number of times an individual of each species was captured. The number of trap nights (see table 4) was calculated by the number of traps multiplied by the number of nights the traps were activated per site (Wilson et al., 1996). The trapping success for a site was the number of total captures of all species divided by the number of trap nights and expressed in percentage (see table 4). The standard error for each external and cranial measurements (see tables 6 and 7) was calculated after Fowler et al. (1998).

Chapter 3

Results :

Capture results by species for the eight trapping sites are presented in table 2. Seven small mammal species were sampled: *Marmosa mexicana*, *Didelphis virginiana*, *Heteromys gaumeri*, *Otonyctomys hatti*, *Otodylomys phyllotis*, *Peromyscus yucatanicus*, and *Sigmodon hispidus*. Overall, *O.phyllotis* represented 90.8% and 86.6% of the total and first captures respectively. On average, individuals of this species were recaptured at a rate of 1.8 times. Trapping success by trapping site is presented in table 4. A total of 414 captures was obtained in 11840 trap nights, thus yielding an overall trapping success of 3.5%. Tables 3 and 5 present for each species the number of total captures per vegetation type (see paragraph 1.3), and the overall trap response to trap types S, T, A1, A2 and A3 (see paragraph 2.3) respectively. However, caution should be taken when comparing the latter results, as the trapping effort is unequal from one trap type, and from one vegetation type to another. External and cranial measurements by species presented in tables 6 and 7 combine adult males and females. Here again, attention should be given as the single specimens of *Didelphis virginiana* and *Otonyctomys hatti* are immature and subadult respectively.

In parallel, direct observations and/or indirect indices (e.g. sets of tracks, scats, sounds) enabled the author to record the presence of 19 additional mammal species within the boundaries of Shipstern Nature Reserve (see appendix 2). Furthermore, a list of 11 unrecorded small mammal species expected in the reserve—geographic expectations (see appendix 1)—was compiled on the basis of their known geographic and ecological distribution (Voss and Emmons, 1996).

According to Nowak (1999), and Wilson and Reeder (1993), the seven small mammal species identified in the present study are classified as follows :

Class Mammalia (28 orders, 146 families, 1192 genera, and 4809 species)

Order Didelphimorphia (4 families, 15 genera, and 66 species)

Family Marmosidae (5 subfamilies)	Herskovitz, 1992
Subfamily Marmosinae (4 genera)	Herskovitz, 1992
Genus <i>Marmosa</i> (2 subgenera)	Gray, 1821
Subgenus <i>Marmosa</i> (8 species)	Gray, 1821
<i>Marmosa mexicana</i>	Merriam, 1897
Family Didelphidae (4 genera)	Gray, 1821
Genus <i>Didelphis</i> (4 species)	Linnaeus, 1758
<i>Didelphis virginiana</i>	Kerr, 1792

Order **Rodentia** (2 suborders, 11 infraorders, 29 families, 468 genera, and 2052 species)

Suborder **Sciurognathi** (7 infraorders)

Infraorder Myomorpha (3 superfamilies)

—	Superfamily Geomyoidea (2 families)		
	Family Heteromyidae (3 subfamilies)	Gray,	1868
	Subfamily Heteromyinae (2 genera)	Gray,	1868
	Genus Heteromys (2 subgenera)	Desmarest,	1817
	Subgenus Heteromys (5 species)	Desmarest,	1817
	<i>Heteromys gaumeri</i>	Allen and Chapman,	1897
—	Superfamily Muroidea (1 family)		
	Family Muridae (16 subfamilies)	Illiger,	1815
	Subfamily Sigmodontinae (90 genera)	Wagner,	1843
	Genus Otonyctomys (1 species)	Anthony,	1932
	<i>Otonyctomys hatti</i>	Anthony,	1932
	Genus Ototylomys (1 species)	Merriam,	1901
	<i>Ototylomys phyllotis</i>	Merriam,	1901
	Genus Peromyscus (13 species groups) <i>mexicanus</i> group (7 species)	Gloger,	1841
	<i>Peromyscus yucatanicus</i>	Allen and Chapman,	1897
	Genus Sigmodon (10 species)	Say and Ord,	1825
	<i>Sigmodon hispidus</i>	Say and Ord,	1825

3.1. Species accounts :

The following accounts present the essential observations regarding the morphological description, the local distribution, the microhabitat, and the general behavior of the 2 species of marsupials and 5 species of rodents captured in Shipstern Nature Reserve. Additional observations of these species are presented in the referred literature (see paragraph 4.1).

Marmosa mexicana **Mexican Mouse Opossum**

Description :

The dorsal pelage is auburn in overall coloration (see fig. 14). Hairs are lead-colored at the base and tipped with orange-brown on top of head, back and rump, fading up to a reddish

color on sides, and cinnamon on outer surfaces of legs. The forehead and top of nose are paler in color. Black eye-rings with prominent ocular stripes extend from in front of eye to the ear basis. Cheeks, throat, belly, and inner surfaces of legs are yellowish white with no darkening of hairs at bases. The color of the sides fade gradually into the color of the belly. The pelage contour on dorsum is even and formed by tips of overhairs, interspersed with thin and inconspicuous guard hairs. The fur on dorsum and venter is smooth and rather short. Mystacial, superciliary, and genal vibrissae are present and colored black. White submental and carpal vibrissae are present, but thin and inconspicuous. Body hair continues on base of tail for about 9mm. The tail is uniformly brown, finely scaled, grooved lengthways on its upper and under surfaces, strongly prehensile, and appears naked unless examined with a hand lens. The pinnae are conspicuous, not concealed in fur of head, and naked-looking. The ears are grayish brown, and the rhinarium is partly unpigmented with two brown patches at tip. Manus has unpigmented palmar surface with four separate interdigital and two separate carpal pads, and without distinctive scalation; the hypothenar and fourth interdigital pads are not fused. Dorsal and lateral surfaces of the metacarpal region and digits are greyish and thinly covered with short silvery hairs. Claws are short and unpigmented, with inconspicuous tufts of hair at their base. Pes has swivelling ankle joints, and opposable hallux. The plantar surface of pes is unpigmented, devoid of distinctive scalation, naked from heel to tips of the digits, with little fringing hairs along its contour, and with four separate interdigital and two separate carpal pads (see fig. 23); the thenar and first interdigital, and the hypothenar and fourth interdigital pads are nearly fused. Dorsal and lateral surfaces of the metatarsal region and digits are a pale cinnamon and naked-looking, sparsely covered with very short white hairs. Digit I is devoid of claw, and claws on digits II to V are short and unpigmented, with inconspicuous tufts of hair at their base.

The cranium is elongate and moderately slender, with a convex dorsal profile (see fig. 13). The rostrum is long and broad, concealing the nasolacrimal capsules in dorsal view. The nasals are long and truncate posteriorly, projecting anteriorly beyond the premaxillae to conceal the nasal orifice from dorsal view. The zygomatic arches are fairly convex from the dorsal aspect, and slightly convergent anteriorly, with stout zygomatic processes of jugal-lacrimal-maxillae and squamosals flaring from sides of rostrum and braincase. The interorbital region is broad relative to braincase, without pronounced postorbital constriction. The supraorbital ridges are moderately grooved dorsally, project laterally only slightly, and transform posteriorly into conspicuous parietal ridges on top of braincase. The braincase is narrow, uninflated, with slanting lateral, and nearly vertical rear walls. Occipital ridges are present, but temporal and lambdoidal ridges are not. The supraoccipital crest is fairly rounded in dorsal view. The occipital condyles are not exposed in dorsal view. The auditory bullae are small and moderately rounded, and their anterior margin lies anteriorly to the basisphenoid/basioccipital suture. The basisphenoid is narrow and elongate, contrasting with a short and wide basioccipital. The bony palate is broad, fenestrated, and extends beyond the molar rows posteriorly. The anterior margin of the maxillary/palatine suture extends between M1 and M2. The posterior margin of the inferior zygomatic root is just above M4. The incisive foramina are short, inconspicuous, and their posterior margins lie in the continuity of the posterior face of the upper canines. The teeth are small and number 50. The maxillary toothrows are straight along their labial margins, and convergent anteriorly. The canines are short and slender, and PM1 is remarkably smaller than PM2 and PM3. The dental formula is : $i\ 5/4$, $c\ 1/1$, $p\ 3/3$, and $m\ 4/4$. The dentary has a long and stout coronoid process, a well developed condyloid process, a moderately delicate angular projection, and a deep and elongate ramus; the capsular process is absent.

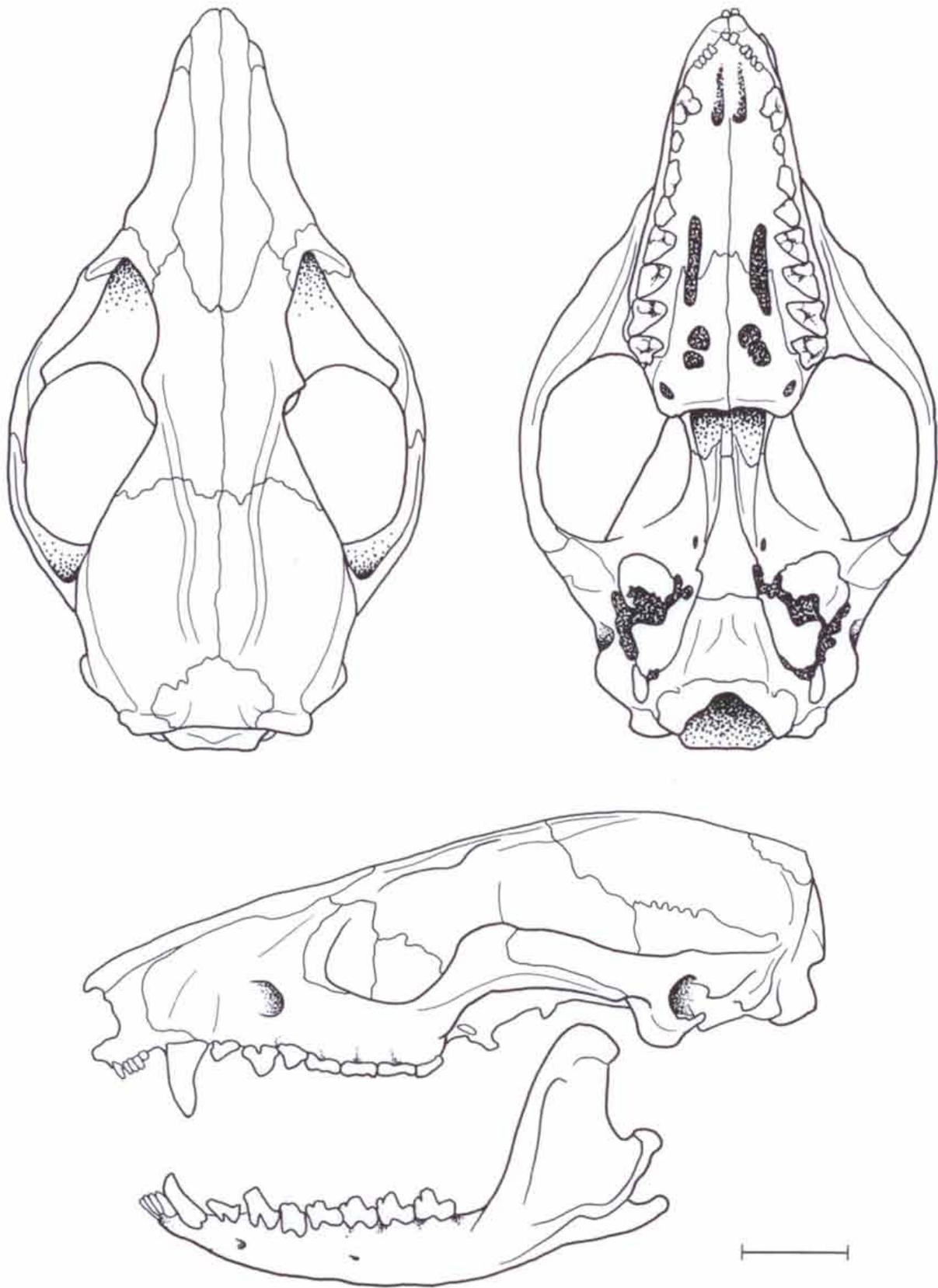


Figure 13. *Marmosa mexicana* (VB054). Dorsal, ventral, and lateral view of cranium and lateral view of left dentary. Scale bar : 5 mm.

Distribution :

The single specimen of *M.mexicana* (VB054) recorded in this study was captured in site n°3 (see table 2).

Habitat :

VB054 was captured in vegetation type 1 (see table 3) at a height of 1 meter (3.3 ft) on the trunk of a fallen tree intermingled with vines and other fallen trees.

Behavior :

The animal showed a characteristic defensive behavior once observed in the trap. With the hind quarters depressed and the forelimbs extended, it was firmly clung to the wire mesh by its feet and prehensile tail. Vibrations could be felt through the cage. From a distance, the animal remained in a contracted posture, imperceptibly hissing with the mouth half opened. At close quarters, it opened the mouth wide before emitting a chirping sound while moving forward in a sudden burst.

Didelphis virginiana

Virginia Opossum

Description :

The dorsal pelage is grey in overall coloration (see fig. 14). On back, rump and sides, and outer and inner surfaces of hind legs, overhairs are white at the base and black-tipped, and guard hairs are white. Overhairs are black from base to tip on outer and paler on inner surfaces of front legs. They are also darker on top of head, and extend to the forehead in a blackish V-shaped pattern fading gradually to a slightly yellowish color on top of nose. Black eye-rings with prominent ocular stripes extend from in front of eye to the ear basis, and outline a whitish supraorbital stripe. White cheeks are distinctly outlined above by the postocular stripe, and behind by the darker color of sides of head and neck. The throat and belly are greyish-beige with no darkening of hairs at tip, and the chin and chest are slightly yellowish. The color of the sides fade gradually into the color of the belly. The pelage contour on dorsum is shaggy and formed by tips of overhairs interspersed with long guard hairs. The fur is long and coarse on dorsum, and wooly on venter. Superciliary and genal vibrissae are black. Mystacial vibrissae are either colored black or white when directed dorsally or ventrally respectively. Submental and carpal vibrissae are present, but inconspicuous. Body hair continues on base of tail for about 20mm. The tail is unpigmented at its base, white for the last 75mm, and otherwise dark brown; it is finely scaled, prehensile, and appears naked unless examined with a hand lens. The pinnae are conspicuous, not concealed in fur of head, black, and naked-looking. The ear base and the rhinarium are unpigmented. Manus has dark brown palmar surface with four separate interdigital and two separate carpal pads, and with distinctive scalation; the hypothenar and fourth interdigital pads are not fused. Dorsal and lateral surfaces of the metacarpal region and digits are blackish and thinly covered with short black hairs. Claws are relatively short and unpigmented, with tufts of inconspicuous black hair at their base. Pes has swivelling ankle joints, and opposable hallux. The plantar surface of pes is dark



Didelphis virginiana



Marmosa mexicana

Figure 14. *Marmosa mexicana* and *Didelphis virginiana*. Reproduced from Reid's (1997) color plates 1 and 3.

brown, with distinctive scalation, naked from heel to tips of the digits, with little fringing hairs along its contour, and with four separate interdigital and one carpal pads (see fig. 23); the hypothelar and fourth interdigital pads are fused, and the thenar and first interdigital pads are nearly so. Dorsal and lateral surfaces of the metatarsal region and digits are blackish and sparsely covered with short black hairs. Digit I is devoid of claw, and claws on digits II to V are relatively long and unpigmented, with tufts of black hair at their base.

The cranium is elongate and broad, with a convex dorsal profile (see fig. 15). The rostrum is long and broad, and the nasolacrimal capsules are only slightly visible in dorsal view. The nasals are relatively short, narrow, and truncate posteriorly, revealing the nasal orifice in dorsal view. The lateralmost extent of each nasal, where intercepted by the maxillo-frontal suture, is aligned from the point where the same suture meets the lacrimal. The lacrimal recedes from the outer margin of the jugal before terminating in an acute point on the superior zygomatic root. The zygomatic arches are fairly convex from the dorsal aspect, and slightly convergent anteriorly, with stout zygomatic processes of jugal-lacrimal-maxillae and squamosals flaring from sides of rostrum and braincase. The dorsal extension of the palatine bones that make up part of the inner wall of the orbits is broad. The interorbital region is broad relative to braincase, without pronounced postorbital constriction. The supraorbital ridges are unextensive, moderately grooved dorsally, project laterally only slightly, and transform posteriorly into conspicuous but short parietal ridges on top of braincase. The braincase is narrow, uninflated, with slanting lateral, and nearly vertical rear walls. Occipital ridges are present, but temporal and lambdoidal ridges are not. The supraoccipital crest is fairly rounded in dorsal view. The occipital condyles are slightly exposed in dorsal view. The auditory bullae are remarkably small and not rounded, and their anterior margin lies in the continuity of the basisphenoid/basioccipital suture. The basisphenoid is narrow and elongate, contrasting with a short and wide basioccipital. The bony palate is broad, fenestrated, and extends beyond the molar rows posteriorly. The anterior margin of the maxillary/palatine suture extends between M1 and M2. The posterior margin of the inferior zygomatic root is just above the site of M3 (barely erupting). M4 and PM3 are absent, whereas M3 and m4 are erupting. The incisive foramina are short, inconspicuous, and their posterior margins lie in front of the premaxillary/maxillary suture and the anterior face of the upper canines. The teeth are fairly broad and number 44. The maxillary toothrows are straight along their labial margins, and convergent anteriorly. The canines are rather long and stout, and PM1 is remarkably smaller than PM2. The dental formula is : i 5/4, c 1/1, p 2/2, and m 3/4. The dentary has a long and stout coronoid process, a well developed condyloid process, a moderately delicate angular projection, and a deep and elongate ramus; the capsular process is absent.

Distribution :

The single specimen of *D. virginiana* (VB062) recorded in this study was captured in site n°4 (see table 2).

Habitat :

VB062 was captured in vegetation type 4 (see table 3) on the ground of a Tasiste marsh, at the basis of the palm *Accoelorrhapha wrightii*.

Behavior :

The animal showed no characteristic behavior. It was found in agony, with the head caught between the body of the trap and the closing door.

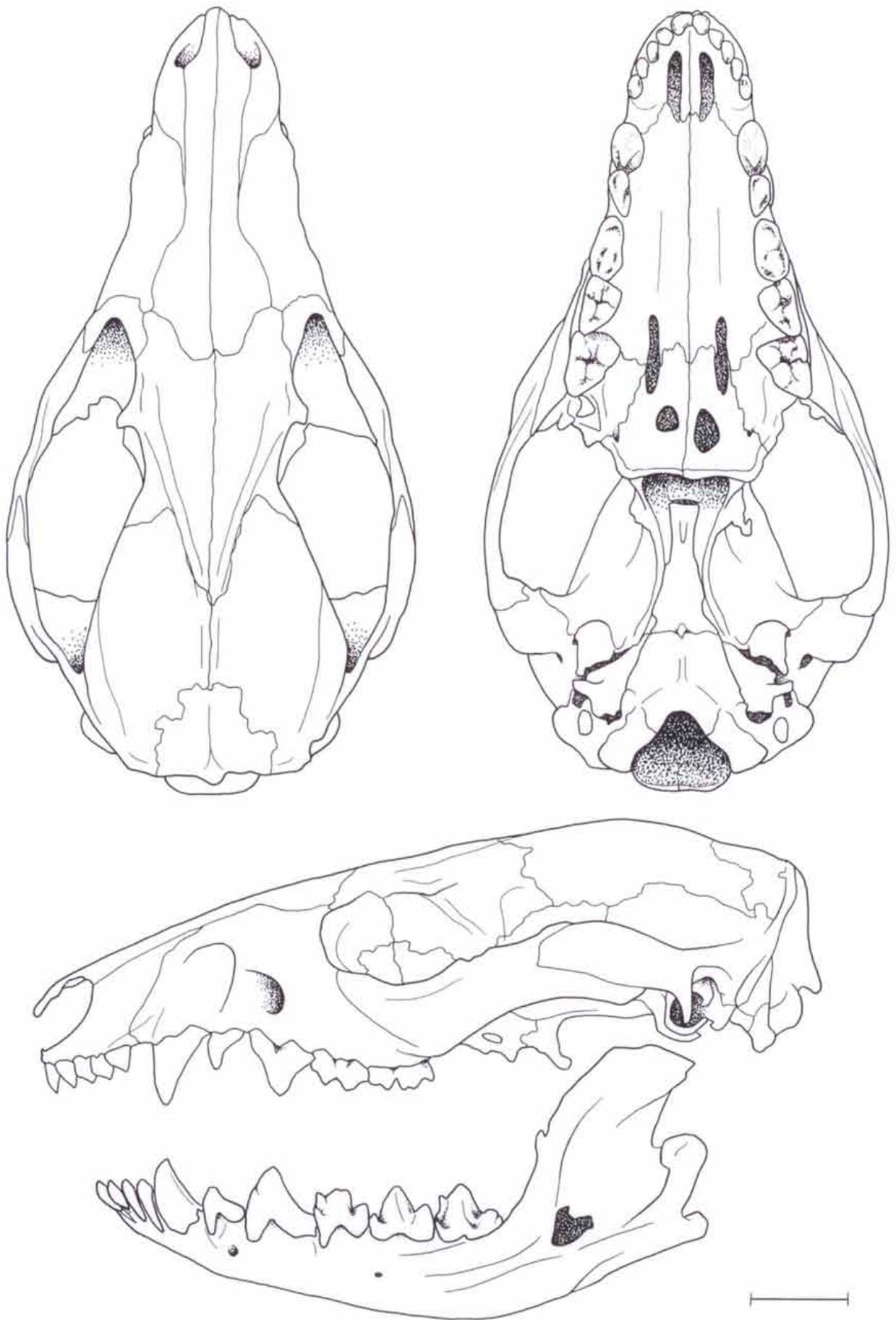


Figure 15. *Didelphis virginiana* (VB062). Dorsal, ventral, and lateral view of cranium and lateral view of left dentary. Scale bar : 7 mm.

Heteromys gaumeri

Gaumer's Spiny Pocket Mouse

Description :

The dorsal pelage is reddish-brown in overall coloration (see fig. 18). On top of head, back and rump, hairs are either entirely orange buff or tipped with dark brown, resulting in a bicolored general appearance with dark « spines » on an orangish background. Hairs are bright red on sides, and like dorsum with less prominent dark hairs on top of nose, forehead, and outer surfaces of legs. Hairs on throat, belly, and inner surfaces of legs are yellowish white from base to tip; they also extend to sides of the neck, resulting in a discontinuous pelage coloration between the outer surfaces of front legs and dorsum. A bright orange stripe on sides extends from cheeks to base of tail, sharply demarcating upperparts from underparts. The pelage contour on dorsum is coarse and spiny, and formed by tips of overhairs, without apparent guard hairs. The fur on dorsum and venter is sleek and rather short. Superciliary and genal vibrissae are black. Mystacial vibrissae are either colored black or white when directed dorsally or ventrally respectively. Submental and carpal vibrissae are present, but inconspicuous. Body hair continues on base of tail for about 5mm. The tail is bicolor, dark brown above and dull white with a purplish median line lengthways below; it is broadly scaled, covered with conspicuous dark brown hairs above and white hairs below, and terminated by a tuft of dark brown hairs. The pinnae are round, conspicuous, moderately concealed in fur of head, and sparsely covered with short reddish hairs on their outer and inner surfaces. The ears are greyish-brown, and the rhinarium is unpigmented. Two external and fur-lined cheek pouches are present. The palmar surface of manus is unpigmented around the interdigital pads and on digits, and is otherwise purplish-brown; it has three separate interdigital and two separate and enlarged carpal pads, with a distinctive scalation; the thenar and hypothenar pads are enlarged. Dorsal and lateral surfaces of the metacarpal region and digits are whitish, and thinly covered with short white hairs. Claws are short and dark brown, with inconspicuous tufts of hair at their base. Digit I is devoid of claw. The plantar surface of pes is unpigmented around the interdigital pads and on digits, and is otherwise dark brown; it has four separate interdigital and two separate carpal pads, with distinctive scalation (see fig. 23); it is thinly covered with short dark brown or reddish hairs from heel to thenar and hypothenar pads, with little fringing hairs along its contour. Dorsal and lateral surfaces of the metatarsal region and digits are whitish, and thinly covered with short white hairs. The three middle digits are much longer than the outer two, and interdigital webbing is present between digits II, III, and IV. The claw on digit II is enlarged. Claws are otherwise short and unpigmented, with inconspicuous tufts of hair at their base.

The cranium is elongate and slender, with a slightly convex dorsal profile (see fig. 16). The rostrum is long and broad, concealing the nasolacrimal capsules in dorsal view. The nasals are long with slightly convergent outer margins posteriorly, and they project anteriorly beyond the premaxillae to conceal the nasal orifice from dorsal view. The zygomatic arches are fairly parallel from the dorsal aspect, and convergent anteriorly, with moderately broad zygomatic processes of maxillae flaring from sides of rostrum. The interorbital region is remarkably broad relative to braincase. Supraorbital shelves accentuate the dorsolateral margins of the interorbit and transform posteriorly into low temporal ridges extending to inconspicuous lambdoidal ridges. The supraorbital ridges are moderately grooved dorsally. Occipital ridges are present, and the supraoccipital crest is angular but barely visible in dorsal view. The braincase is moderately inflated but not globose, with nearly vertical lateral and rear walls.

The occipital condyles are not exposed in dorsal view. The auditory bullae are relatively large and moderately rounded, and their anterior margin lies anteriorly to the basisphenoid/basioccipital suture. The basisphenoid is narrow and short, contrasting with an elongate and moderately wide basioccipital. The bony palate is narrow, without fenestration, and extends slightly beyond the molar rows posteriorly. The posterior margin of the maxillary/palatines suture extends between M1 and M2. The posterior margin of the inferior zygomatic root is just above the anterocone of M1. The incisive foramina are short and inconspicuous, and their convex lateral margins are widest at the premaxillary-maxillary suture in lateral view. The teeth number 20. The molar toothrows are straight along their labial margins, and convergent anteriorly. Incisors are moderately large with smooth orangish enamel faces; in lateral profile, the uppers curve back toward the molar rows, an opisthodont configuration. The dental formula is : i 1/1, c 0/0, p 1/1, and m 3/3. The dentary has a falciform coronoid process, a long and stout condyloid process, a well developed angular projection and a deep but short ramus; the capsular process is visible.

Distribution :

H.gaumeri was captured in all sites except n°1 (see table 2).

Habitat :

The animal was captured in vegetation types 1, 2, 3 (not including its structural variant), 4 (Tasistal), and 8 (see table 3). All specimens were captured on the ground, in varied microhabitats : along fallen tree trunks; next to a log covered by botan (*Sabal yapa*) leaves; under logs intermingled with fallen branches; at the basis of the palm *Accoelorrhaphé wrightii* (Tasiste marsh), the chicle (*Manilkara zapota*) and the chechem (*Metopium brownei*); and in rock cavities.

Behavior :

Released animals ran away on the ground, either totally exposed for several meters or directly into a near cavity. Very few individuals were recaptured. VB037 was captured twice, at five day intervals, and in two different traps set in adjoining stations. Broken seeds and shells (snails) were found in some traps with *H.gaumeri*. VB022 was found dead in the trap, with two distinctive wounds at the side of the neck (snake).

Otonyctomys hatti

Yucatan Vesper Mouse

Description :

The dorsal pelage is dark orange in overall coloration (see fig. 18). Hairs are either black at the base and tipped with bright orange, or entirely black, on top of nose, forehead, top of head, back and rump; they are only of the first type on sides, outer surfaces of legs, and cheeks. Black eye-rings with prominent ocular stripes extend anteriorly from in front of eye to the nose. The chin is partly black. The throat, belly, and inner surfaces of legs are white with no

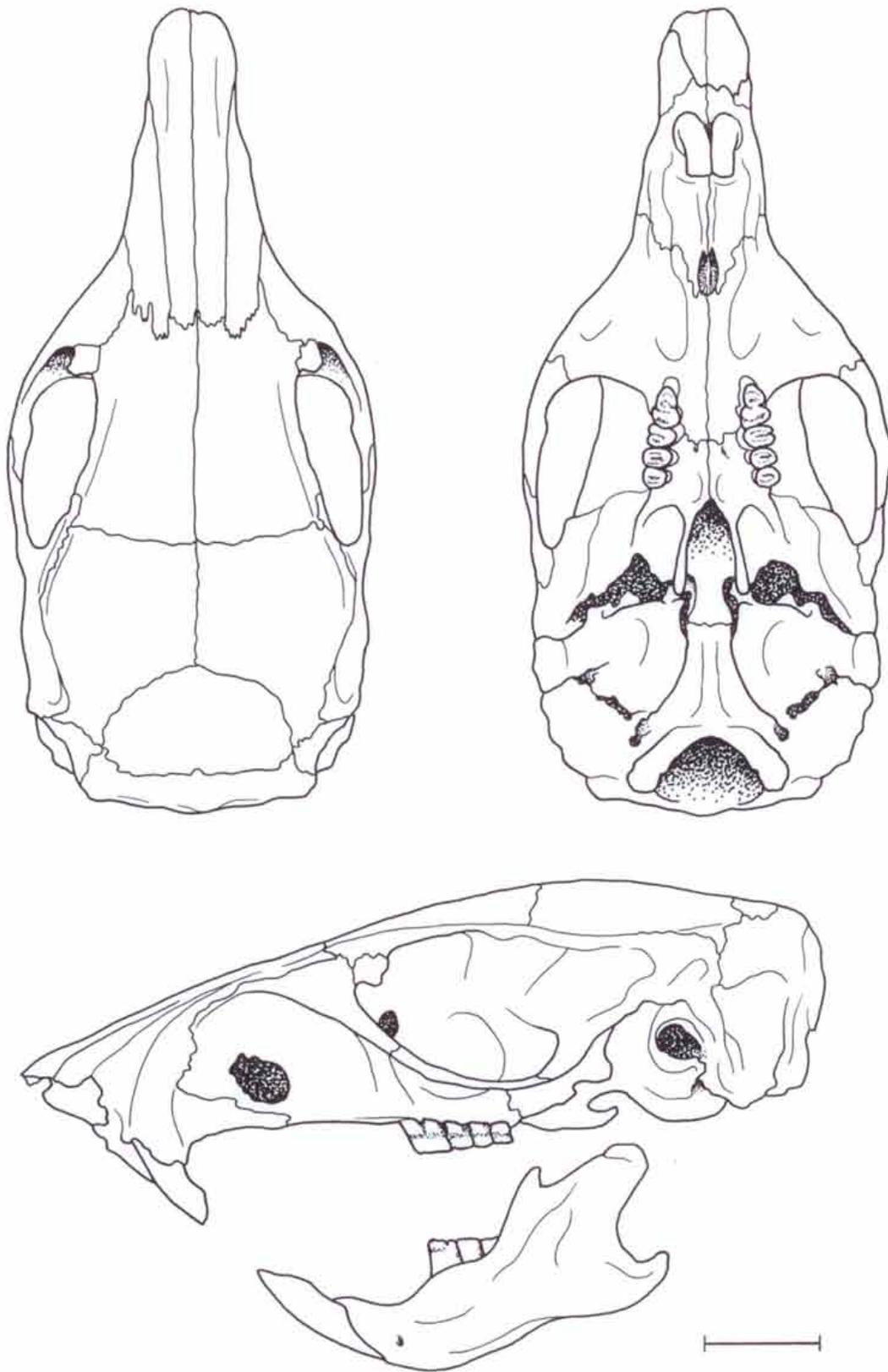


Figure 16. *Heteromys gaumeri* (VB017). Dorsal, ventral, and lateral view of cranium and lateral view of left dentary. Scale bar : 5 mm.

darkening of hairs at bases. The bright orange color of the sides fade gradually into the color of the belly. The pelage contour on dorsum is even and formed by tips of overhairs, with thin and inconspicuous guard hairs. The fur on dorsum and venter is smooth and rather short. Mystacial, superciliary, and genal vibrissae are present and black colored. Submental, interramal, and carpal vibrissae are present, but inconspicuous. Body hair continues on base of tail for about 5mm. The tail is uniformly brown, finely scaled, and sparsely covered with conspicuous black hairs of increasing length from base (1mm) to terminal tuft (7mm). The pinnae are conspicuous, not concealed in fur of head, and naked-looking. The ears are brown, and the rhinarium is partly dark brown and unpigmented. The palmar surface of manus is unpigmented on digits and pads and otherwise partly purplish, with three separate interdigital and two separate and enlarged carpal pads, and without distinctive scalation. Dorsal and lateral surfaces of the metacarpal region and digits are whitish and naked-looking, thinly covered with short white hairs. Claws are short and unpigmented, with a tuft of white hair at their base. Digit I is reduced, and devoid of claw. Pes has moderately swivelling ankle joints, but no opposable hallux. The plantar surface of pes is unpigmented on digits and otherwise purplish, devoid of distinctive scalation, naked from heel to tips of the digits, with little fringing hairs along its contour, and with four separate interdigital and two separate carpal pads (see fig. 23). Dorsal and lateral surfaces of the metatarsal region and digits are pale brown and naked-looking, thinly covered with short white hairs. Claws are short and unpigmented, with a tuft of white hair at their base.

The cranium is rather short and angular, with a convex dorsal profile (see fig. 17). The rostrum is short and narrow, not concealing the nasolacrimal capsules in dorsal view. The nasals are moderately long with slightly convergent outer margins posteriorly, and they project anteriorly beyond the premaxillae to conceal the nasal orifice from dorsal view. The zygomatic arches are fairly parallel from the dorsal aspect, and strongly convergent anteriorly, with stout zygomatic processes of maxillae flaring from sides of rostrum. The interorbital region is narrow relative to braincase. Supraorbital shelves accentuate the dorsolateral margins of the interorbit and transform posteriorly into temporal ridges extending to conspicuous lambdoidal ridges. The supraorbital ridges are moderately grooved dorsally. Occipital ridges are present, and the supraoccipital crest is rounded but barely visible in dorsal view. The braincase is well inflated but not globose, with nearly vertical lateral and rear walls. The occipital condyles are not exposed in dorsal view. The auditory bullae are greatly enlarged and rounded, and their anterior margin lies anteriorly to the basisphenoid/basioccipital suture. Both the basisphenoid and the basioccipital are narrow and elongate. The bony palate is rather broad, without fenestration, and does not extend beyond the molar rows posteriorly. The anterior margin of the maxillary/palatines suture extends between M1 and M2. The posterior margin of the inferior zygomatic root is just above the anterocone of M1. The incisive foramina are long and conspicuous, and their posterior margins lie slightly posteriorly to the anterior margin of the orbits; their lateral margins are convex, and widest at the anterior margin of the zygomatic plate in lateral view. The teeth number 16. The molar toothrows are straight along their labial margins, and parallel. Incisors are moderately large with smooth orangish enamel faces; in lateral profile, the uppers curve back toward the molar rows, an opisthodont configuration. The dental formula is : i 1/1, c 0/0, p 0/0, and m 3/3. The dentary has a falciform coronoid process, a long and stout condyloid process, a well developed angular projection, and a deep but short ramus; the capsular process is barely visible.

Distribution :

The single specimen of *O.hatti* (VB182) recorded in this study was captured in site n°7 (see table 2).

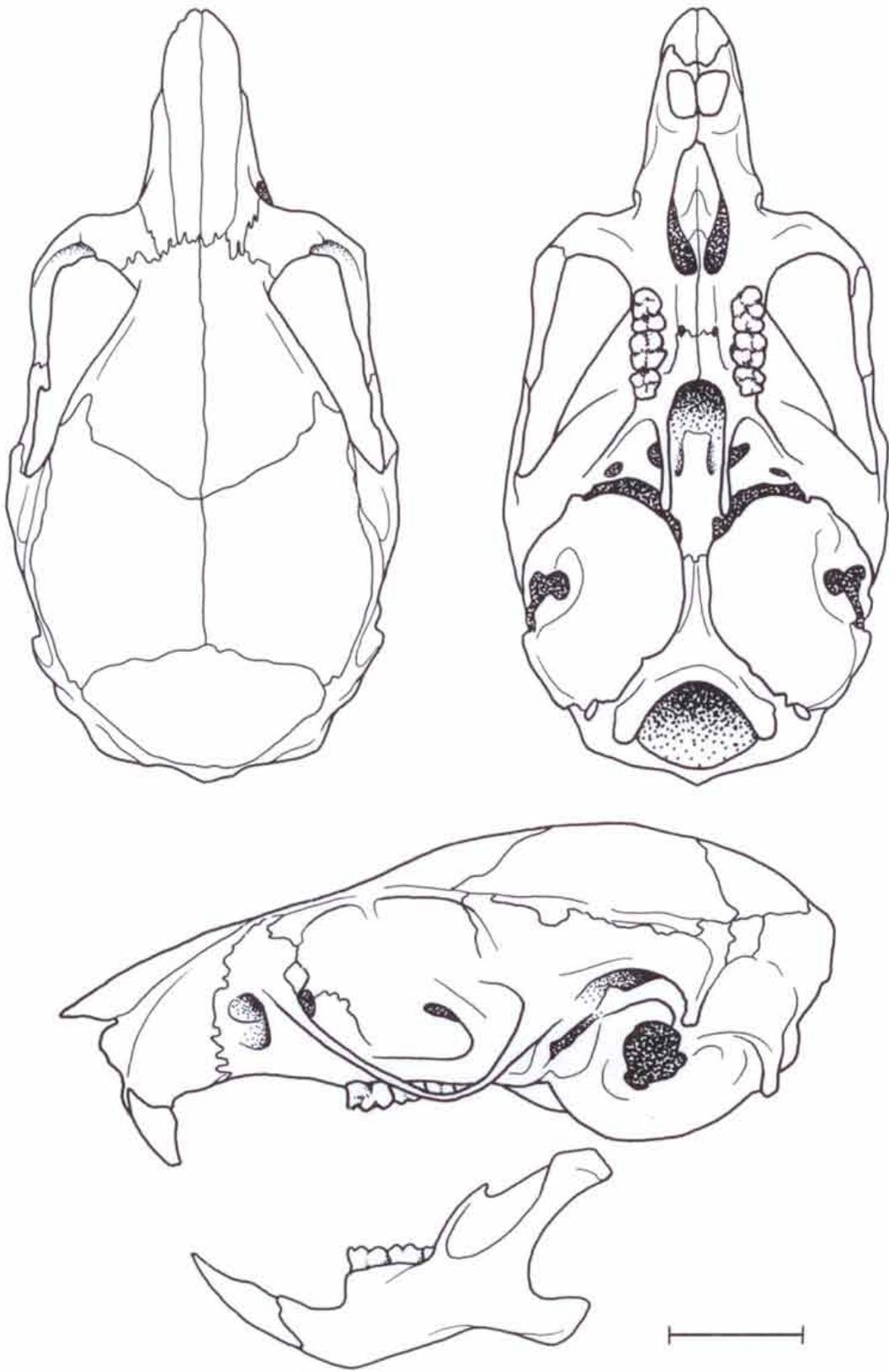
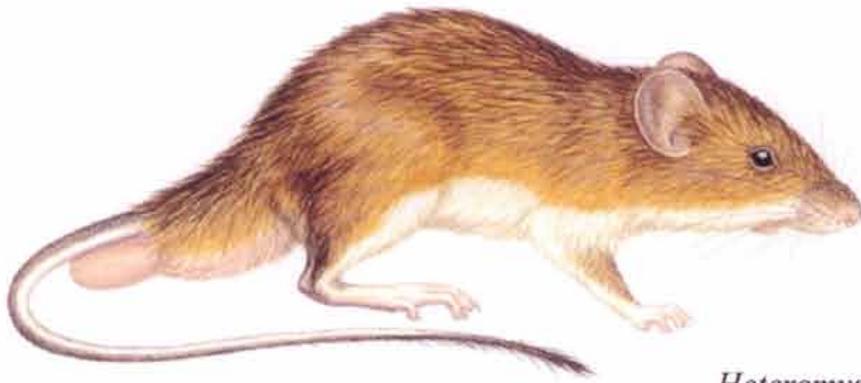
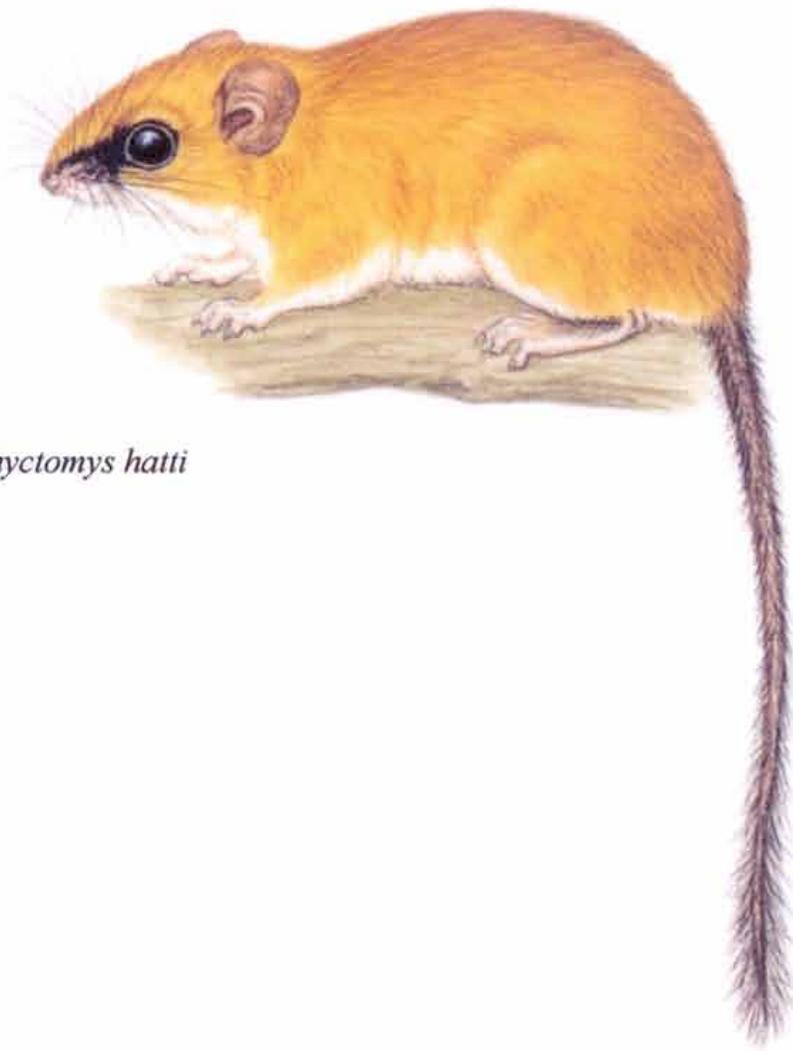


Figure 17. *Otonyctomys hatti* (VB182). Dorsal, ventral, and lateral view of cranium and lateral view of left dentary. Scale bar : 5 mm.



Heteromys gaumeri



Otonyctomys hatti

Figure 18. *Heteromys gaumeri* and *Otonyctomys hatti*. Reproduced from Reid's (1997) color plates 24 and 30.

Habitat :

VB182 was captured in vegetation type 1 (see table 3) at a height of 1.5 meters (5 ft) on the sloping trunk of a large tree surrounded by give-and-take palms (*Cryosophila stauracantha*).

Behavior :

Besides a remarkable agility to climb on all surfaces of the mesh wire trap, the animal showed no characteristic behavior.

Otodylomys phyllotis

Big-eared Climbing Rat

Description :

The dorsal pelage is greyish-brown in overall coloration (see fig. 21). Hairs are dark greyish-brown at the base and gradually paler to tip of cheeks, top of nose, forehead, top of head, back, rump, and outer surfaces of legs. The sides and the supraorbital region are paler in color. The throat, belly, and inner surfaces of legs are creamy white with no darkening of hairs at bases. A patch of white fur is present at the ear basis. Upperparts are rather sharply demarcated from underparts. The pelage contour on dorsum is even and formed by tips of overhairs, interspersed with thin and inconspicuous guard hairs. The fur on dorsum and venter is smooth and rather short. Mystacial, superciliary, and genal vibrissae are present and colored black. Submental and carpal vibrissae are present, but inconspicuous. Body hair does not continue on base of tail. The tail is faintly bicolor, dark brown above and partly unpigmented below; it is broadly scaled, shiny, and appears naked unless examined with a hand lens. The pinnae are large and conspicuous, not concealed in fur of head, and naked-looking. The ears are brown, and the rhinarium is unpigmented. The palmar surface of manus is unpigmented on digits and pads, and otherwise partly purplish, with three separate interdigital and two separate carpal pads, and without distinctive scalation. Dorsal and lateral surfaces of the metacarpal region and digits are whitish, and thinly covered with short white hairs. Claws are short and unpigmented, with a tuft of white hair at their base. Digit I is reduced, and devoid of claw. The plantar surface of pes is unpigmented on digits and pads, and otherwise purplish, devoid of distinctive scalation, naked from heel to tips of the digits, with little fringing hairs along its contour, and with four separate interdigital and two separate carpal pads (see fig. 23). Dorsal and lateral surfaces of the metatarsal region and digits are greyish white, and thinly covered with short white hairs. Claws are short and unpigmented, with a tuft of white hair at their base.

The cranium is elongate and angular, with a flattened dorsal profile, gently convex over braincase (see fig. 19). The rostrum is long and narrow, not concealing the nasolacrimal capsules in dorsal view. The nasals are rather long and terminate in a rounded angle anteriorly, projecting beyond the premaxillae to conceal the nasal orifice from dorsal view. The zygomatic arches are fairly parallel from the dorsal aspect, and strongly convergent anteriorly, with stout zygomatic processes of maxillae and squamosals flaring from sides of rostrum and braincase. The interorbital region is rather narrow relative to braincase. Supraorbital shelves accentuate the dorsolateral margins of the interorbit and transform posteriorly into low temporal ridges extending to prominent lambdoidal ridges. The supraorbital ridges are

moderately grooved dorsally. Occipital ridges are present, and the supraoccipital crest is clearly angular in dorsal view. The braincase is boxlike, with nearly vertical lateral and rear walls. The occipital condyles are not exposed in dorsal view. The auditory bullae are large and rounded, and their anterior margin lies anteriorly to the basisphenoid/basioccipital suture. Both the basisphenoid and the basioccipital are fairly narrow and elongate. The bony palate is narrow, without fenestration, and does not extend beyond the molar rows posteriorly. The anterior margin of the maxillary/palatines suture extends in the continuity of M2. The posterior margin of the inferior zygomatic root is just above the anterocone of M1. The incisive foramina are long and conspicuous, and their posterior margins lie slightly posteriorly to the anterior margin of the orbits; their lateral margins are convex, and widest at the anterior margin of the zygomatic plate in lateral view. The teeth number 16. The molar toothrows are straight along their labial margins, and slightly convergent anteriorly. Incisors are fairly large with smooth orangish enamel faces; in lateral profile, the uppers curve back toward the molar rows, an opisthodont configuration. The dental formula is : i 1/1, c 0/0, p 0/0, and m 3/3. The dentary has a delicate coronoid process, a long and stout condyloid process, a broad and well developed angular process, and a moderately deep and short ramus; the capsular process is barely visible.

Distribution :

O.phyllotis was captured in all sites (see table 2).

Habitat :

The animal was captured in vegetation types 1, 2, 3 (including its structural variant), 4 (Mucal and Tasistal), 5, 6, and 8 (see table 3). Specimens were captured at all levels from the ground to a height exceeding 3 meters, in varied microhabitats : on muk (*Dalberia glabra*) branches and vines; on the sloping trunk of large trees; along fallen tree trunks; under logs intermingled with fallen branches; at the bottom of various large trees such as the mahogany (*Swietenia macrophylla*), the chicle (*Manilkara zapota*), the chechem (*Metopium brownei*) and others; in rock cavities.

Behavior :

Released animals ran away mostly on the ground, either totally exposed for several meters or directly into a near cavity. A fraction of them climbed up on to the surrounding vegetation to a height of about 13 ft (4m) before going back down, either by directly jumping or by moving on the vegetation; alternatively, some specimens remained totally motionless once in the vegetation, until the observer left. VB081 ran directly to a trap occupied by another specimen at a distance of 17 ft (5m), and remained next to it for several minutes. VB076 came back about half an hour later to its trap of first capture, and fed on the renewed bait. Recaptures were fairly common, and some specimens were captured five to six times in one trapping session. VB066 was captured six times in the same trap, at seven day intervals. VB003 was captured in four different traps set in four adjoining stations, thus covering a distance of approximately 200 ft (60m). Four different specimens were captured in the same trap n°146 of site n°4. Four specimens were captured at the same trap station n°15 of site n°4, right under a large tree bearing two nests occupied by White-nosed coatis (*Nasua narica*). VB083 was

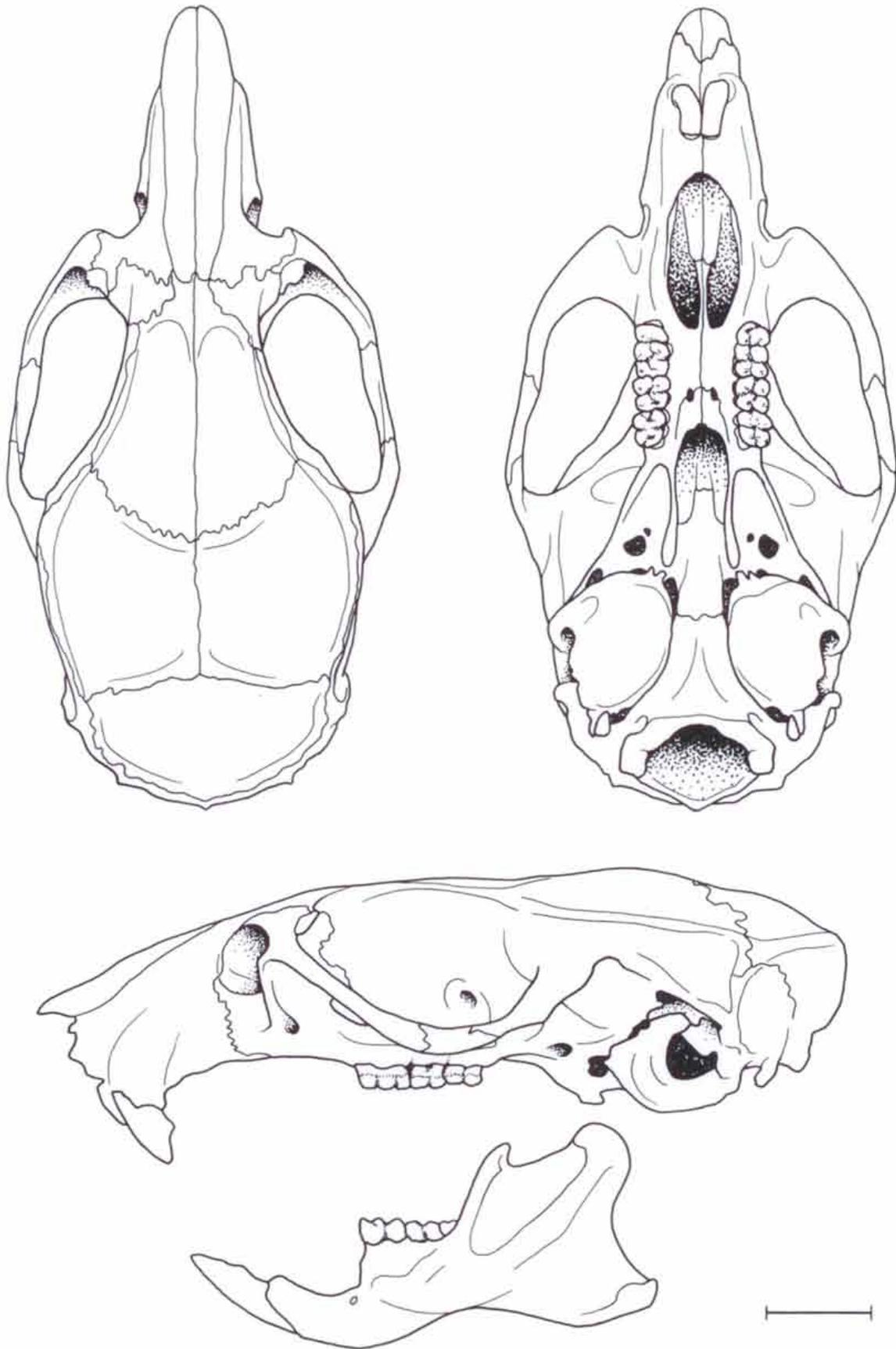


Figure 19. *Ototylomys phyllotis* (VB002). Dorsal, ventral, and lateral view of cranium and lateral view of left dentary. Scale bar : 5 mm.

found bleeding, extensively skinned on forehead and top of head, and highly agitated in a trap surrounded by an Imperial boa (*Boa constrictor*); when released, it took refuge in a cavity neighboring (1.5m) the one occupied by the snake. A Yucatan White-lipped snake (*Symphimus mayae*) was found jammed in the mesh wire of the trap, with the body inflated by a prey (probably VB219). VB156 (male) and VB157 (female) were captured together in one trap, and the tail of a neonate was flaring out of the vagina of the female. VB230 was found with two neonates in the trap.

Peromyscus yucatanicus

Yucatan Deer Mouse

Description :

The dorsal pelage is greyish-brown in overall coloration (see fig. 21). Hairs are dark grey at the base and tipped with brown on top of nose, forehead, top of head, back and rump, and outer surfaces of legs, fading to brownish-ochre on the sides and cheeks. This ochraceous stripe also extends on sides of the neck, resulting in a discontinuous pelage coloration between the outer surfaces of legs and dorsum. Dark greyish-brown eye-rings are present, but narrow (1-2mm wide). Hairs on the throat, belly, and inner surfaces of legs are dark grey at the base and tipped with white. Upperparts are sharply demarcated from underparts. The pelage contour on dorsum is even and formed by tips of overhairs, without apparent guard hairs. The fur on dorsum and venter is smooth and rather short. Mystacial, superciliary, and genal vibrissae are present and colored black at their base, fading to white at tip. Submental, interramal, and carpal vibrissae are present, but inconspicuous. Body hair continues on base of tail for about 5mm. The tail is bicolor, dark grey above and dull white (a few scales are greyish at the base of tail) with a purplish median line lengthways below; it is thinly scaled, covered with conspicuous but short (1-2mm) black hairs above and white hairs below, without terminal tuft. The pinnae are grey brown, large and conspicuous, not concealed in fur of head, and appear naked unless examined with a hand lens; thin but fairly long (2-3mm) fringing hairs are present along the anterior edge of the pinnae. The ears are paler at their base, and the rhinarium is partly unpigmented, with two greyish brown patches at the tip. Manus has pale greyish-brown palmar surface with three separate interdigital and two separate and enlarged carpal pads, and without distinctive scalation. Dorsal and lateral surfaces of the metacarpal region and digits are white, thinly covered with short white hairs. Claws are short and unpigmented, with a tuft of white hair at their base. Digit I is reduced, and devoid of claw. The plantar surface of pes is greyish-brown, devoid of distinctive scalation, thinly covered with short black hairs on the heel, with little fringing hairs along its contour, and with four separate interdigital and two separate carpal pads (see fig. 23). Dorsal and lateral surfaces of the metatarsal region and digits are white, thinly covered with short white hairs. Claws are short and unpigmented, with a tuft of white hair at their base.

The cranium is elongate and slender, with a convex dorsal profile (see fig. 20). The rostrum is long and narrow, not concealing the nasolacrimal capsules in dorsal view. The nasals are rather long and terminate in a rounded angle anteriorly, projecting beyond the premaxillae to conceal the nasal orifice from dorsal view. The zygomatic arches are fairly parallel from the dorsal aspect, and strongly convergent anteriorly, with stout zygomatic processes of maxillae flaring from sides of rostrum. The interorbital region is narrow relative to braincase. Supraorbital shelves accentuate the dorsolateral margins of the interorbit and transform

posteriorly into barely visible low temporal ridges extending to inconspicuous lambdoidal ridges. The supraorbital ridges are moderately grooved dorsally. Occipital ridges are absent, and the supraoccipital at its margin with the interparietal is smooth in dorsal view. The braincase is inflated but not globose, with nearly vertical lateral and rear walls. The occipital condyles are not exposed in dorsal view. The auditory bullae are fairly small and rounded, and their anterior margin lies anteriorly to the basisphenoid/basioccipital suture. The basisphenoid is narrow and moderately elongate, contrasting with a rather short and wide basioccipital. The bony palate is broad, without fenestration, and does not extend beyond the molar rows posteriorly. The anterior margin of the maxillary/palatines suture extends between M1 and M2. The posterior margin of the inferior zygomatic root is just above the anterocone of M1. The incisive foramina are long and conspicuous, and their posterior margins lie slightly posteriorly to the anterior margin of the orbits; their lateral margins are convex, and widest just posteriorly to the premaxillary-maxillary suture. The teeth number 16. The molar toothrows are straight along their labial margins, and slightly convergent posteriorly. Incisors are rather small with smooth orangish enamel faces; in lateral profile, the uppers curve back toward the molar rows, an opisthodont configuration. The dental formula is : i 1/1, c 0/0, p 0/0, and m 3/3. The dentary has a falciform coronoid process, a long and stout condyloid process, a broad and well developed angular process, and a moderately deep and short ramus; the capsular process is barely visible.

Distribution :

The two specimens of *P.yucatanicus* (VB089 and VB225) recorded in this study were captured in sites n°4 and 8 (see table 2).

Habitat :

VB089 was captured in vegetation type 1 (see table 3) on a fallen branch lying on the ground, and VB225 was captured in vegetation type 8 at a height of 0.6 meters (2 ft) on a complicated intermingle of branches and vines.

Behavior :

The animal showed no characteristic behavior.

Sigmodon hispidus

Hispid Cotton Rat

Description :

The dorsal pelage is blackish-brown with an orangish admixture in overall coloration (see fig. 21). Hairs are black at the base and tipped with orangish-brown on top of nose, forehead, top of head, cheeks, back and rump, sides, and outer surfaces of legs. Pale brown eye-rings are present, but narrow (1-2mm wide). Hairs on the throat and belly are dark grey at the base and tipped with paler grey; the same on the inner surfaces of legs, but very sparse. The color of the sides fade gradually into the color of the belly. The pelage contour on dorsum is shaggy and formed by tips of overhairs, with thin and inconspicuous guard hairs. The fur on dorsum and

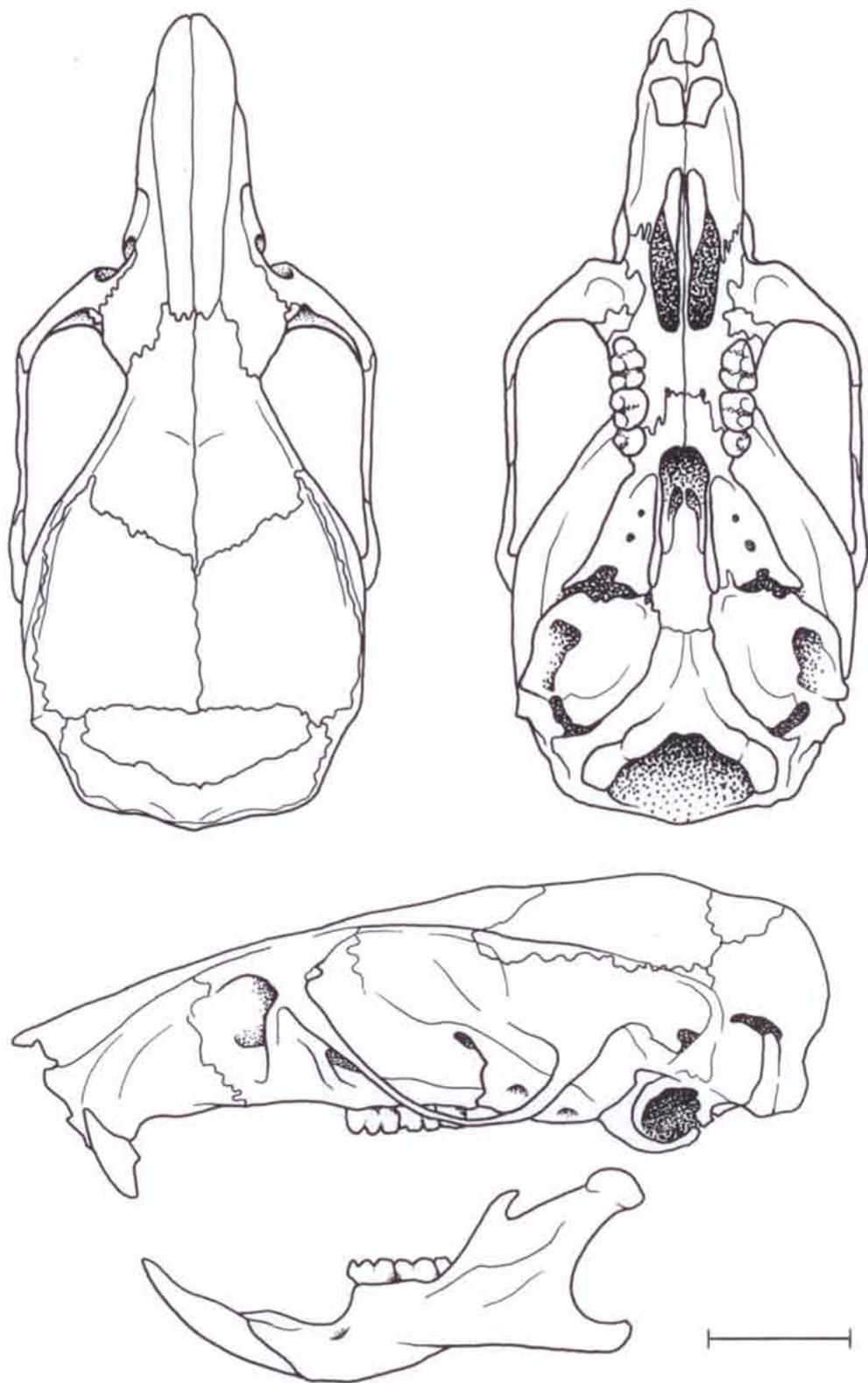
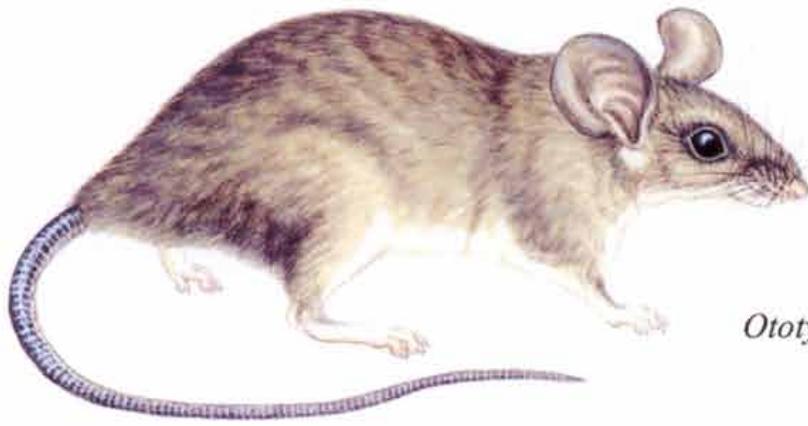


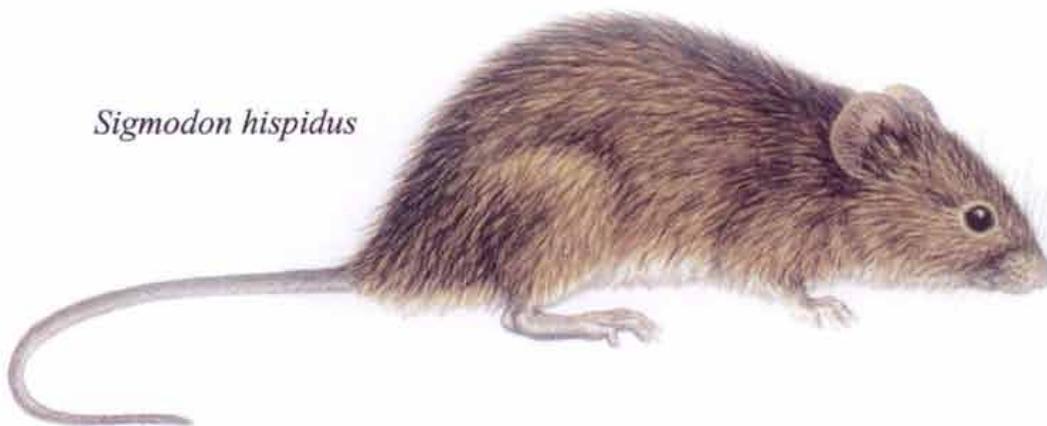
Figure 20. *Peromyscus yucatanicus* (VB225). Dorsal, ventral, and lateral view of cranium and lateral view of left dentary. Scale bar : 5 mm.



Ototylomys phyllotis



Peromyscus yucatanicus



Sigmodon hispidus

Figure 21. *Ototylomys phyllotis*, *Peromyscus yucatanicus*, and *Sigmodon hispidus*.
Reproduced from Reid's (1997) color plates 27, 29, and 30.

venter is coarse and rather long. Mystacial, superciliary, and genal vibrissae are colored black. Submental, interramal, and carpal vibrissae are present, but inconspicuous. Body hair continues on base of tail for about 5mm. The tail is bicolor, black above and grey below; it is rather broadly scaled (about 0.7mm), and covered with conspicuous but short (1-2mm) black hairs above and greyish below, with a short terminal tuft. The pinnae are round, conspicuous, moderately concealed in fur of head, and sparsely covered with short reddish or black hairs on their outer and inner surfaces. The ears are brown, and the rhinarium is partly so and unpigmented. Manus has unpigmented palmar surface with three separate interdigital and two separate carpal pads, and with a distinctive scalation. Dorsal and lateral surfaces of the metacarpal region and digits are dark grey, and thinly covered with short silvery hairs. Claws are short and greyish, with a conspicuous tuft of silvery hair at their base. Digit I is reduced and devoid of claw. The plantar surface of pes is dark grey, with a distinctive scalation, naked from heel to tips of the digits, with conspicuous fringing hairs along its contour, and with four separate interdigital and two separate carpal pads (see fig. 23). Dorsal and lateral surfaces of the metatarsal region and digits are grey, and thinly covered with short orangish or silvery hairs. The three middle digits are much longer than the outer two, and have enlarged claws. Claws are otherwise greyish, with a conspicuous tuft of silvery hair at their base.

The cranium is elongate and moderately slender, with a convex dorsal profile (see fig. 22). The rostrum is rather long and broad, but not concealing the deeply excavated nasolacrimal capsules in dorsal view. The nasals are long and terminate in a rounded angle anteriorly, projecting beyond the premaxillae to conceal the nasal orifice from dorsal view. The zygomatic arches are fairly convex from the dorsal aspect, and convergent anteriorly, with stout zygomatic processes of maxillae and squamosals flaring from sides of rostrum and braincase. The interorbital region is moderately broad relative to braincase. Supraorbital shelves accentuate the dorsolateral margins of the interorbit and transform posteriorly into low temporal ridges extending to conspicuous lambdoidal ridges. The supraorbital ridges are grooved dorsally. Occipital ridges are present, and less than 3.5mm distant from temporal ridges. The supraoccipital crest is angular in dorsal view, but also when viewed posteriorly. The braincase is inflated but not globose, with nearly vertical lateral and rear walls. The occipital condyles are not exposed in dorsal view. The auditory bullae are rather small and rounded, and their anterior margin lies anteriorly to the basisphenoid/basioccipital suture. The basisphenoid is narrow and moderately elongate, contrasting with a long and wide basioccipital. The flattened ventral surface of the presphenoid is narrow. The diameter of the foramen ovale is less than three-quarters the diameter of M3. The bony palate is fairly broad, without fenestration, and with a well-developed median crest extending beyond the molar rows posteriorly (spinous process). The anterior margin of the maxillary/palatines suture extends between M2 and M3. The posterior margin of the inferior zygomatic root is just above the anterocone of M1. The spinous anterodorsal process of the zygomatic plate is blunt and rather broad. The incisive foramina are long and conspicuous, and their posterior margins lie slightly posteriorly to the anterior margin of the orbits; their lateral margins are convex, and widest at the anterior margin of the zygomatic plate in lateral view. The teeth number 16. The molar toothrows are straight along their labial margins, and slightly convergent anteriorly. Incisors are rather large with ungrooved orangish enamel faces; in lateral profile, the uppers curve back toward the molar rows, an opisthodont configuration. The dental formula is : $i\ 1/1$, $c\ 0/0$, $p\ 0/0$, and $m\ 3/3$. The dentary has a falciform coronoid process, a long and stout condyloid process, a broad and well developed angular process, and a deep and short ramus; the capsular process is clearly visible.

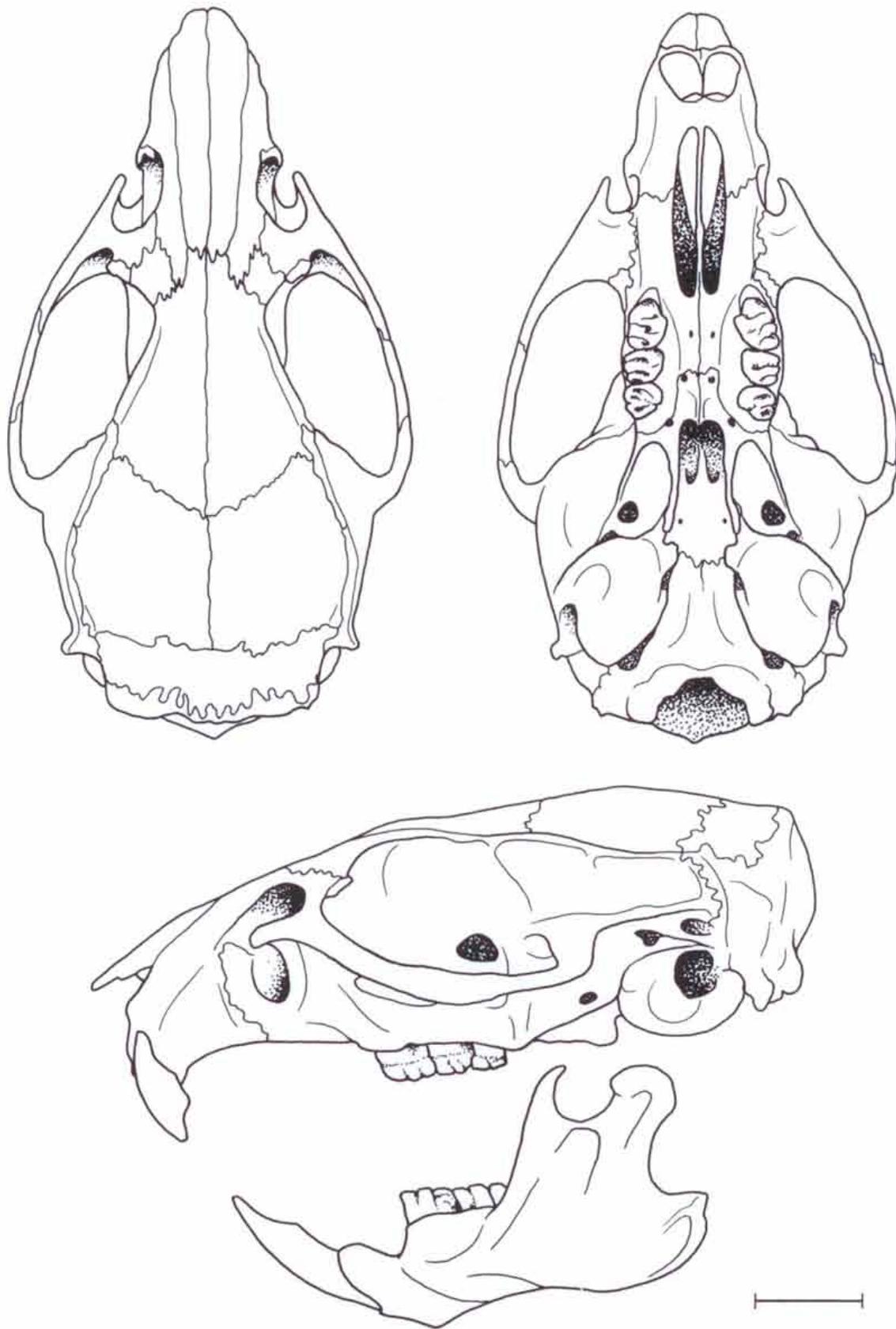
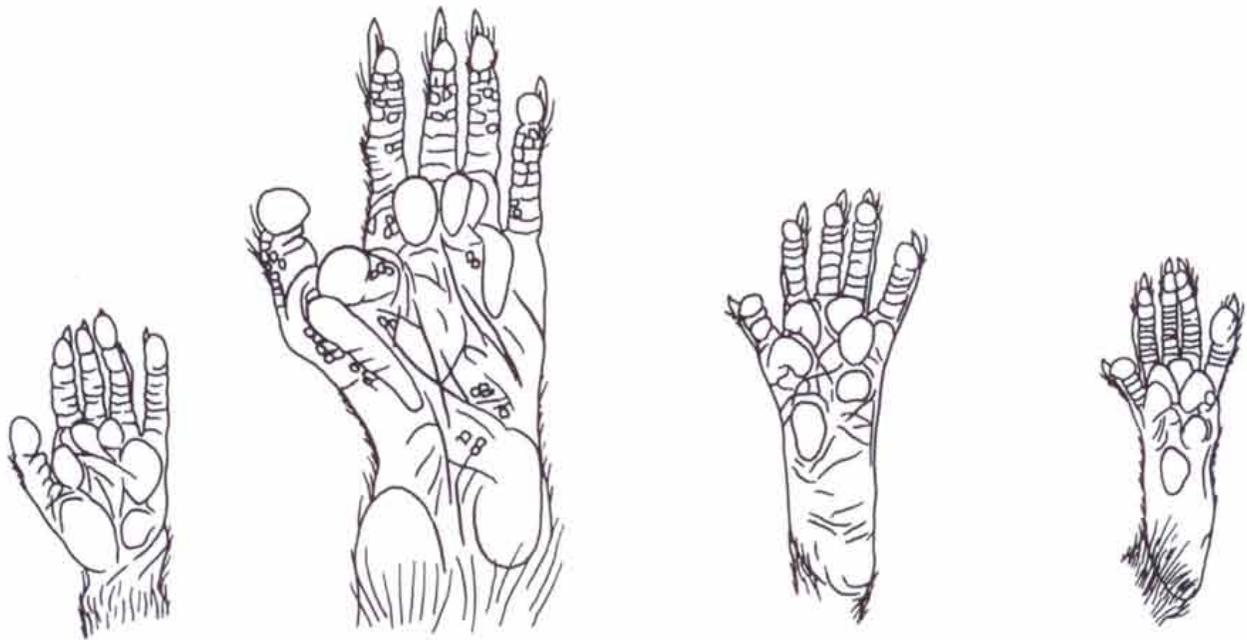


Figure 22. *Sigmodon hispidus* (VB147). Dorsal, ventral, and lateral view of cranium and lateral view of left dentary. Scale bar : 5 mm.

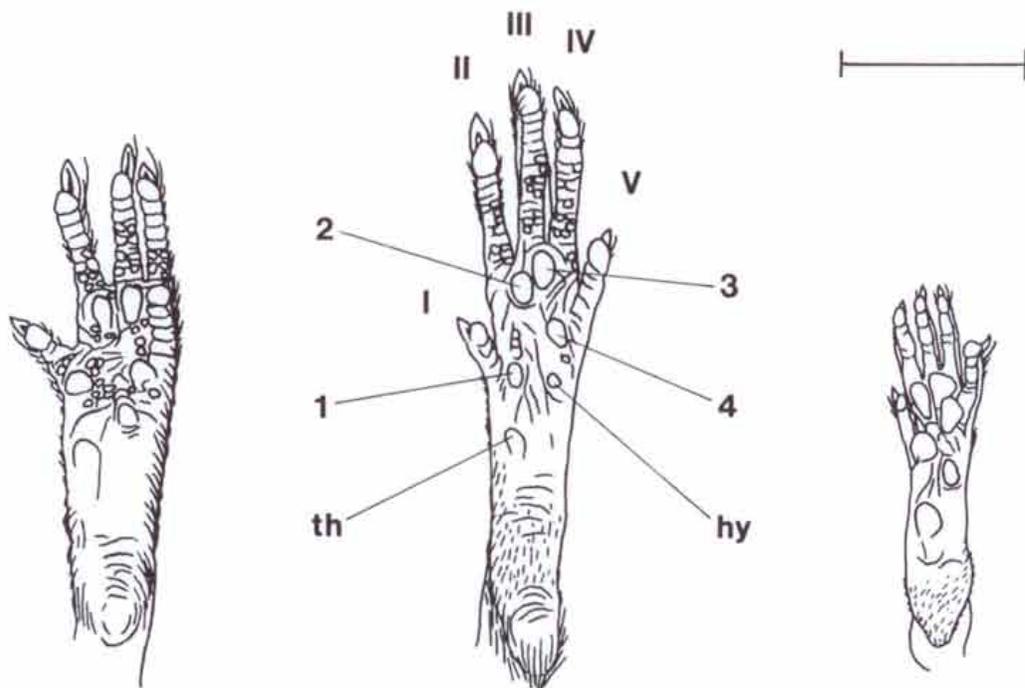


VB054

VB062

VB004

VB182



VB147

VB021

VB225

Figure 23. *Marmosa mexicana* (VB054), *Didelphis virginiana* (VB062), *Heteromys gaumeri* (VB021), *Otonyctomys hatti* (VB182), *Otodylomys phyllotis* (VB004), *Peromyscus yucatanicus* (VB225), and *Sigmodon hispidus* (VB147). Plantar view of left pes. **hy**, hypothenar pad; **th**, thenar pad; **1-4**, carpal pads; **I-V**, digits. Scale bar : 10 mm.

Distribution :

All specimens of *S.hispidus* were captured in site n°6 (see table 2).

Habitat :

The animal was captured in vegetation types 6 and 7 (see table 3). All specimens were captured on the ground, in a single type of microhabitat : between the bases of red mangroves (*Rhizophora mangle*) surrounded by sedges (*Cladium jamaicense*).

Behavior :

Released animals ran away on the ground for several meters between sedges. Very few individuals were recaptured. VB151 was captured three times successively, and in three different traps set in adjoining stations. The specimens were rather motionless when holding the trap above the ground, but tried to escape vigorously by rushing against the mesh wire doors as soon as the cage was left on the ground.

3.2. Ecto- and endoparasites :

The number of endoparasites per host species for the three sections of intestine—small intestine, caecum, and rectum (-colon)—is presented in table 8. Endoparasites were mostly found in the small intestine, and belonging to the superfamily Trichostrongyloidea of the phylum Nematoda (see below). The total number of ecto- and endoparasites belonging to the taxa mentioned in table 9 is presented for the seven host species. Overall, two groups of ectoparasites were collected : fleas (phylum Arthropoda, subphylum Uniramia, class Insecta, order Siphonaptera) and mainly ticks (phylum Arthropoda, subphylum Chelicerata, class Arachnida, order Acarina, suborder Metastigmata). *Didelphis virginiana* (VB062) alone totaled 80 ticks almost exclusively found inserted between the digits of left (30) and right (28) manus, and left (5) and right (15) pes respectively. Besides, six pentastomid, or tongue worm, larvae (phylum Pentastomida, class Porocephalida) were found in the peritoneal cavity or encysted in the liver of *Marmosa mexicana* (VB054). In addition, at least one case of well developed cutaneous myiasis caused by a non-identified species of cyclorrhaphan fly (class Insecta, order Diptera, suborder Cyclorrhapha) was recorded from *Ototylomys phyllotis* (VB103). A case of phoresy by two male pseudoscorpions of the species *Epichernes navarroi* (phylum Arthropoda, subphylum Chelicerata, class Arachnida, order Pseudoscorpionidae; identified by Volker Mahnert, NHMG Director) was also recorded from *Heteromys gaumeri* (VB160).

The following text presents the essential observations regarding the morphological description, the distribution within the intestine, and the corresponding hosts of the single species and three genera of trematode, the single species of cestode, and the single genus of nematode identified during the present study. Additional observations of these species are presented in the referred literature (see paragraph 4.2), and according to Cheng (1986), Yamaguti (1971), Grassé et al. (1961 and 1965), and Durette-Desset (*in* Anderson and Chabaud, 1983), they are classified as follows :

Phylum **Platyhelminthes** (3 classes)

Class **Trematoda** (3 orders)

Order Digenea (3 suborders)

Suborder Anepitheliocystida (12 superfamilies)

Superfamily Echinostomatoidea (9 families)			
Family Rhopaliasidae (1 genus)		Yamaguti,	1958
	Genus <i>Rhopalias</i>	Stiles and Hassall,	1898
Superfamily Brachylaemoidea (3 families)			
Family Brachylaemidae (5 subfamilies)		Joyeux and Foley,	1930
Subfamily Scaphiostominae (1 genus)		Yamaguti,	1958
Genus <i>Scaphiostomum</i>		Braun,	1901
	<i>Scaphiostomum pancreaticum</i>	McIntosh,	1934
Subfamily Brachylaeminae (5 genera)		Joyeux and Foley,	1930
Genus <i>Brachylaemus</i>		Dujardin,	1843
Superfamily Notocotyloidea (4 families)			
Family Nudacotylidae (2 genera)		Barker,	1916
	Genus <i>Nudacotyle</i>	Barker,	1916

Class **Cestoidea** (2 subclasses)

Subclass **Eucestoda** (12 orders)

Order Cyclophyllidea (7 families)

Family Davaineidae (2 subfamilies)		Braun,	1900
Subfamily Davaineinae (31 genera)		Braun,	1900
Genus <i>Raillietina</i>		Fuhrmann,	1920
	<i>Raillietina sigmodontis</i>	Smith,	1953

Phylum **Nemata** (2 classes)

Class **Secernentea** (3 subclasses)

Subclass **Rhabditida** (3 orders)

Order Strongylida (5 superfamilies)

Superfamily Trichostrongyloidea (14 families)

Family Ornithostrongylidae (2 subfamilies)		D.-Desset/Chabaud,	1981
Subfamily Ornithostrongylinae (7 genera)		Travassos,	1914
Genus <i>Vexillata</i>		Durette-Desset,	1971

Family **Rhopaliasidae**

Four specimens of the genus *Rhopalias* were found in the small intestine of *Didelphis virginiana* (VB062). Their body is elongate and spinose. The forebody is ventrally excavated, and provided on each side with a retractile proboscis armed with numerous hooks (see fig. 24). The oral sucker is subterminal, and separated from the elliptical pharynx by a prepharynx. The oesophagus is fairly long, bifurcating just anterior to the acetabulum. The acetabulum is near the anterior extremity, and much larger than the oral sucker. The intestine reaches the posterior extremity. Testes are angular, directly tandem, and situated posteriorly. The cirrus pouch is long and claviform, extending posteriorly to the acetabulum. The genital pore is median, just preacetabular. The ovary is median, rounded, and separated from testes by the uterus. The uterus is long, and winding in the intercecal field between the genital pore and the testes. The vitellaria are confined to the lateral fields of the hindbody, but barely visible. Main measurements are : maximum length of body, 1.2 millimeters (mm); maximum width of body, 0.5 mm; oral sucker length/width, 120/110 micrometers (μm); pharynx length/width, 140/67 μm ; acetabulum length/width, 240/200 μm ; proboscis length/width, 250/105 μm .

Family **Brachylaemidae**

Subfamily Scaphiostominae

Three specimens of the species *Scaphiostomum pancreaticum* were found in the small intestine of *Heteromys gaumeri* (VB018), and one in the pancreas of *Ototylomys phyllotis* (VB004). Their body is very long and filiform. The cuticle is smooth. The oral sucker is large and terminal, and separated from the globular pharynx by a short prepharynx (see fig. 25). The oesophagus is short and barely visible. The acetabulum is smaller than the oral sucker, and near the anterior extremity. The intestine reaches the posterior extremity. Testes are rounded, tandem, and near the posterior extremity. Both the cirrus pouch and the genital pore are pretesticular, whereas the ovary is intertesticular. The uterus is very long, and winding in the intercecal field between the ovary and the anterior third of the body. The vitellaria are confined to the lateral fields of the body, and extend anteriorly from the pretesticular region to the forebody. The excretory vesicle is tubular, and bifurcates immediately behind the posterior testis. Main measurements are : maximum length of body, unknown; maximum width of body, 0.7 millimeters (mm); oral sucker length/width, 275/295 micrometers (μm); pharynx length/width, 145/175 μm ; acetabulum length/width, 225/235 μm .

Subfamily Brachylaeminae

Two immature specimens of the genus *Brachylaemus* were found in the small intestine of *Didelphis virginiana* (VB062). Their body is rather short and tongue-shaped (see fig. 26). The cuticle is smooth. The oral sucker is large and terminal, and separated from the globular pharynx by a short prepharynx. The oesophagus is short and barely visible. The acetabulum is smaller than the oral sucker, and in the anterior half of the body. The intestine is bent on both sides of the pharynx, otherwise rather straight, and reaches the posterior extremity. Testes are rounded, tandem, and near the posterior extremity. The cirrus pouch is pretesticular and lateral to the anterior testis, just as the genital pore. The ovary is more or less oval, and intertesticular. The uterus is rather short, and moderately winding in the intercecal field

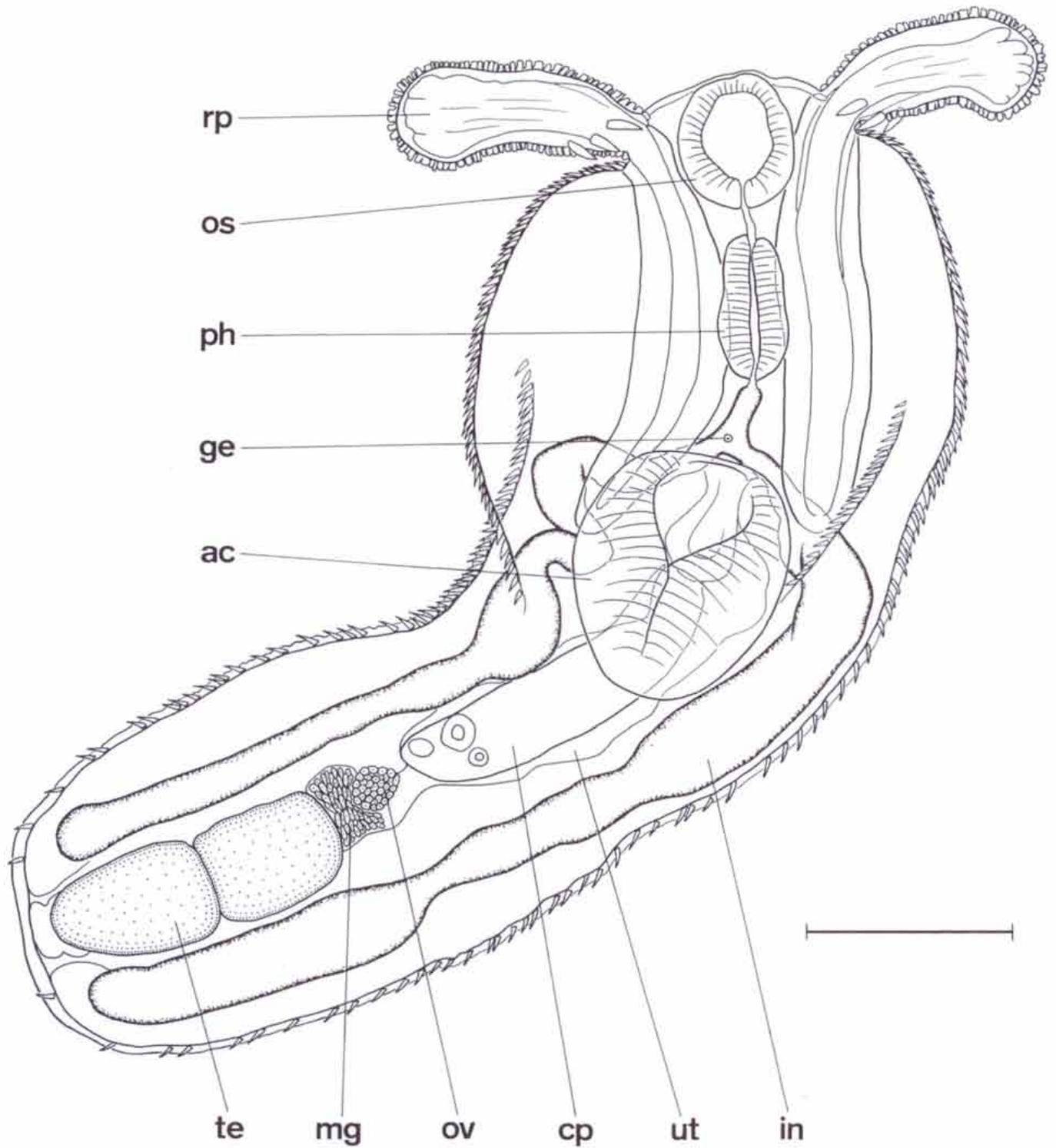


Figure 24. *Rhopalias*. Ventral view of the entire worm. **ac**, acetabulum; **cp**, cirrus pouch; **ge**, genital pore; **in**, intestine; **mg**, Mehlis' gland; **os**, oral sucker; **ov**, ovary; **ph**, pharynx; **rp**, retractile proboscis; **te**, testis; **ut**, uterus. Scale bar : 200 μ m.

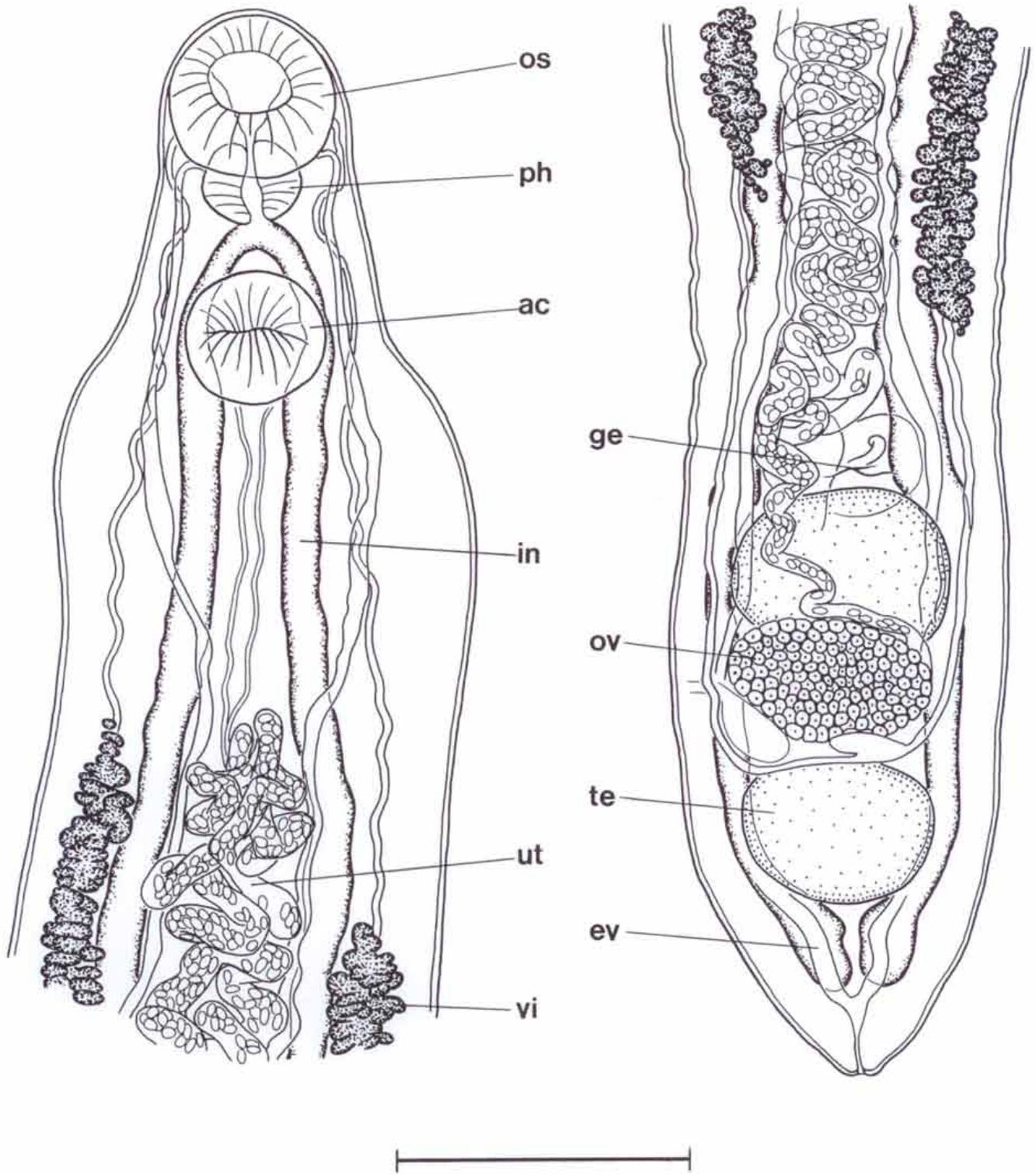


Figure 25. *Scaphiostomum pancreaticum*. Ventral view of the entire worm. ev, excretory vesicle; vi, vitellaria. Other abbreviations, see figure 23. Scale bar : 500 μ m.

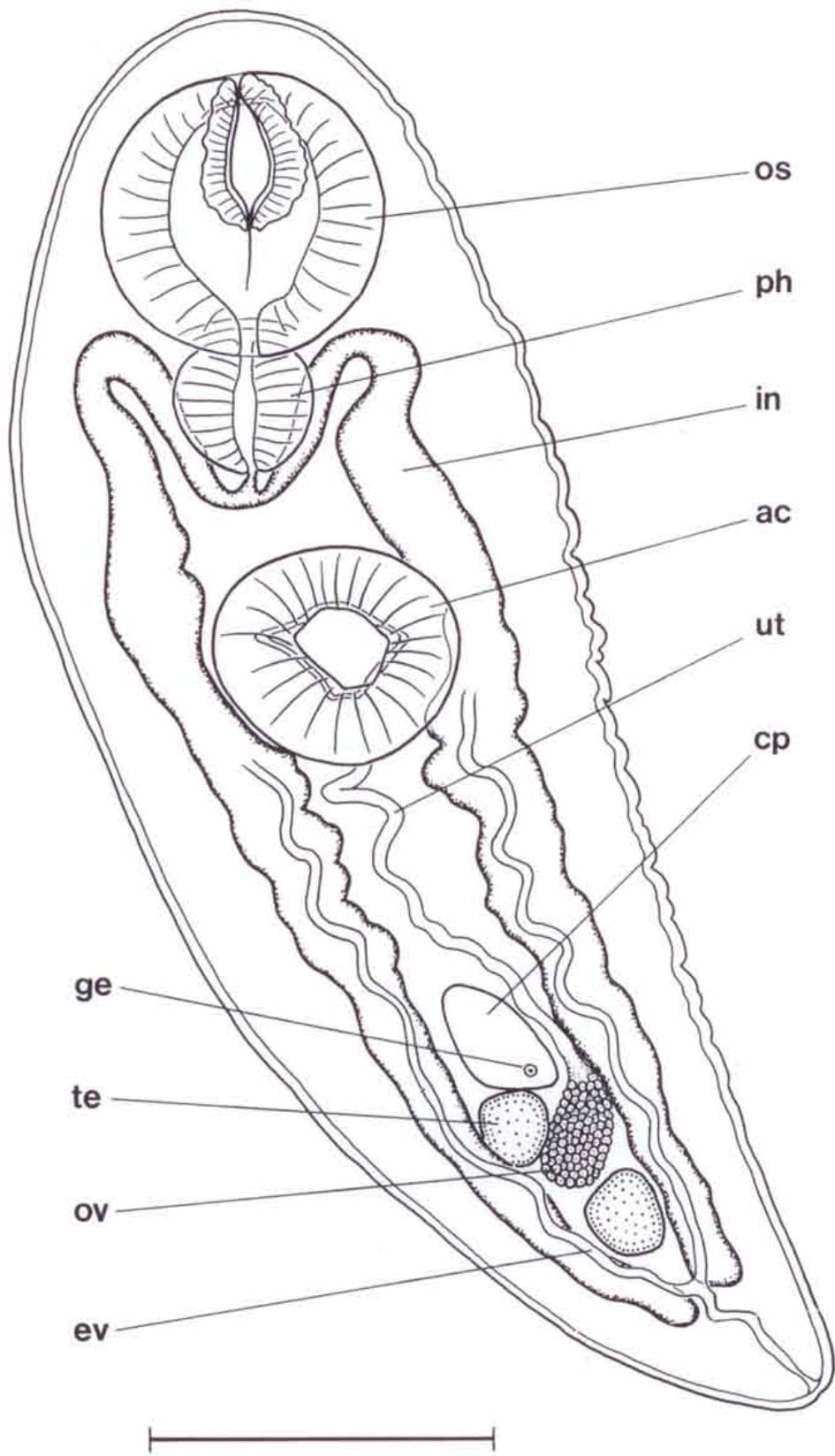


Figure 26. *Brachylaemus*. Ventral view of the entire worm. Abbreviations, see figures 23 and 24. Scale bar : 200 μm .

between the ovary and the acetabulum. The vitellaria are confined to the lateral fields of the body, but barely visible. The excretory vesicle is tubular, and bifurcates immediately behind the posterior testis. Main measurements are : maximum length of body, 0.9 millimeters (mm); maximum width of body, 0.3 mm; oral sucker length/width, 165/165 micrometers (μm); pharynx length/width, 78/78 μm ; acetabulum length/width, 130/145 μm .

Family **Nudacotylidae**

Hundreds of specimens of the genus *Nudacotyle* were found in the small intestine of *Sigmodon hispidus* (VB146, VB147, and VB148). Their body is small, oval, strongly flattened, convex dorsally, and concave ventrally (see fig. 28). The cuticle is smooth. The oral sucker is slightly subterminal, and the pharynx and acetabulum absent. The intestine is short and terminating anteriorly to testes. Testes are somewhat oval and lobed, and situated at the posterior extremity on both sides of the excretory vesicle. The cirrus pouch is large, lying obliquely across the median portion of the body in front of the testes. Only one genital pore is clearly visible—it is median, and situated just above the cirrus pouch in ventral view. The ovary is rounded, between and posterior to the left testis in ventral view. The uterus is coiled transversely between the cirrus pouch and the oesophagus, and extends laterally beyond the ceca. The eggs are small, with polar filament at each pole. The vitellaria consist of clusters of follicles, and are situated in the pretesticular lateral fields in the middle third of the body. The excretory vesicle is lobed in outline, and opens in the center of the posterior lobe, giving off two radiating canals. Main measurements are : maximum length of body, 0.5 millimeters (mm); maximum width of body, 0.3 mm; oral sucker length/width, 72/72 micrometers (μm).

Family **Davaineidae**

Subfamily Davaineinae

Several specimens of the species *Raillietina sigmodontis* were found in the small intestine of *Sigmodon hispidus* (VB148), along with gravid proglottids in the caecum and rectum (-colon); single specimens of this same species were also recorded from the small intestine and caecum of *H. gaumeri* (VB018), and the small intestine of *O. phyllotis* (VB002). The body is segmented externally (see fig. 29). The scolex is in one part, and provided with four spinose suckers. The rostellum is armed with 84 minute hammer-shaped hooks in two rows; these two rows appear as one row, unless carefully examined. The strobila is dorsoventrally flattened and hermaphroditic; the genital organs male and female are single in each proglottid. Genital pores are unilateral. The cirrus pouch is small, not reaching the osmoregulatory organ. Testes number 21-26 in mature segments, and are scattered laterally on both sides of the uterus. The mature uterus is lobed, and otherwise replaced by uterine capsules. The paruterine organ is absent. Up to 50 egg capsules containing several eggs are present in gravid segments. The vitellarium is compact and posterior to the lobed and median ovary. Main measurements are : maximum width of body, 1.7 millimeters (mm); scolex length, 0.28 mm; scolex width, 0.43 mm; rostellar sac diameter, 0.15 mm; rostellum diameter at crown of hooks, 0.12 mm; hooks length, 25.6 micrometers (μm); length across anterior root and blade of hooks, 10.24 μm ; suckers diameter, 98.7 μm ; sucker aperture diameter, 72.4 μm ; mature segments length/width, 0.13/0.92 mm; pregravid segments length/width, 0.28/1.7 mm; gravid segments length/width, 1.12/0.71 mm; cirrus pouch length/width, 84.5/46.1 μm ; testis diameter, 48.6 μm ; capsule length/width (gravid segments), 0.15/0.09 μm ; egg diameter (gravid segments), 23.0 μm .

Family **Ornithostrongylidae**

Subfamily Ornithostrongylinae

With the exception of *Sigmodon hispidus* (VB146, VB147, and VB148), nematodes of the superfamily Trichostrongyloidea were found in all host species (see table 9), sometimes along with other non-identified groups of the phylum Nemata. Members of this superfamily were especially numerous in the small intestine of *H.gaumeri* (VB017, VB018 and VB021), with the genus *Vexillata* among others. In males, the synophe is dorsoventrally symmetrical, with a carene about the same size than body (see fig. 27). The cuticular ridges are markedly unequal in size, and number 6 and 5 on the dorsal and ventral surfaces respectively. The carene is supported by a pair of hypertrophied left lateral cuticular ridges (dorsal and ventral). With the exception of the carene, ridges are decreasing in size from right to left on both the dorsal and ventral surfaces. On the right side, both the apex of the first dorsal and ventral ridges are directed tangential to the body. On the left side, the hypertrophied ridges making the carene are directed perpendicular to the body. Between, ridges are more or less directed oblique to the body surface. The dorsal ridge making the carene is slightly thinner and shorter than the ventral ridge; the fourth dorsal ridge is small and distant from the body, also supporting the carene.

In addition, five immature specimens belonging to two non-identified species of trematodes, as well as a non-identified species of cestode, were recorded from *H.gaumeri* in the small intestine (VB017 and VB018) and the caecum (VB021) respectively.

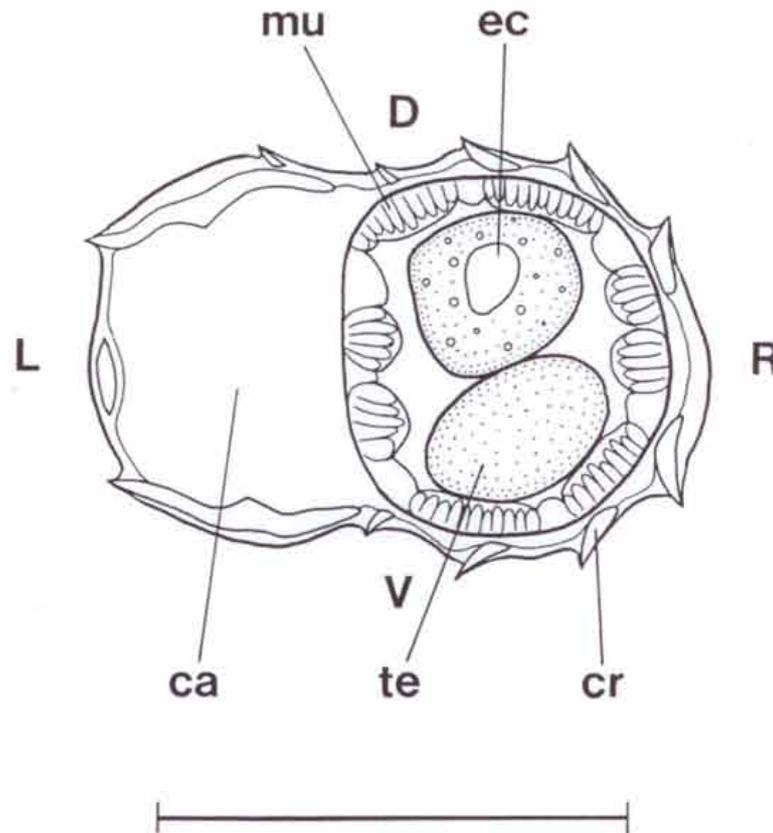


Figure 27. *Vexillata*. Synophe, transverse section of and adult male. **D**, dorsum; **V**, venter; **L**, left; **R**, right; **ca**, carene; **cr**, cuticular ridges; **ec**, excretory canal; **mu**, muscles; **te**, testis. Scale bar : 100 μ m.

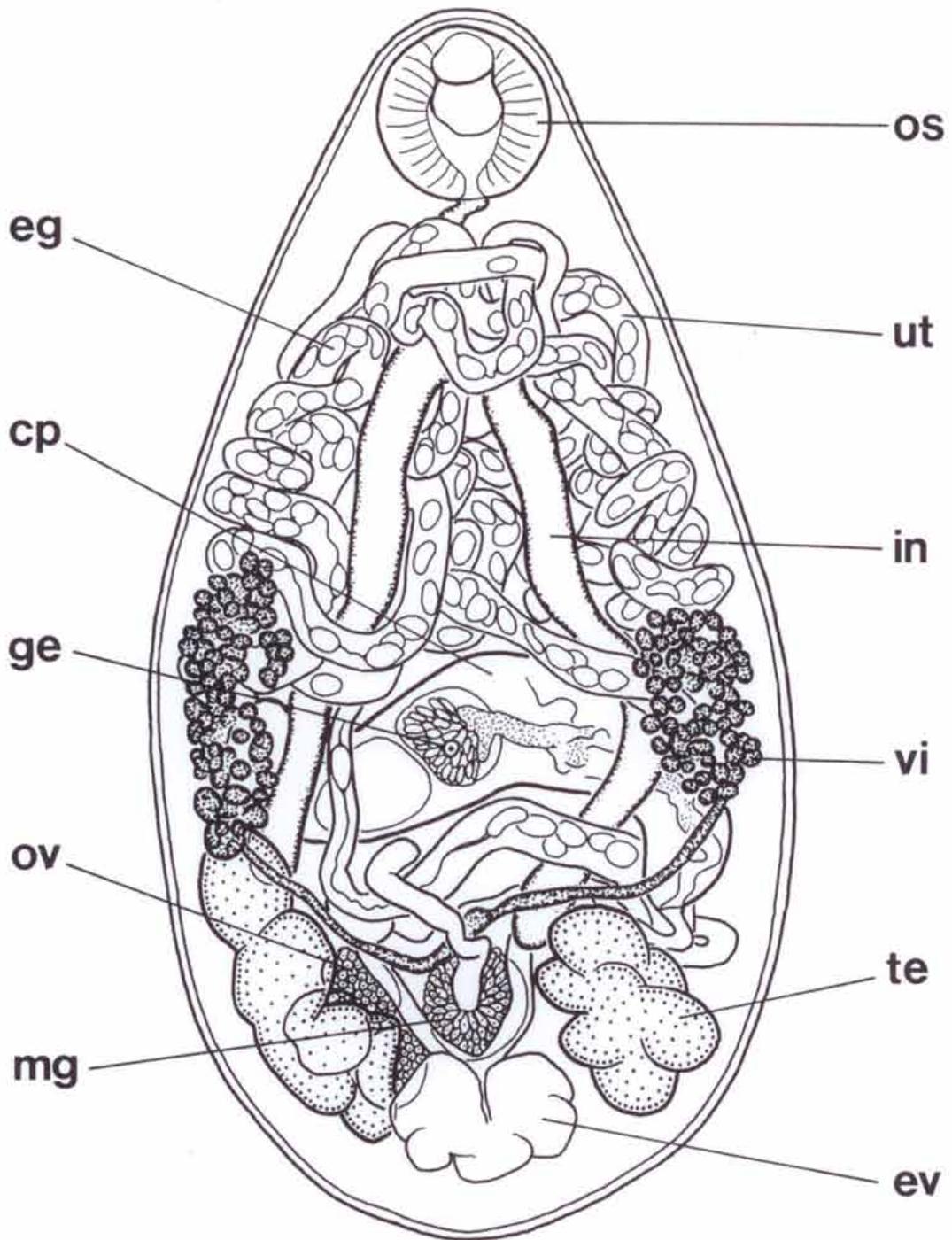


Figure 28. *Nudacotyle*. Ventral view of the entire worm. eg, eggs. Other abbreviations, see figures 23 and 24. Scale bar : 200 μ m.

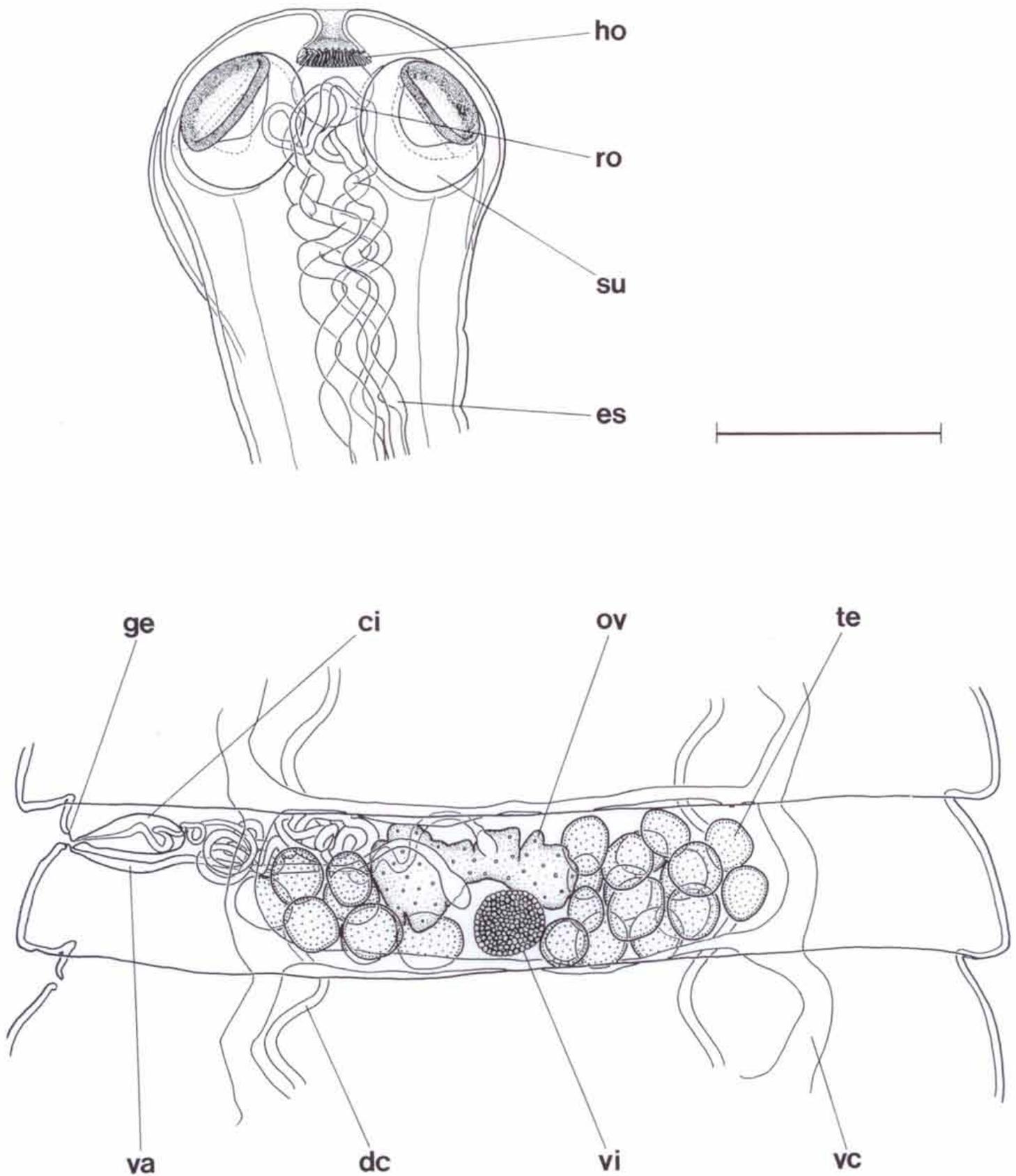


Figure 29. *Raillietina sigmodontis*. Above : scolex, lateral view. Below : mature proglottide, ventral view. **ci**, cirrus pouch; **dc**, dorsal excretory canal; **es**, excretory system; **ge**, genital pore; **ho**, hooks; **ov**, ovary; **ro**, rostellum; **su**, sucker; **te**, testis; **va**, vagina; **vc**, ventral excretory canal; **vi**, vitellaria. Scale bar : 200 μ m.

Chapter 4

Discussion :

The list of small mammals obtained in this study is certainly not exhaustive. Indeed, trapping for small mammals, and especially rodents, in Neotropical forests is frequently unproductive because of ants, rain, or bright moonlight, but trap success is usually low even in the best of circumstances. Typically less than 10% of the traps set on a given night are successful, and only a few taxa usually account for most captures (Voss and Emmons, 1996). Therefore, intensive trapping programmes are the standard approach, but still, elusive species can suddenly appear after months or years of work, so completeness is hard to document.

Besides, although relevant inventory data are rapidly accumulating in literature, real site-to-site diversity differences are hard to identify because many confounding factors can affect the size and composition of faunal lists (Voss and Emmons, 1996). All inventory methods are biased because each is suitable for collecting or observing only a fraction of the morphologically and behaviorally diverse mammalian fauna that inhabits Neotropical forests, and special methods are required to add elusive species to faunal lists. Hence, many methods must be used in combination to census whole communities, and virtually all existing inventories are incomplete. Furthermore, the degree of incompleteness is inversely correlated with inventory duration, so that species lists always increase with additional sampling effort up to an asymptote.

Ideally, fieldwork should be continued until asymptotic species lists are obtained, but even in the case of field stations with long histories of inventory work, new species were recently added to the overall list. High diversity—quantified as species richness (number of species)—was nevertheless obtained from several regions in Central America. For example, in the vicinity of the La Selva Biological Station, nearby the Braulio Carrillo National Park, Costa Rica, up to 114 mammalian species including 5 species of marsupials and 13 species of small rodents were recorded since the first inventory published by Slud in 1960 (Timm et al., 1989). Further south in central Panamá, up to 113 mammalian species including 6 species of marsupials and 10 species of small rodents were obtained from Barro Colorado Island, Gatun Lake, since Enders' surveys from 1929 to 1937 (Eisenberg and Thorington, 1973; Voss and Emmons, 1996). In the states of Veracruz and Oaxaca, Mexico, two species accounts based on long-term studies were reported by Hall and Dalquest (1963), and Goodwin (1969) respectively. In the first case, 156 mammalian species including 4 species of marsupials, 48 species of small rodents, and 7 species of shrews were recorded since Dalquest's first account in 1947. And in the state of Oaxaca, 204 mammalian species including 6 species of marsupials, 54 species of small rodents, and 10 species of shrews were listed since McDougall's surveys from 1943 to 1967. An essential problem with inventory comparisons is highlighted by the latter data in which diversity appears to be highest in Mexico where the sampled areas are, however, much greater. In fact, mammalian diversity is greatest in lowland tropical rainforests and decreases along gradients of increasing latitude, elevation, and aridity (Voss and Emmons, 1996). In this way, a gradient of decreasing diversity along the Central American isthmus from the Colombian frontier to southern Mexico is evident for rainforest marsupials, edentates, bats, primates, and rodents, but not for carnivores or ungulates (Voss and Emmons, 1996; Ceballos, *in* Bullock et al., 1995). This pattern results from the incremental loss of species with predominantly South American distributions, most of which are not replaced by Central American endemics. As a consequence, rainforest mammal faunas in southern Mexico are perhaps the least diverse of any in Central and South America.

By comparing the present study with the inventories mentioned above, the list of small mammals obtained in Shipstern Nature Reserve appears very incomplete with only 2 species of marsupials, 5 species of myomorph rodents, and no species of shrews. However, an expedition of six months is considered as very brief, and in such a case adding missing species to the inventory is just a matter of time. Thus, the most important role for this project was to provide crucial diversity data for research and conservation objectives, before habitat destruction makes moot the absence of relevant information for ecologists, biogeographers, and land-use planners. Indeed, inventory results combine the advantage of concreteness (the listed species are definitely known to have occurred together at a particular place and time) with the disadvantage of incompleteness. Furthermore, the usefulness of such a brief collecting was maximized by focusing on marsupials and rodents, that is taxa known to respond to ecological or zoogeographic gradients, and ignoring faunally uninformative groups (Voss and Emmons, 1996). Also, fresh material was subsequently added to museum collections (NHMG), the bedrock on which revisionary monographs, field guides, range maps, and other essential resources for biodiversity research are fundamentally based.

Consequently, results obtained in the present study are better compared to other short term inventories. In Belize, Rabinowitz and Nottingham (1989) sampled small mammals in the Cockscomb Basin of the Maya Mountains for several months in 1983 and 1984. Inventory sites such as the latter comprising both riparian and terra firme habitats are likely to have more diverse mammalian communities than more arid sites such as the one in Shipstern Nature Reserve (SNR). This was confirmed by their results, with 4 species of marsupials, including *M.mexicana*, and 9 species of myomorph rodents, including *O.phyllotis* and *S.hispidus*. Beside, they recorded that three species—*Heteromys desmarestianus*, *Tylomys nudicaudus*, and *O.phyllotis*—accounted for 67.5% of the total capture. With *O.phyllotis* accounting for 90.8% and *H.gaumeri* 5.55% of the total capture (see table 2), results are even more striking in SNR, and confirm the general trend highlighted by Fleming (1975, in Rabinowitz and Nottingham, 1989) that neotropical mammal communities generally contain one or two relatively common species and many uncommon species of small mammals. Similarly, Disney (1968) reported from his study in central Belize that *O.phyllotis* and *H.gaumeri* were together the most common species with 76.7% of the total capture. Perhaps, these two species are the most aggressive of the community in northern Belize, and preclude the capture of trap-shy species.

Recently, another study was completed in the Chiquibul Forest Reserve of the Maya mountains (Caro et al., 2001). Their capture results were fairly similar to those of Rabinowitz and Nottingham (1989), with 4 species of marsupials including *M.mexicana* and *D.virginiana*, and 7 species of myomorph rodents, including *H.gaumeri* and *O.phyllotis*. By combining these latter results with those obtained in SNR, it appears that at least 4 small mammal species—*M.mexicana*, *D.virginiana*, *H.gaumeri* and *O.phyllotis*—are sympatric throughout Belize. In addition, two species of squirrels—*Sciurus yucatanensis* and *S.deppei*—were recorded from the Cockscomb Basin, Chiquibul Forest Reserve, and SNR by sight (see appendix 2), and can also be considered as sympatric. However, a main difference in SNR is the presence of species such as *O.hatti* and *P.yucatanicus* that are endemic to the Yucatán Peninsula (McCarthy et al., 1998). In this way, with additional endemics such as *H.gaumeri* and *S.yucatanensis*, the small mammal fauna in SNR appears to be closely related to the rodent fauna listed by Jones et al. (1974) in Yucatán.

The small mammal species list (see appendix 1) predicted from range overlap—geographic expectations (Voss and Emmons, 1996)—relies on distributional data obtained from various authors (Reid, 1997; Emmons and Feer, 1997; McCarthy et al., 1998; Murie, 1935; and Hershkovitz, 1951). However, the resulting discrepancy between the expected diversity (from

distributional data) and the observed diversity (from the inventory) is subject to several sources of uncertainty. Indeed, among others, very rare species are less frequently captured in inventories, and therefore their geographic range is often underestimated in poorly inventoried areas. Furthermore, geographic expectations might consistently overestimate sympatric diversity if many species are patchily distributed within their known range limits, or underestimate diversity if many taxa are unrevised or undescribed (Voss and Emmons, 1996). Uneven geographic sampling and unrevised taxonomy are therefore additional bias towards the diversity results. Hence, diversity estimation from range data requires much supplementary information (e.g. about natural history) to minimize inaccuracy.

The overall trapping success (3.5%) realized in this study falls within the range of observed success rates in other neotropical small mammal inventories. In the state of Minas Gerais, Brazil, Da Fonseca and Kierulff (1989) recorded a trapping success of 2.4%, and Stallings (1989) 7.5%. In the Maya Mountains, Belize, Rabinowitz and Nottingham (1989) recorded a trapping success of 5.23%, and Caro et al. (2001) 0.8%. However, the site-to-site trapping success realized in Shipstern Nature Reserve (see table 4) is fluctuating markedly, ranging from 1.2% in site n°2 to 8.8% in site n°4. Such a fluctuation was also reported by Stallings (1989) where the trapping success ranged from 2.3% to 18.8% from one site to another. In the case of SNR, these irregular trapping results are unlikely to be due to a temporal fluctuation in density, since both sites n°2 and 4 were surveyed during the driest months. Furthermore, the highest results (8.8% and 6.6%) were both recorded from sites n°4 and 8, that is in the Shipstern area (see fig. 1). The latter observation leads to consider a possible higher density in forests situated south to Shipstern Lagoon, at least for *O.phyllotis*. Indeed, such results are biased by the very high predominance of *O.phyllotis* in sites n°4 and 8—with a total capture of 96.5% and a recapture rate of 2.3, and 95.2% and 1.8, respectively (see table 2)—and therefore cannot be extrapolated to other species such as *H.gaumeri* which remained fairly elusive with a recapture rate of 1.0.

Methods employed during the present study were the least selective possible, but nevertheless focused on the small mammal fauna of Shipstern Nature Reserve (see above). In spite of this, use of larger wire live traps (e.g. Tomahawk of 14.5 X 14.5 X 41.0 cm) set as high as possible in trees was probably needed for arboreal species of large opossums such as *Didelphis virginiana* and *D.marsupialis*. Because local populations of some species of marsupials apparently undergo dramatic fluctuations in density, long-term site-to-site surveys would also have provided the most reliable diversity data—marsupial diversity in Central American rainforests is likely to range from an expected minimum of 7 species in southern Mexico to an expected maximum of 10 in eastern Panama (Voss and Emmons, 1996). Among insectivores, special methods such as the use of pitfall traps were certainly required to confirm the presence of *Cryptotis mayensis* (see appendix 1) in SNR. On the other hand, scirurids are minor and inconspicuous component of the rodent fauna—despite the omnipresence of the genus *Sciurus* in Central America, the highest diversity recorded at any inventory site was 3, including both habitat generalists that occur throughout the forest, and habitat specialists that prefer viny riverside vegetation or the tangled margins of treefalls—and attempts to capture them are often unsuccessful and time-consuming. Nevertheless, all Neotropical squirrels are diurnal and can be located by sight or sound in the morning when they are most active, and this was the method employed to add *Sciurus yucatanensis* and *S.deppei* to the mammal list in Appendix 0. Such is not the case for myomorph rodents—they are mostly muroids in Central America, where their diversity ranges from an expected minimum of 6 species in lowland rainforests of southern Mexico to an expected maximum of 12 species near the Colombian frontier—that are

mostly nocturnal and seldom forage in unprotected situations. Here again, trapping duration is likely to have impeded success—three week-old lines continue to accumulate new species at some localities—and a daily rebaiting combined to a regular cleaning of traps would probably have increased the percentage of captures as well. But still, some muroids with unusual diets or microhabitats can only be collected by special efforts; among others, a greater proportion of arboreal traps was surely required to record strongly scansorial species. Furthermore, snap traps should be used together with live traps, so that none of the captured specimens are released (Voss and Emmons, 1996). Indeed, trap-shy species may not be captured until more aggressive species are removed; and for this reason, mark-and-release trapping programs are generally unsuitable for rainforest inventory work. Extensive kill-trapping, however, was inconceivable within the boundaries of SNR.

In the following text, the attribution of a name species to the specimens collected in Shipstern Nature Reserve is discussed, knowing that few genera of Neotropical rainforest mammals are wholly free of taxonomic problems. Indeed, most of them have never been revised, or were last revised many years ago, so species concepts reflected in current taxonomic references are often little more than conventions sanctioned by long use (Voss and Emmons, 1996). Even genera with recent revisions are not free of taxonomic ambiguities. Especially suspect are some « species » of small marsupials, bats, and rodents whose ranges are currently believed to extend for thousands of kilometers across landscapes divided by major rivers and other zoogeographic barriers. In many such cases, close study may reveal morphological and/or molecular discontinuities among taxa currently ignored as obsolete synonyms or subspecies.

4.1. Characterization and comparisons :

Marmosa mexicana

M.mexicana is easily confused with *M.robinsoni*. But, whereas *M.m.* is ubiquitous and a typical Central American endemic (McCarthy et al., 1998), *M.r.* was previously known only from Panama, with disjunct populations in southern Belize and Roatán Island in Honduras (Reid, 1997). However, *M.r.* has recently been reported in Guatemala and El Salvador, so that it may be present throughout Central America, and specimens may have been confused with *M.m.*. A reappraisal of all specimens of the two species in Central America is therefore needed to determine their exact distribution.

On the basis of external characters, *M.m.* and *M.r.* are hardly distinguishable; *M.r.* is usually larger, with a longer and slightly wooly fur (Reid, 1997). This is confirmed by the external and cranial measurements of VB054 (see tables 6 and 7) that are falling perfectly within the ranges given for *M.m.* in Alonso-Mejía and Medellín (1992), but are rather at the bottom of the ranges for *M.r.* in O'Connell (1983).

These species can be distinguished by skull characters when adult, but skulls of young and subadult *M.m.* are virtually indistinguishable from those of *M.r.* (Reid, 1997). Nevertheless, VB054 is clearly distinguished from *M.r.* by its supraorbital ridges that are moderately grooved dorsally, and project laterally only slightly (Alonso-Mejía and Medellín, 1992); also, the postorbital constriction is not as pronounced as in *M.r.* (O'Connell, 1983).

By referring to the observations given in Alonso-Mejía and Medellín (1992), VB054 is probably belonging to the subspecies *M.m.mayensis* described by Osgood (1913, in Alonso-Mejía and Medellín, 1992) in Izamal, Yucatán, Mexico.

Although serious conclusions on habitat and habits cannot be drawn from a single capture, the hindfeet with swivelling ankle joints and opposable hallux, and the strongly prehensile tail observed in VB054 (see paragraph 3.1) suggest that it is highly scansorial. Furthermore, the habitat description in Reid (1997) leads to infer that *M.m.* is probably ubiquitous in the forests of Shipstern Nature Reserve. Besides, the defensive behavior showed by VB054 in the trap was also reported by Eisenberg (1989, in Alonso-Mejía and Medellín, 1992), but does not seem to be particular to the species (Kimble, 1997).

Didelphis virginiana

D.virginiana is difficult to distinguish with certainty from *D.marsupialis* at night. Also, both species are ubiquitous in Central America—*D.m.* extends from NE Argentina, Bolivia, and Peru in South America to northern Mexico (Reid, 1997), whereas *D.v.*, which is thought to have arisen from *D.m.* (Gardner, 1973), is not found any further than NW Costa Rica, but extends northerly to southern Canada—and are expected to be sympatric in Shipstern Nature Reserve. Thus, the observation of *D.m.* during a dark phase of the moon was retained in appendix 2, but is to be confirmed.

Perhaps the most distinctive and easily observed external character separating *D.v.* and *D.m.* is the hair color of the cheek region (Gardner, 1973): it is pure white in *D.v.*, and clearly set off from the rest of the head by the darker color of the sides and neck behind, and by a dark band extending from the ear through the eye above. Also, the extent of the black pigmented basal portion of the tail ranges from half to all black in *D.v.* (Reid, 1997), whereas it tends to be less in *D.m.*, a criterion however considered as too variable for broad application by Gardner (1973). Additional characters observed in *D.v.*, such as long white mystacial and genal whiskers, and more evenly distributed guard hairs over the dorsum, can be useful to separate *D.v.* from *D.m.*, but are still not determining in some cases. Among others, the single specimen captured in this study (VB062) is assigned to the age class 2 (Gardner, 1973), and is probably too young to be distinguished with certainty. For the same reason, the external and cranial measurements of VB062 (see tables 6 and 7) are not comparable with the ranges given for *D.v.* in McManus (1974), Gardner (1973), and Goodwin (1969).

However, *D.v.* and *D.m.* can be separated by skull characters that are independent of age classes (Gardner, 1973). Thus, VB062 is clearly distinguished from *D.m.* by its bone configuration in the naso-lacrimal and lacrimo-jugal regions, and on the inner wall of the orbit (see paragraph 3.1).

Referring to the observations given in McManus (1974), and Gardner (1973), VB062 is probably belonging to the subspecies *D.v.yucatanensis* described by Allen (1901, in McManus, 1974) in Chichén Itzá, Yucatán, Mexico.

Although serious conclusions on habitat and habits cannot be drawn from a single capture, the hindfeet with swivelling ankle joints and opposable hallux, and the prehensile tail observed in VB062 (see paragraph 3.1) suggest that it is highly scansorial. Furthermore, the habitat description in Reid (1997), and McManus (1974), leads to infer that *D.v.* is probably ubiquitous in the forests of Shipstern Nature Reserve. On the other hand, no characteristic behavior was observed, since VB062 was found weakened by its capture.

Heteromys gaumeri

In the field, *H.gaumeri* could be confused with *H.desmarestianus*. But, whereas *H.d.* is a typical Central American endemic (McCarthy et al., 1998) seemingly absent from the state of

Yucatán, Mexico, *H.g.* is endemic to the Yucatán Peninsula, and its southern range extends no further than N Belize and N Guatemala (Reid, 1997). Nevertheless, *H.d.* has been reported to the west of Chetumal (Jones et al., 1974), Quintana Roo, Mexico, and is therefore likely to be found in sympatry with *H.g.* in the south of the Yucatán Peninsula and in northern Belize.

On the basis of external characters, *H.g.* and *H.d.* are easily distinguishable when closely examined in hand. Indeed, *H.g.* differs from all other species of the genus *Heteromys* by the presence of hair on the posterior portion of the sole of the hind foot (Schmidt et al., 1989). Also, *H.g.* is distinguished from *H.d.* by a discontinuous pelage coloration between the outer surfaces of front legs and dorsum (Reid, 1997), a relatively well haired tail with a conspicuous terminal tuft, and by averaging smaller in most external and cranial measurements. This is confirmed by the external and cranial measurements of VB017, VB021, and VB022 (see tables 6 and 7) that are falling perfectly within the ranges given for *H.g.* in Schmidt et al. (1989), and Jones et al. (1974), but are below the ranges for *H.d.* in Rogers and Schmidly (1982), and Goodwin (1969).

Very few skull characters are known to separate *H.g.* from *H.d.*. *H.g.* was only reported to have relatively large auditory bullae to compare with *H.d.* (Schmidt et al., 1989).

H.g. is monotypic; and whereas it was formerly included within the *H.desmarestianus* species group of the subgenus *Heteromys*, it exhibits several unique morphological and chromosomal features, and biochemical characters that distinguish it from other heteromyines (Rogers, 1990).

All specimens of *H.g.* were caught on the ground (see table 5), and ran away on the ground, sometimes directly into a near cavity, when released. Besides, no morphological adaptations towards arboreality were observed from sampled specimens, thus suggesting that *H.g.* is strongly terrestrial. Furthermore, the fact that *H.g.* was captured in all sites except n°1 (see table 2), and in all forest habitats (see table 3), leads to infer that it is ubiquitous in the forests of Shipstern Nature Reserve, and probably absent from exposed areas covered by vegetation types 6 and 7. The broken seeds and shells (snails) found in some traps with *H.g.* (see paragraph 3.1) were certainly the remnant of what was carried in its two cheek pouches at the time of capture (Reid, 1997).

Otonyctomys hattii

O.hatti is easily confused with *Nyctomys sumichrasti*. However, *N.s.* is a typical Central American endemic (McCarthy et al., 1998) seemingly absent from the Yucatán Peninsula, Mexico, apart from southern Belize (Jones et al., 1974). Whereas *O.h.* is endemic to the Yucatán Peninsula, and its southern range extends no further than N Belize and N Guatemala (Reid, 1997; Peterson, 1966). Consequently, although juxtaposed, their respective ranges are not overlapping, and they have never been reported as sympatric as yet.

On the basis of external characters, *O.h.* and *N.s.* are hardly distinguishable, except that *N.s.* is larger (Reid, 1997). However, the single specimen captured in this study (VB182) is assigned to the age class II (Genoways and Jones, 1972), and is probably too young (subadult) to be distinguished with certainty. The external and cranial measurements of VB182 (see tables 6 and 7) are therefore not comparable with the ranges given for *O.h.* in Jones et al. (1974), Peterson (1966), and Lee et al. (1965), and for *N.s.* in Genoways and Jones (1972), and Goodwin (1969).

Very few skull characters are known to separate *O.h.* from *N.s.*. However, the skull of *O.h.* is easily characterized by its greatly enlarged auditory bullae, which are more than twice as large as those of *N.s.* (Peterson, 1965). VB182 is clearly distinguished from *N.s.* by this character (see fig. 17).

O.h. is monotypic, same as the genus *Otonyctomys*.

Although serious conclusions on habitat and habits cannot be drawn from a single capture, the hindfeet with moderately swivelling ankle joints, and the remarkable agility to climb on all surfaces of the trap observed in VB182 (see paragraph 3.1) suggest that it is scansorial. Furthermore, the habitat description in Reid (1997) leads to infer that, although rare, *O.h.* is probably ubiquitous in the forests of Shipstern Nature Reserve.

Ototylomys phyllotis

In the field, *O.phyllotis* could be confused with *Tylomys nudicaudus*. Also, both species are typical Central American endemics (McCarthy et al., 1998), *O.p.* being ubiquitous in the Yucatán Peninsula, whereas *T.n.* is seemingly absent from the states of Campeche, Yucatán, and Quintana Roo, Mexico (Reid, 1997; Jones et al., 1974). *O.p.* and *T.n.* are therefore likely to be sympatric throughout Belize.

On the basis of external characters, *O.p.* and *T.n.* are easily distinguishable when closely examined in hand. Indeed, *O.p.* is characterized by a conspicuous patch of white fur at the ear basis (see paragraph 3.1). Also, if both species have a shiny, naked-looking, and broadly scaled tail, its distal half is white or yellow pigmented in *T.n.* (Lawlor, 1982). Beside, *O.p.* averages smaller in most external and cranial measurements. External and cranial measurements of VB001, VB002, VB004, VB005, VB063, VB105, VB121, and VB128 (see tables 6 and 7), however, are rather at the bottom, or even below, the ranges given for *O.p.* in Lawlor (1982). Nevertheless, the same author (1969) reported that *O.p.* is characterized by considerable local and geographic variation in size and pelage coloration. Indeed, it varies gradually from small and dusky brown in the lowlands of the Yucatán Peninsula, to large and dark greyish-brown in Costa Rica, and in the highlands of Chiapas and Guatemala.

Few skull characters are distinctly separating *O.p.* from *T.n.*. *O.p.* was reported to have larger, more inflated, and without anterior protuberances auditory bullae, a narrower and more elongate rostrum, deep zygomatic notches, and a dentary with a reduced coronoid process (Lawlor, 1982).

Referring to the observations given in Lawlor (1969), the examined specimens are probably belonging to the subspecies *O.p.phyllotis* described by Merriam (1901, in Lawlor, 1982) in Tunkás, Yucatán, Mexico. The genus *Ototylomys* is otherwise monotypic.

Specimens of *O.p.* were caught at all levels from the ground to a height exceeding three meters (see table 5), and over a distance exceeding 200 ft (60m). Also, when released, most of them ran away on the ground, sometimes directly into a near cavity, whereas a fraction of them climbed on the surrounding vegetation before returning to the ground (see paragraph 3.1). Such observations were also recorded by Lackey (1989), and suggest that *O.p.* is terrestrial—numerous dens were observed in the ground—but also very common in the vegetation composing the forest understory. Beside, several adult specimens were commonly caught at the same trap station, or even in the same trap, at a few days interval, or the same night, thus suggesting that territoriality behavior is probably little developed in *O.p.*; Lackey (1989), however, suggested that territories were established between the ages of four and seven weeks. Furthermore, the fact that *O.p.* was captured in all sites (see table 2), and in all forest habitats (see table 3), leads to infer that it is ubiquitous in the forests of Shipstern Nature Reserve, and probably absent from exposed areas covered by vegetation type 7. Regarding the percentage of total captures recorded for *O.p.* (see table 2), and the frequent observations of predators around the traps, the big-eared climbing rat is certainly important in the diets of many sympatric vertebrate carnivores in SNR.

Peromyscus yucatanicus

P.yucatanicus is easily confused with *P.mexicanus*. Nevertheless, *P.m.* is a typical Central American endemic seemingly absent from the Yucatán Peninsula, Mexico, apart from southern Belize (McCarthy et al., 1998). Whereas *P.y.* is endemic to the Yucatán Peninsula, and its present southern range extends no further than in the southern part of the states of Campeche and Quintana Roo, Mexico (Reid, 1997). Consequently, their respective ranges are not overlapping, and *P.y.* is considered as allopatric from *P.m.* (Young and Jones, 1983). However, Huckaby (1980) reported that the southern limits of the range of *P.y.* are not clearly known, which is confirmed by the present study. Indeed, the presence of *P.y.* in Shipstern Nature Reserve constitutes a first mention for Belize (McCarthy et al., 1998), and suggests that its range is extending more southerly to the limit agreed at present.

P.y. could also be confused with *P.leucopus*. But, the distribution of *P.l.* is scattered, and apart from its northern range extending from the state of Oaxaca, Mexico, to Canada, it is found only in the north-western part of the Yucatán Peninsula (Lackey et al., 1985); *P.y.* is therefore absent from the state of Quintana Roo, and unlikely to be sympatric with *P.l.* in northern Belize.

On the basis of external characters, *P.y.* and *P.m.* are hardly distinguishable; *P.y.* differs in being smaller, both externally and cranially (Young and Jones, 1983). This is confirmed by the external and cranial measurements of VB225 (see tables 6 and 7) that are falling perfectly within the ranges given for *P.y.* in Lawlor (1965), Huckaby (1980), and Lackey (1976), but are below the ranges for *P.m.* in Huckaby (1980), and Goodwin (1969).

Juvenile *P.y.* can be confused with adult *P.l.*. However, *P.l.* has a proportionally shorter tail and smaller ears (Reid, 1997), and adult *P.y.* are otherwise larger in most dimensions, without pectoral mammae (Young and Jones, 1983). Here also, this is confirmed by the external and cranial measurements of VB225 that are rather at the top, or even above, the ranges for *P.l.* in Lackey et al. (1985), and Jones et al. (1974).

These three species can be distinguished by skull characters. Indeed, whereas VB225 differs from *P.l.* by having moderately developed and slightly beaded supraorbital ridges (Young and Jones, 1983), it is best distinguished from *P.m.* by the accessory ridges of its upper and lower molars that are well-developed and fused with the labial styles (Lawlor, 1965; Hooper, 1957). Referring to the observations given in Lawlor (1965), and Huckaby (1980), VB225 can be considered, either as monotypic, or as belonging to the subspecies *P.y.badius* described by Osgood (1904, in Young and Jones, 1983) in Apazote, Campeche, Mexico.

Although serious conclusions on habitat and habits cannot be drawn from two isolate captures, the fact that VB089 and VB225 were captured on the ground and at a height of 2 ft respectively (see table 5), and that little morphological adaptations towards arboreality were observed, suggest that it is mainly terrestrial, with a moderate ability to climb on the low vegetation composing the understory. Furthermore, the habitat description in Reid (1997) leads to infer that *P.y.* is probably ubiquitous in the forests of Shipstern Nature Reserve, although it was only recorded from the Shipstern area (see fig. 1).

Sigmodon hispidus

The relationships among the seven valid species of the genus *Sigmodon* that are currently recognized in North and Central America have long been the subject of controversy, and the genetic integrity of *S.hispidus* cannot be assumed as yet (Elder and Lee, 1985; Voss, 1992; Peppers and Bradley, 2000). Indeed, *hispidus* as currently recognized may prove to consist of

several morphologically cryptic but genetically distinct geographical units, and particularly in Central American populations that have virtually received no revisionary attention (Voss, 1992).

Traditionally, the genus *Sigmodon* is divided into two controversial (Elder and Lee, 1985) taxonomic groups: the *S.hispidus* and the *S.fulviventer* groups. Apart from the members of the *S.fulviventer* group from which it differs by having a sparsely haired tail, with large scales (0.75mm wide rather than 0.5mm), *S.hispidus* could be confused with the two other species of the *S.hispidus* group: *S.arizonae* and *S.mascotensis*. But, whereas *S.h.* is ubiquitous in Central America—its range extends from Northern Venezuela to Central and South-East United States, but it is absent from the west coast of Mexico—*S.a.* and *S.m.* are confined to the northern and southern part respectively of the Mexican west coast (Zimmerman, 1970). As a result, the three species are not expected to be sympatric in Belize.

S.h., *S.a.*, and *S.m.* are remarkably uniform in external appearance, with virtually no interspecific variation. *S.h.* is, nevertheless, distinguishable from *S.a.*, and *S.m.* by having a generally shorter hind foot—less than 34 mm, usually averaging 32 mm (Cameron and Spencer, 1981; Zimmerman, 1970). With a mean of 26.5 mm, the adult specimens (Voss, 1992) examined during the present study are therefore clearly below the average. Similarly, the external and cranial measurements of VB146, VB147, and VB148 (see tables 6 and 7) are rather at the bottom, or below, the ranges given for *S.h.* in Cameron and Spencer (1981), Voss (1992), and Goodwin (1969). However, they better correspond to the measurements given in Jones et al. (1974) for specimens that were caught to the west of Chetumal, Quintana Roo, Mexico. The latter observations lead to formulate the hypothesis of a morphologically smaller *S.h.* population in the south of Quintana Roo and northern Belize, and further underlines the need for a complete revision of the genus in the Yucatán Peninsula.

S.h. can be separated from *S.a.* and *S.m.* by several skull characters. Indeed, the combination of a distance between the temporal and occipital ridges inferior to 3.6 mm (it averages 3.1 mm), a foramen ovale with a diameter inferior to $\frac{3}{4}$ the diameter of M3, and a well developed crest on the posterior part of the bony palate, observed in VB146, VB147, and VB148 (see paragraph 3.1) distinguish them clearly from *S.a.* and *S.m.* (Zimmerman, 1970). Also, *S.h.* differs from *S.a.* by having a narrower ventral surface of the presphenoid, a blunt and rather broad spinous anterodorsal process of the zygomatic plate, and an angular supraoccipital crest in posterior view (Severinghaus and Hoffmeister, 1978).

Referring to the observations given in Jones et al. (1974), and Cameron and Spencer (1981), the specimens sampled can be considered as belonging to the subspecies *S.h.microdon* described by Bailey (1902, in Cameron and Spencer, 1981) in Puerto Morelox, Quintana Roo, Mexico.

S.h. is a habitat specialist, generally found wherever grass is a significant component of the local vegetation (Voss, 1992). This is confirmed by the fact that *S.h.* was only captured in vegetation types 6 and 7 of the site n°6 (see tables 2 and 3); it is therefore expected to be ubiquitous in such habitats, but absent from the forests of Shipstern Nature Reserve. Furthermore, all specimens of *S.h.* were caught on the ground (see table 5), and ran away on the ground when released. Besides, no morphological adaptations towards arboreality were observed from sampled specimens, thus suggesting that *S.h.* is strongly terrestrial.

4.2. Ecto- and endoparasites :

The ecto- and endoparasites collected in Shipstern Nature Reserve were sketchily analysed, and deeper analyses to be carried out within the framework of a subsequent study will be necessary. Indeed, the priority was given to the classes Trematoda and Cestoidea (see paragraph 2.6), whereas no attempts were made to identify to the species the specimens belonging to the phylum Nemata. Similarly, the analysis of ectoparasites was limited to a count and an identification to the order, beside various field observations (see paragraph 3.2).

Very few ectoparasites of the order Siphonaptera were collected (see table 9); they were only present in low numbers on two host species, *O.phyllotis* and *P.yucatanicus*. Inversely, specimens of the suborder Metastigmata were very numerous, at least on some host species—no ectoparasites were found on *M.mexicana* and *O.hatti*. Although a more extensive sampling would be needed to draw any serious conclusion, these results suggest that ticks are fairly common in Shipstern Nature Reserve, and of primary concern regarding the small mammal fauna.

Other forms of parasitism affecting marsupials and myomorph rodents were observed in SNR. A case of pentastomiosis was recorded from *M.mexicana* (VB054) in which six pentastomid larvae were found (see paragraph 3.2). Adult pentastomids are usually found parasitic in the respiratory tract and lungs of vertebrates, but the larvae are found in the viscera (liver and mesenteric nodes) of the intermediate host, which is commonly a mammal or another vertebrate (Cheng, 1986; Grassé et al., 1949). Therefore, VB054 was certainly affected as an intermediate host, and the larvae found in its peritoneal cavity or encysted in the liver were probably in place for completing their life cycle in the final host—presumably a predator of *M.mexicana*.

In the vicinity of SNR, several cases of cutaneous myiasis were observed on domestic animals, and even on humans, but only one case was recorded from small mammals, with *O.phyllotis* (VB103). This specimen was parasitized on the rump by a black larvae, apparently covered with small but numerous spines, and coiled into a crater-like pouch—probably a cuterebrid-like third-stage larvae (Schizophora group, family Cuterebridae). Indeed, cuterebrids, commonly called robust botflies or warble flies, are primary invaders known to form cystlike pockets in the subdermal zone that communicate with the exterior via a pore (Cheng, 1986). Furthermore, some members of this family are also known to occur in the Neotropics, and to be parasitic on rodents.

Although not a case of true parasitism, two males of the species *Epichernes navarroi* were recorded from the specimen VB160 (*H.gaumeri*). Such pseudoscorpions were also observed hanging motionless on the antennae of a much larger insect (order Coleoptera), being thus carried by their host without any apparent interaction. This phenomenon is probably a case of phoresis, in which the host provides involuntary transportation for the phoronts, whereas the life process and welfare of both partners are not obligatorily dependent on what is essentially an accidental relationship (Cheng, 1986)—some pseudoscorpions are believed to end up in a phoretic state during their quest for nutriment (Grassé et al., 1949). Therefore, VB160 was certainly not « parasitized » by these two pseudoscorpions, but rather an accidental host temporarily carrying them.

Class Secernentea

Family **Ornithostrongylidae**

Subfamily Ornithostrongylinae

With the exception of *D.virginiana* (VB062), and *H.gaumeri* (VB018, and VB021), endoparasites were mostly found in the small intestine; and apart from *S.hispidus* (VB146, VB147, and VB148), they were mostly belonging to the superfamily Trichostrongyloidea of the phylum Nemata (see tables 8 and 9)—this phylum is being designated the Nemata by referring to Cheng (1986). This superfamily consists of monoxenous parasites with reduced buccal capsules, which inhabit the stomach or small intestine of all classes of terrestrial vertebrates (Durette-Desset, *in* Anderson and Chabaud, 1983). Also, they constitute the richest superfamily of parasitic nematodes in numbers of genera and species. Their taxonomy is therefore complex and difficult, not only because of the large number of species involved, but also because the worms are small and superficially similar in form. Among others, the caudal bursa and the synlophe have essential diagnostic characters, the structure of the latter being appreciated only by studying a transverse section generally taken through the midbody region.

As a first approach towards the taxonomy of the overall collection of nematodes, this was done for two specimens male and female collected from the small intestine of *H.gaumeri* (VB018). They were identified as closely related to the genus *Vexillata* (see fig. 27) on the basis of the key presented in Anderson and Chabaud (1983), and the morphological descriptions given in Durette-Desset (1971 and 1972). The combination of a dorsoventrally symmetrical synlophe, a well developed carene supported by hypertrophied dorsal and ventral left lateral cuticular ridges, and six dorsal, five ventral cuticular ridges markedly unequal in size and with cuticular supports, was considered as characteristic. However, it remains to be confirmed by the analysis of other characters—among others, the structure of the ovejector (monodelphic or didelphic) separates the genus *Vexillata* from the other members of the subfamily Ornithostrongylinae (Durette-Desset, *in* Anderson and Chabaud, 1983).

Class Trematoda

Apart from five immature specimens presumably belonging to two non-identified species, three genera and one species of trematodes were found parasitic in the small mammal intestine (see paragraph 3.2). All of them are digenetic trematodes, or digeneans, comprising the largest group of monozoic platyhelminths, with a number of known species well over 4000 (Cheng, 1986). Within their hosts, these parasites can also be found in the gallbladder, urinary bladder, blood, oesophagus, and practically every other major organ; based exclusively on the analysis of the intestine, the present list is therefore unlikely to be exhaustive.

Family **Rhopaliasidae**

Four specimens of the genus *Rhopalias* (see fig. 24) were found in the small intestine of *D.virginiana* (VB062). This identification is primarily based on the key presented in Skrjabin et al. (1964), and on the family and generic diagnoses given in Yamaguti (1971). The combination of an elongate and spinose body, and a ventrally excavated forebody with two symmetrical and retractile armed proboscides, was considered as diagnostic among other

characters. Furthermore, this genus is commonly described as parasitic in the intestine of marsupials, occasionally in other animals, and the type species—*R.coronatus* (Rudolphi, 1819)—was reported from *D.virginiana* (Yamaguti, 1971). However, an identification to the species requires a closer analysis of the proboscis structure (Skrjabin et al., 1964), and further comparisons with the available literature.

Family **Brachylaemidae**

Subfamily Scaphiostominae

Three specimens of the species *Scaphiostomum pancreaticum* (see fig. 25) were found in the small intestine of *H.gaumeri* (VB018), and one in the pancreas of *O.phyllotis* (VB004). This identification is primarily based on the key presented in Skrjabin et al. (1964), and on the family and generic diagnoses given in Yamaguti (1971). The combination of a long and filiform body, a large and terminal oral sucker directly followed by a globular pharynx and a smaller acetabulum, and a pair of testes at the posterior extremity with an intertesticular ovary and a pretesticular genital pore, was considered as diagnostic among other characters. Also, members of the subfamily Scaphiostominae are intestinal parasites of birds and mammals—in the genus *Scaphiostomum*, only *S.pancreaticum* is presently known as parasitic of mammals (Yamaguti, 1971). This identification remains to be confirmed, however, since no morphological characters diagnostic to the species were found in the referred literature.

Subfamily Brachylaeminae

Two immature specimens closely related to the genus *Brachylaemus* (see fig. 26) were found in the small intestine of *D.virginiana* (VB062). This identification is primarily based on the keys presented in Skrjabin et al. (1964), and in Yamaguti (1971). The combination of a tongue-shaped body, a genital pore anterolateral to the anterior testis, an intertesticular ovary, a rather straight intestine, and a uterus extending into the forebody, was considered as diagnostic among other characters. Furthermore, this genus is commonly described as parasitic in the small intestine or the caecum of birds and mammals, and at least one species—*B.opisthotrias* (Lutz, 1895)—was reported from *D.virginiana* (Yamaguti, 1971). The presence of such digenetic trematodes in the small intestine of VB062 is therefore plausible, but is to be confirmed, whereas further identification to the species based on immature specimens may prove to be difficult.

Family **Nudacotylidae**

Hundreds of specimens of the genus *Nudacotyle* (see fig. 28) were found in the small intestine of *S.hispidus* (VB146, VB147, and VB148). This identification is primarily based on the keys presented in Skrjabin et al. (1964), and in Yamaguti (1971), and on the morphological description given in Zdzitowiecki (1980). The combination of a small, oval, flattened, convex dorsally, and concave ventrally body, an ovary located between and posterior to the testes, a large cirrus pouch lying obliquely across the median portion of the body, an intestine terminating in the testicular zone, and small eggs with polar filament at each pole, was considered as diagnostic among other characters. Members of this genus are, in turn, intestinal parasites of mammals, and in particular in the Neotropics (Yamaguti, 1971). However, the male and female genital pores could not be observed as clearly separate, a character

distinguishing the present genus from the genus *Neocotyle*; therefore, here again, more comparative work with the available literature will be necessary to confirm this first identification.

Class Cestoidea

Family Davaineidae

Subfamily Davaineinae

Apart from a collection of fragments found without scolex in the caecum of *H.gaumeri* (VB021)—being improperly preserved, they remained non-identified—only a single species of cestode, *Raillietina sigmodontis*, was recorded among the seven small mammal species sampled. It belongs to the Eucestoda, or true tapeworms, that is a large and highly specialized group of the Platyhelminthes. All adult members of this subclass are endoparasitic in the alimentary tract and associated ducts of various vertebrates (Cheng, 1986).

Several specimens of the species *R.sigmodontis* (see fig. 29) were found in the small intestine of *S.hispidus* (VB148), whereas only gravid proglottids were collected from the caecum and rectum (-colon). Besides, single specimens of this same species were recorded from the small intestine and caecum of *H.gaumeri* (VB018), and the small intestine of *O.phyllotis* (VB002). *R.sigmodontis* was identified by referring to the keys given in Khalil et al. (1994), and to the measurements and morphological descriptions given in Smith (1954). The combination of a small cirrus-sac, a single set of reproductive organs, an unilateral genital pore, a median ovary, a rostellum with two circular rows of hammer-shaped hooks, and suckers armed with numerous small spines, was considered as diagnostic among other characters. Furthermore, the genus *Raillietina* is parasitic of birds and mammals, and cosmopolitan (Khalil et al., 1994); and *R.sigmodontis* was recorded from the small intestine of *S.hispidus* in Oklahoma, United States (Smith, 1954). However, measurements presented in paragraph 3.2 do not exactly correspond to those of Smith, and diagnostic characters such as the number of rostellar hooks, the number of testes per mature segment, the number of egg capsules per gravid segment, and the number of eggs per capsule, differ markedly. Therefore, if the genus is clearly *Raillietina*, the species name remains to be confirmed.

Chapter 5

Conclusion :

The results of this small mammal inventory give substance to the impression of a diverse rodent community that is clearly affiliated to the partly endemic fauna of the Yucatán Peninsula, Mexico. The presence of species such as *P.yucatanicus* in Shipstern Nature Reserve gives the area a certain degree of uniqueness in Belize, which emphasizes the important role that SNR plays in terms of wildlife and habitat conservation by representing one of the very few protected areas in northern Belize.

Very few mammalian surveys were completed in the north of Belize—most collecting has been concentrated in a few historically accessible areas in the Maya Mountains, and further north in the Yucatán Peninsula. This sampling gap means that the information on diversity is certainly incomplete, and in turn that the geographic distribution of at least some small mammal species remains uncertain in this region of the Yucatán Peninsula. There is therefore a clear need towards an aggressive programme of short-term collecting expeditions in northern Belize, since complete (or even nearly complete) species lists are unavailable. Indeed, a long-term inventory project would inevitably be time-consuming and expensive—although indispensable for understanding the ecological organization of sympatric communities, for documenting biogeographic gradients, or as a standard for calibrating rapid assessment protocols—now bulldozers and chain saws work faster than field biologists. Consequently, short-term inventories have the advantage of rapidly providing concrete and crucial diversity data—including fresh material to museum collections, the bedrock for the urgent task of revising species, illustrating characters for field identification, documenting habitat associations, and mapping geographic distributions—before habitat destruction makes moot the absence of relevant information for ecologists, biogeographers, and land-use planners.

Obtaining parasites from mammals that are collected during inventories is also time-consuming, and such collections have rarely been made. Parasites and other symbionts are important components of the biology of the host, however, and must be sampled for a complete picture of its ecology and other aspects of its life history. Of course, studies of the systematics and ecological characteristics of hosts and parasites require proper identification of both groups. Now, as far as the ecto- and endoparasites collected in SNR are concerned, this could not be achieved within the framework of this study. Therefore, substantial research still remains to be carried out in this area.

The results of this study also demonstrate the important role that *O.phyllotis* plays in the community structure of small mammals in SNR. That a single species of rodent represents such a high percentage of the total capture, was not recorded in any of the studies cited in the text. Thus, the trapping methods used during this inventory may prove to be particularly effective in trapping *O.phyllotis*, but this factor alone is surely not preponderant. Consequently, further study focused on the ecological requirements of this species will be of great interest with a view to characterizing the overall ecosystem prevailing in SNR. On the other hand, much research at the community level will be needed to ascertain the role of *O.phyllotis*, and other small mammals, in their maintenance of predators at higher trophic levels. Finally, by referring to the very short period in which the collecting took place, and the geographic expectations, the sympatric diversity concretely obtained in SNR is certainly underestimated. In this way, further sampling will be needed to assess the presence of other small mammal species in the reserve, and the present inventory is therefore regarded as a preliminary assessment.

Chapter 6

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Chapter 7

References :

7.1. Literature cited :

- Alonso-Mejía, A., and R.A.Medellín. 1992.
Marmosa mexicana. Amer. Soc. Mammalogists. Mammal. Sp. 421 : 1-4.
- Anderson, R.C., and A.G.Chabaud. 1983.
CIH keys to the nematode parasites of vertebrates. Com. Agr. Bur., U.K., Farnham Royal. 86pp.
- Animal Care and Use Committee. 1998.
Guidelines for the capture, handling, and care of mammals as approved by the American Society of Mammalogists. J. Mammal. 79(4) : 1416-1431.
- Bärtschi, D. 1998.
Chiroptères de la Réserve Naturelle de Shipstern et de ses environs : inventaire et biologie. Master degree, Univ. Neuchâtel, Switzerland. Unpublished manuscript. 101pp.
- Bijleveld, C.F.A. 1990.
Freshwater fishes of the Shipstern Nature Reserve. ITCF Publ., Marin/NE, Switzerland. 136pp.
- Bijleveld, C.F.A. 1998.
The vegetation of Shipstern Nature Reserve : a structural and floristic approach. Master degree, Univ. Bern and Neuchâtel, Switzerland. ITCF Publ. 136pp.
- Boomsma, T. 1993.
Dragonflies and damselflies of the Shipstern Nature Reserve. Occ. Pap. Belize Nat. Hist. Soc. 2 (6) : 54-58.
- Brown, J.C. 1971.
The description of mammals. 1. The external characters of the head. Mammal Rev. 1 : 151-168.
- Bullock, S.H., E.Medina, and H.A.Mooney. 1995.
Seasonally dry tropical forests. Cambridge Univ. Press, Cambridge, UK. 450pp.
- Burton, D.W., J.W.Bickham, H.H.Genoways, and T.J.McCarthy. 1987.
Karyotypic analysis of five rodents and a marsupial from Belize, Central America. Ann. Carnegie Mus. 56 : 103-112.
- Cameron, G.N., and S.R.Spencer. 1981.
Sigmodon hispidus. Amer. Soc. Mammalogists. Mammal. Sp. 158 : 1-9.
- Catzeflis, F., C.Richard-Hansen, C.Fournier-Chambrillon, A.Lavergne, and J.-C.Vié. 1997.
Biométrie, reproduction et sympatrie chez *Didelphis marsupialis* et *D.albiventris* en Guyane française (Didelphidae : Marsupialia). Mammalia 61(2) : 231-243.

- Catzefflis, F. 1991.
Animal tissue collections for molecular genetics and systematics. *Trends Ecol. Evol.* 6 : 168pp.
- Ceballos, G. 1995.
Vertebrate diversity, ecology, and conservation in neotropical dry forests. 8 : 195-220. *In* : S.H.Bullock, E.Medina, and H.A.Mooney (eds). 1995. *Seasonally dry tropical forests*. Cambridge Univ. Press, Cambridge, UK. 450pp.
- Cheng, T.C. 1986.
General parasitology. Acad. Press Coll., 2nd ed. 827pp.
- Da Fonseca, G.A.B., and M.C.M.Kierulff. 1989.
Biology and natural history of Brazilian Atlantic forest small mammal. *Bull. Florida State Mus., Biol. Sci.* 34 (3) : 99-152.
- De Chambrier, A. 2001.
A new tapeworm from the Amazon, *Amazotaenia yvettae* gen. n., sp. n., (Eucestoda : Proteocephalidea) from the siluriform fishes *Brachyplatystoma filamentosum* and *B.vaillanti* (Pimelodidae). *Rev. Suisse Zool.* 108 (2) : 1-14.
- Disney, R.H.L. 1968.
Observations on a zoonosis, leishmaniasis in British Honduras. *J. Appl. Ecol.* 5 : 1-59.
- Dieckman, L.E. 1973.
Mammals of Belize, a preliminary list. *BAS Bull.* 5 (1) : 1-3.
- Durette-Desset, M.-C. 1971.
Essai de classification des nématodes héligmosomes, corrélations avec la paléobiogéographie des hôtes. *Mém. Mus. Nati. Hist. Nat., nouv. série, France, Paris. Série A, tome 49.* 126pp.
- Durette-Desset, M.-C. 1972.
Compléments morphologiques à l'étude de quelques nématodes héligmosomes, parasites de rongeurs américains. *Ann. Paras. Hum. Comp. Masson et Cie éd.* 47 (2) : 243-249.
- Durette-Desset, M.-C., and A.-G.Chabaud. 1993.
Nomenclature des Strongylida au-dessus du groupe-famille. *Ann. Paras. Hum. Comp.* 68 (2) : 111-112.
- Eisenberg, J.F., and R.W.Thorington. 1973.
A preliminary analysis of a Neotropical mammal fauna. *Biotropica* 5 (3) : 150-161.
- Elder, F.F.B., and M.R.Lee. 1985.
The chromosomes of *Sigmodon ochrognathus* and *S.fulviventor* suggest a realignment of *Sigmodon* species group. *J. Mamm.* 66 (3) : 511-518.
- Emmons, L.H. 1995.
Mammals of rain forest canopies. *In* : M.D.Lowman and N.M.Nadkarni (eds.). *Forest canopies*. Acad. Press, San Diego, California 10 : 199-223.
- Emmons, L.H., and F.Feer. 1997.
Neotropical rainforest mammals : a field guide. Univ. Chicago Press, Chicago and London, 2nd ed. 307pp.

- Fleming, T. 1975.
The role of small mammals in tropical ecosystems : 269-298. *In* : F.B.Golley, K.Petrusewicz, and L.L.Ryszkowski (eds). *Small mammals : their productivity and population dynamics*. Cambridge Univ. Press, Cambridge, UK.
- Fowler, J., L.Cohen, and P.Jarvis. 1998.
Practical statistics for field biology. John Wiley and Sons, 2nd ed. 259pp.
- Gardner, A.L. 1973.
The systematics of the genus *Didelphis* (Marsupialia : Didelphidae) in North and Middle America. *Spec. Publ., Mus., Texas Tech Univ.* 4 : 81pp.
- Genoways, H.H., and J.K.Jones. 1972.
Variation and ecology in a local population of the Vesper Mouse (*Nyctomys sumichrasti*). *Occas. Papers Mus., Texas Tech Univ.* 3 : 1-21.
- Gentry, A.H. 1995.
Diversity and floristic composition of neotropical dry forests. 7 : 146-194. *In* : S.H.Bullock, E.Medina, and H.A.Mooney (eds). 1995. *Seasonally dry tropical forests*. Cambridge Univ. Press, Cambridge, UK. 450pp.
- Goodwin, G.G. 1969.
Mammals from the state of Oaxaca, Mexico, in the American Museum of Natural History. *Bull. Am. Mus. Nat. Hist.* 141 (1) : 266pp.
- Grassé, P.-P., M.André, L.Berland, L.Cuénot, C.Dawydoff, L.Fage, J.Millot, L.Störmer, M.Vachon, A.Vandel, and G.Waterlot. 1949.
Traité de Zoologie, anatomie, systématique, biologie. Onychophores, Tardigrades, Arthropodes, Trilobitomorpes, Chélicérates. Masson et Cie éd. Tome VI. 979pp.
- Grassé, P.-P., J.-G.Baer, P.De Beauchamp, M.Caullery, L.Euzet, M.Gontcharoff, and C.Joyeux. 1961.
Traité de Zoologie, anatomie, systématique, biologie. Plathelminthes, Mésozoaires, Acanthocéphales, Némertiens. Masson et Cie éd. Tome IV (1). 944pp.
- Grassé, P.-P., A.Chabaud, P.De Beauchamp, A.Dorier, M.Ritter, J.Roger, E.Roman, and J.Théodoridès. 1965.
Traité de Zoologie, anatomie, systématique, biologie. Némathelminthes (Nématodes, Gordiacés), Rotifères, Gastrotriches, Kinorhynques. Masson et Cie éd. Tome IV (3). 761pp.
- Hall, E.R., and W.W.Dalquest. 1963.
The mammals of Veracruz. *Univ. Kansas Publ., Mus. Nat. Hist.* 14 (14) : 165-362.
- Hartshorn, G.S., et al. (17 authors). 1984.
Belize, country environmental profile, a field study. Robert Nicolait and Assoc. Ltd., Belize City, Belize.
- Hershkovitz, P. 1951.
Mammals from British Honduras, Mexico, Jamaica and Haiti. *Fieldiana, Zool., Nat. Hist. Mus. Chicago* 31(47) : 547-569.
- Hooper, E.T. 1957.
Dental patterns in Mice of the genus *Peromyscus*. *Miscell. Publ., Mus. Zool., Univ. Michigan* 99 : 1-59.

- Huckaby, D.G. 1980.
Species limits in the *Peromyscus mexicanus* group (Mammalia : Rodentia : Muroidea).
Contrib. Sci. Nat. Hist. Mus., Los Angeles County 326 : 1-24.
- Jones, J.K., Jr., H.H.Genoways, and T.E.Lawlor. 1974.
Annotated checklist of mammals of the Yucatan peninsula, Mexico. II. Rodentia. Occas.
Papers Mus., Texas Tech Univ. 22 : 1-24.
- Khalil, L.F., A.Jones, and R.A.Bray. 1994.
Keys to the cestode parasites of vertebrates. Centre Agr. Bioscience Int., Int. Inst. Paras, U.K.,
Wallingford. 751pp.
- Kimble, D.P. 1997.
Didelphid behavior. Neurosci. Biobehav. Rev. 21(3) : 361-369.
- King, R.B., I.C.Baillie, T.M.B.Abell, J.R.Dunsmore, D.A.Gray, J.H.Pratt,H.R.Versey,
A.C.S.Wright, and S.A.Zisman. 1992.
Land resource assessment of northern Belize. Nat. Res. Inst. Bull. 43 : 513pp.
- Kirkpatrick, R.D., and A.M.Cartwright. 1975.
List of mammals known to occur in Belize. Biotropica 7 : 136-140.
- Lackey, J.A. 1974.
Reproduction, growth, and development in the Yucatan Deer Mouse, *Peromyscus yucatanicus*. J. Mammal. 57 (4) : 638-655.
- Lackey, J.A. 1989.
Notes on the biology of the Big-eared Climbing Rat, *Otodylomys phyllotis*, on the Yucatan
Peninsula, Mexico. Texas J. Sci. 41 (3) : 253-264.
- Lackey, J.A., D.G.Huckaby, and B.G.Ormiston. 1985.
Peromyscus leucopus. Amer. Soc. Mammalogists. Mammal. Sp. 247 : 1-10.
- Lawlor, T.E. 1965.
The Yucatan Deer Mouse, *Peromyscus yucatanicus*. Univ. Kansas Publ. Mus. Nat. Hist. 16
(4) : 421-438.
- Lawlor, T.E. 1969.
A systematic study of the rodent genus *Otodylomys*. J. Mammal. 50 (1) : 28-42.
- Lawlor, T.E. 1982.
Otodylomys phyllotis. Amer. Soc. Mammalogists. Mammal. Sp. 181 : 1-3.
- Lee, M.R., L.L.Getz, J.N.Layne, W.Z.Lidicker Jr., R.S.Miller, and W.B.Quay. 1965.
Otonyctomys hattii in Guatemala. J. Mammal. 46 : 335-336.
- McCarthy, T.J., J.Lumb, E.Méndez, and L.Waight. 1998.
Mammals of Belize : a checklist. Belize Audubon Society, Producciones de la Hamaca,
Belize. 19pp.
- McManus, J.J. 1974.
Didelphis virginiana. Amer. Soc. Mammalogists. Mammal. Sp. 40 : 1-6.

- Meerman, J.C. 1993a.
Provisional annotated checklist of the flora of the Shipstern Nature Reserve. Occ. Pap. Belize Nat. Hist. Soc. 2 (2) : 8-36.
- Meerman, J.C. 1993b.
Miscellaneous invertebrates of the Shipstern Nature Reserve. Occ. Pap. Belize Nat. Hist. Soc. 2 (7) : 59-60.
- Meerman, J.C. 1993c.
Checklist of the reptiles and amphibians of the Shipstern Nature Reserve. Occ. Pap. Belize Nat. Hist. Soc. 2 (9) : 65-69.
- Meerman, J.C. 1993d.
Checklist of the birds of the Shipstern Nature Reserve. Occ. Pap. Belize Nat. Hist. Soc. 2 (10) : 70-82.
- Meerman, J.C. 1993e.
Mammals of the Shipstern Nature Reserve. Occ. Pap. Belize Nat. Hist. Soc. 2 (11) : 83-85.
- Meerman, J.C., and T.Boomsma. 1993a.
Biodiversity of the Shipstern Nature Reserve. Occ. Pap. Belize Nat. Hist. Soc. 2 (1) : 1-7.
- Meerman, J.C., and T.Boomsma. 1993b.
Checklist of the butterflies of the Shipstern Nature Reserve. Occ. Pap. Belize Nat. Hist. Soc. 2 (3) : 37-46.
- Miller, B.W., C.M.Miller, and H.B.Quigley. 1995.
Shipstern Nature Reserve : mammal survey. Wildlife Conservation Society, New York. 29pp.
- Murie, A. 1935.
Mammals from Guatemala and British Honduras. Misc. Publ. Mus. Zool. Univ. Michigan 26 : 1-31.
- Murphy, P.G., and A.E.Lugo. 1995.
Dry forests of Central America and the Caribbean. 2 : 9-34. In : S.H.Bullock, E.Medina, and H.A.Mooney (eds). 1995. Seasonally dry tropical forests. Cambridge Univ. Press, Cambridge, UK. 450pp.
- Musser, G.G., M.D.Carleton, E.M.Brothers, and A.L.Gardner. 1998.
Systematic studies of oryzomyine rodents (Muridae, Sigmodontinae) : diagnoses and distributions of species formerly assigned to *Oryzomys «capito»*. Bull. Am. Mus. Nat. Hist. 236 : 376pp.
- Nagorsen, D.W., and R.L.Peterson. 1980.
Mammal collector's manual : a guide for collecting, documenting, and preparing mammal specimens for scientific research. Life Sci. Misc. Pub., Royal Ontario Mus. 79pp.
- Nowak, R.N. 1999.
Walker's mammals of the world. Johns Hopkins Univ. Press, Baltimore and London, 6th ed., vol.1 and 2. 1936pp.
- O'Connell, M.A. 1983.
Marmosa robinsoni. Amer. Soc. Mammalogists. Mammal. Sp. 203 : 1-6.

- Patton, J.L., M.N.F. Da Silva, and J.R. Malcolm. 2000.
Mammals of the Rio Juruá and the evolutionary and ecological diversification of Amazonia. *Bull. Am. Mus. Nat. Hist.* 244 : 306pp.
- Peppers, L.L., and R.D. Bradley. 2000.
Cryptic species in *Sigmodon hispidus* : evidence from DNA sequences. *J. Mammal.* 81 (2) : 332-343.
- Peterson, R.L. 1966.
Notes on the Yucatan Vesper Rat, *Otonyctomys hattii*, with a new record, the first from British Honduras. *Canad. J. Zool.* 44 : 281-284.
- Rabinowitz, A., and B.G. Nottingham. 1989.
Mammal species richness and relative abundance of small mammals in a subtropical wet forest of Central America. *Mammalia* 53(2) : 217-225.
- Reid, F.A. 1997.
A field guide to the mammals of Central America and Southeast Mexico. Oxford Univ. Press, New York. 334pp.
- Rogers, D.S. 1990.
Genic evolution, historical biogeography, and systematic relationships among Spiny Pocket Mice (subfamily Heteromyinae). *J. Mammal.* 71 (4) : 668-685.
- Rogers, D.S., and D.J. Schmidly. 1982.
Systematics of Spiny Pocket Mice (genus *Heteromys*) of the *desmarestianus* species group from Mexico and northern Central America. *J. Mammal.* 63 (3) : 375-386.
- Sayer, E.J. 2000.
The phenology of trees in a seasonally dry tropical forest in Belize, Central America, the effects of water availability. Master degree, Univ. Bern, Switzerland. Unpublished manuscript. 66pp.
- Schmidt, C.A., M.D. Engstrom, and H.H. Genoways. 1989.
Heteromys gaumeri. *Amer. Soc. Mammalogists. Mammal. Sp.* 345 : 1-4.
- Severinghaus, W.D., and D.F. Hoffmeister. 1978.
Qualitative cranial characters distinguishing *Sigmodon hispidus* and *Sigmodon arizonae*, and the distribution of these two species in northern Mexico. *J. Mamm.* 59 (4) : 868-870.
- Skrjabin, K.I., et al. 1964.
Keys to the trematodes of animals and man. Univ. Illinois Press, Urbana. 351pp.
- Smith, C.F. 1954.
Four new species of cestodes of rodents from the High Plains, Central and Southern Rockies, and notes on *Catenotaenia dendritica*. *J. Paras.* 40 : 245-256.
- Stafford, P.J., and J.R. Meyer. 2000.
A guide to the reptiles of Belize. *Nat. Hist. Mus., London, Academic Press.* 356pp.
- Stallings, J.R. 1989.
Small mammal inventories in an eastern Brazilian park. *Bull. Florida State Mus., Biol. Sci.* 34 (4) : 153-200.

- Timm, R.M., D.E.Wilson, B.L.Clauson, R.K.LaVal, and C.S.Vaughan. 1989.
Mammals of the La Selva-Braulio Carrillo Complex, Costa Rica. US Depart. Inter. Fish Wild.
Serv., North Amer. Fauna 75 : 162pp.
- Voss, R.S. 1988.
Systematics and ecology of ichthyomyine rodents (Muroidea) : patterns of morphological
evolution in a small adaptive radiation. Bull. Am. Mus. Nat. Hist. 188(2) : 260-493.
- Voss, R.S. 1992.
A revision of the South American species of *Sigmodon* (Mammalia : Muridae) with notes on
their natural history and biogeography. Am. Mus. Nat. Hist., New York, Novitates 3050 :
56pp.
- Voss, R.S., and L.H.Emmons. 1996.
Mammalian diversity in neotropical lowland rainforests : a preliminary assessment. Bull. Am.
Mus. Nat. Hist. 230 : 115pp.
- Walker, S.H. 1973.
Summary of climatic records for Belize. Land Res. Div., Surbiton, Surrey, UK, Suppl. 3. In :
G.S.Hartshorn et al. (17 authors). 1984. Belize, country environmental profile, a field study.
Robert Nicolait and Assoc. Ltd., Belize City, Belize.
- Wilson, D.E., F.R.Cole, J.D.Nichols, R.Rudran, and M.S.Foster. 1996.
Measuring and monitoring biological diversity : standard methods for mammals. Smithson.
Inst. Press, Washington and London. 409pp.
- Wilson, D.E., and D.M.Reeder. 1993.
Mammal species of the world : a taxonomic and geographic reference. Smithson. Inst. Press.,
Washington and London, 2nd ed. 1206pp.

7.2. Other references :

- August, P.V. 1983.
The role of habitat complexity and heterogeneity in structuring tropical mammal communities. *Ecology* 64 (6) : 1495-1507.
- Barnum, S.A., C.J.Manville, J.R.Tester, and W.J.Carmen. 1992.
Path selection by *Peromyscus leucopus* in the presence and absence of vegetative cover. *J. Mammal.* 73 (4) : 797-801.
- Begon, M., J.L.Harper, and C.R.Townsend. 1996.
Ecology : individuals, populations, and communities. Blackwell Science, 3rd ed. 1068pp.
- Burt, W.H., and R.P.Grossenheider. 1980.
A field guide to the mammals : North America and north of Mexico. Houghton Mifflin Company, Boston and New York, 3rd ed. 289pp.
- Cameron, G.N. 1995.
Temporal use of home range by the hispid cotton rat. *J. Mammal.* 76 (3) : 819-827.
- Catzefflis, F., and A.Lavergne. 1998.
Diversité génétique et diversité taxonomique chez les mammifères : deux apports pour la biologie de la conservation en Guyane française? *JATBA, Revue d'Ethnobiologie* 40 (1-2) : 447-464.
- Ellis, L.M., M.C.Molles, and C.S.Crawford. 1997.
Short-term effects of annual flooding on a population of *Peromyscus leucopus* in a Rio Grande riparian forest of Central New Mexico. *Am. Midl. Nat.* 138 (2) : 260-267.
- Fleck, D.W., and J.D.Harder. 1995.
Ecology of marsupials in two amazonian rain forests in northeastern Peru. *J. Mammal.* 76(3) : 809-818.
- Fleming, T. 1970.
Notes on the rodent faunas of two Panamanian forests. *J. Mamm.* 51 (3) : 473-490.
- Fleming, T. 1972.
Aspects of the population dynamics of three species of opossums in the Panama Canal zone. *J. Mamm.* 53 (3) : 619-623.
- Fleming, T. 1973.
The reproductive cycles of three species of opossums and other mammals in the Panama Canal zone. *J. Mamm.* 54 (2) : 439-455.
- Fleming, T. 1973.
The number of rodent species in two Costa Rican forests. *J. Mamm.* 54 (2) : 518-521.
- Flowerdew, J.R., and J.Gurnell. 1994.
Live trapping small mammals : a practical guide. *Mammal Soc.* 3 : 36pp.
- Helm III, J.D. 1975.
Reproductive biology of *Ototylomys phyllotis*. *J. Mamm.* 56 (3) : 575-590.

- Mares, M.A., and K.A.Ernest. 1995.
Population and community ecology of small mammals in a gallery forest of central Brazil. *J. Mammal.* 76 (3) : 750-768.
- O'Connell, M.A. 1989.
Population dynamics of Neotropical small mammals in seasonal habitats. *J. Mammal.* 70 (3) : 532-548.
- O'Farrell, M.J., W.A.Clark, F.H.Emmerson, S.M.Juarez, F.R.Kay,T.M.O'Farrell, and T.Y.Goodlett. 1994.
Use of a mesh live trap for small mammals : are results from Sherman live traps deceptive? *J. Mammal.* 75 (3) : 692-699.
- Passamani, M. 1995.
Vertical stratification of small mammals in Atlantic Hill forest. *Mammalia* 59 (2) : 276-279.
- Shump, K.A.Jr., and R.H.Baker. 1978.
Sigmodon alleni. *Amer. Soc. Mammalogists. Mammal. Sp.* 95 : 1-2.
- Shump, K.A.Jr., and R.H.Baker. 1978.
Sigmodon leucotis. *Amer. Soc. Mammalogists. Mammal. Sp.* 96 : 1-2.
- Sunquist, M.E., S.N.Austad, and F.Sunquist. 1987.
Movement patterns and home range in the Common Opossum (*Didelphis marsupialis*). *J. Mamm.* 68 (1) : 173-176.
- Wetzel, R.M. 1985.
Geographic areas of the Neotropics poorly represented in mammal research collections. *Acta Zool. Fennica* 170 : 43-46.

Chapter 8

Tables :

Table 1. Trapping sites (1 to 8). **A** and **B**, transects; *north, south, west* and *east*, ends of transects. See figures 1 and 2 (paragraph 1.3).

General area	Site n ^o	GPS position	Structure and access	General habitat
New Trail	1	A <i>north</i> 18°18'693"N / 88°11'223"W <i>south</i> 18°18'295"N / 88°11'196"W B <i>north</i> 18°18'687"N / 88°11'158"W <i>south</i> 18°18'565"N / 88°11'151"W	A and B are positioned on each side of the Thomson trail next to the junction with the New Trail. A is only accessible from the junction, which is 50 ft (15m) from <i>north</i> . B is accessible either from the junction by using a 450 ft (135m) forest trail ^a leading to <i>north</i> , or from the Thomson trail passing next to <i>south</i> (33 ft). The overall site is best accessed from Headquarters by following the Botanical trail then the New trail for about 0.6 mile (1km) until the junction.	A and B are situated in a transitional area between vegetation type 3 (Lysiloma-dominated variant) and veg. type 4 (Mucal variant). A is in 4 at <i>north</i> , and 3 at <i>south</i> . B is in 3 at <i>north</i> , and 4 at <i>south</i> .
	6	A <i>north</i> 18°18'230"N / 88°12'084"W <i>south</i> 18°18'087"N / 88°12'086"W B <i>north</i> 18°18'236"N / 88°12'006"W <i>south</i> 18°18'082"N / 88°12'007"W	A and B are positioned at the southern side of the New trail, about halfway between the junctions with the Thomson trail and the Main trail. A is only accessible from the trail, which is 33 ft (10m) away from <i>north</i> . B is only accessible at <i>north</i> , by using a 500 ft (150m) forest trail heading east and starting from A <i>north</i> . The overall site is best accessed from the Main road ^b at milestone 35, where a 170 ft (50m) long forest trail joins the New trail. The latter must then be followed for about 70 ft (20m) westward to the access point to A <i>north</i> .	A and B are situated in a transitional area between vegetation types 3, 4 (Mucal variant), 5, 6 and 7. A is in 3 at <i>north</i> , and 6 at <i>south</i> , with 4 and 5 in between. B is in 3 at <i>north</i> , and 7 at <i>south</i> , with 4, 5 and 6 in between.
Main Trail	2	A <i>north</i> 18°18'179"N / 88°12'683"W <i>south</i> 18°18'037"N / 88°12'717"W B <i>north</i> 18°18'204"N / 88°12'650"W <i>south</i> 18°18'056"N / 88°12'667"W	A and B are positioned at the east side of the Main trail next to the junction with the New trail. Starting 33 ft (10m) away from the junction, A goes north by bordering the Main trail at a distance of 50 ft (15m), so that it is accessible all the way. B is accessible from the New trail, either at <i>south</i> close (33 ft) to the point where the trail starts to go northward, or nearby <i>north</i> where the trail crosses the transect at two points before going eastward. The overall site is best accessed from the Main road by following the Main trail for about 0.5 mile (800m) to the junction.	A and B are situated in a transitional area between vegetation types 1 and 2. Both A and B are in 2 from <i>north</i> to <i>south</i> .
	5	A <i>north</i> 18°17'656"N / 88°12'965"W <i>south</i> 18°17'476"N / 88°12'952"W B <i>north</i> 18°17'646"N / 88°12'866"W <i>south</i> 18°17'488"N / 88°12'863"W	A and B are positioned on each side of the Main trail in the vicinity of Treetop M ^c . From the trail at a distance of about 0.4 mile (640m) northerly from the latter, the only access to the transects is by two 250 ft (75m) long forest trails. One trail is westward to A <i>north</i> , and the other eastward to B <i>north</i> . The overall site is best accessed from the Main road by following the Main trail for about 1.2 miles (2km) to the start of the two forest trails.	A and B are situated in a transitional area between vegetation types 2, 4 (Mucal and Tasistal) and 5. Both A and B are in 2 at <i>north</i> , and 4 at <i>south</i> . In B , 5 comes between 2 and 4.

Xo-Pol	3	<p>A west 18°14'963"N / 88°15'087"W east 18°14'964"N / 88°14'920"W</p> <p>B west 18°15'048"N / 88°15'108"W east 18°15'039"N / 88°14'949"W</p>	A and B are positioned at the east side of Tiger Road ^d about 0.3 mile (500m) northerly from the junction with the Xo-Pol southern survey line. A and B are only accessible by the trail, and are both 50 ft (15m) away from it at <i>west</i> . Starting from the access to A , the access to B is 500 ft (150m) further north on the trail. The overall site is best accessed by going from Cowpen road ^c when following the Xo-Pol southern survey line for about 0.4 mile (640m) until the junction.	A and B are situated in vegetation type 1. Both A and B are in 1 from <i>west</i> to <i>east</i> .
	7	<p>A north 18°15'825"N / 88°16'025"W south 18°15'680"N / 88°16'039"W</p> <p>B north 18°15'842"N / 88°15'953"W south 18°15'691"N / 88°15'973"W</p>	A and B are positioned at the southern side of the Pond trail ^f in the vicinity of Treetop X ^g . Both A and B are only accessible from the trail, which is 33 ft (10m) away from <i>north</i> . Starting from the access to A , the access to B is to be found 500 ft (150m) further east on the trail. The overall site is best accessed from Cowpen road by following the Treetop road ^h for about 0.4 mile (640m) until Treetop X, then the Pond trail for about 0.1 mile (160m) eastward to the point of access to A .	A and B are situated in vegetation type 1. Both A and B are in 1 from <i>north</i> to <i>south</i> .
Shipstern	4	<p>A west 18°11'855"N / 88°11'302"W east 18°11'838"N / 88°11'123"W</p> <p>B west 18°11'939"N / 88°11'295"W east 18°11'927"N / 88°11'114"W</p>	A and B are positioned at the east side of the Field Base trail ⁱ approximately 0.7 mile (1.1km) south from the Field Base. A is only accessible from the trail, which is 65 ft (20m) from <i>west</i> . B is only accessible at <i>west</i> , either from A <i>west</i> by following a 500 ft (150m) forest trail heading northwards, or from the trail by following a 230 ft (70m) forest trail. The latter access to B is 300 ft (90m) further north on the trail, when starting from the access to A . The overall site is best accessed from the village of Fireburn by following the Fireburn road ^j for about 1 mile (1.6km) until the junction with the Field Base trail.	A and B are situated in a transitional area between vegetation types 1 and 4 (Tasistal). A is in 1 at <i>west</i> , and 4 at <i>east</i> . B is in 1 from <i>west</i> to <i>east</i> .
	8	<p>A west 18°13'599"N / 88°10'972"W east 18°13'586"N / 88°10'799"W</p> <p>B west 18°13'683"N / 88°10'953"W east 18°13'683"N / 88°10'790"W</p>	A and B are positioned at both sides of the Shipstern trail ^k , halfway between Shipstern Landing and Shipstern Old Village ^l . From the trail at a distance of about 0.4 mile (640m) west from the latter, two 250 ft (75m) long forest trails give access to the transects. One is going southwards to A <i>west</i> , and the other northwards to B <i>west</i> . This is the only access to B , but A can be accessed 0.1 mile (160m) further east, where it crosses the trail. The overall site is best accessed from Shipstern Landing by following the Shipstern trail for about 0.5 mile (800m) until the start of the two forest trails.	A and B are situated in a transitional area between vegetation types 1, 4 (Mucal) and 8. A is in 4 at <i>west</i> , and 8 at <i>east</i> , with 1 coming between. B is in 4 at <i>west</i> , and 1 at <i>east</i> , with 8 between.

^a Trail opened by the author to access the wanted position.

^b Name given by the author to the road marking the northern boundary of Shipstern Nature Reserve, and leading to the village of Sarteneja.

^c Name given by the author to the observatory positioned at the southern end of the Main trail.

^d Old forest road made into a trail.

^e Name given by the author to the road starting from the Main Road, and leading to the Shipstern Lagoon.

^f Name given by the author to the trail around the Xo-Pol pond.

^g Name given by the author to the observatory positioned along the Xo-Pol Western survey line on the southern shore of the Xo-Pol pond.

^h Name given by the author to an old forest road made into a trail, starting from Cowpen road, and ending at Treetop X.

ⁱ Name given by the author to the trail passing in front of the Field Base.

^j Name given by the author to a forest road starting from the village of Fireburn, and leading down to the Shipstern Lagoon.

^k Name given by the author to an old forest road made into a trail, starting from Shipstern Landing, and leading to Shipstern Old Village.

^l Village of Shipstern that fell into ruin after having been entirely destroyed by hurricane Janet, in 1955.

Table 2. Capture results. Field numbers in brackets represent the specimens captured at each site. See paragraph 2.7.

Site n°1 (VB001-VB016)

Species	Total captures	% Total	First captures	% Total	Recapture index
<i>Marmosa mexicana</i>	-	-	-	-	-
<i>Didelphis virginiana</i>	-	-	-	-	-
<i>Heteromys gaumeri</i>	-	-	-	-	-
<i>Otonyctomys hatti</i>	-	-	-	-	-
<i>Ototylomys phyllotis</i>	27	100.0	16	100.0	1.7
<i>Peromyscus yucatanicus</i>	-	-	-	-	-
<i>Sigmodon hispidus</i>	-	-	-	-	-
Total :	27	100.0	16	100.0	-

Site n°2 (VB017-VB031)

Species	Total captures	% Total	First captures	% Total	Recapture index
<i>Marmosa mexicana</i>	-	-	-	-	-
<i>Didelphis virginiana</i>	-	-	-	-	-
<i>Heteromys gaumeri</i>	6	31.6	4	26.7	1.5
<i>Otonyctomys hatti</i>	-	-	-	-	-
<i>Ototylomys phyllotis</i>	13	68.4	11	73.3	1.2
<i>Peromyscus yucatanicus</i>	-	-	-	-	-
<i>Sigmodon hispidus</i>	-	-	-	-	-
Total :	19	100.0	15	100.0	-

Site n°3 (VB032-VB058)

Species	Total captures	% Total	First captures	% Total	Recapture index
<i>Marmosa mexicana</i>	1	2.1	1	3.7	1.0
<i>Didelphis virginiana</i>	-	-	-	-	-
<i>Heteromys gaumeri</i>	2	4.2	1	3.7	2.0
<i>Otonyctomys hatti</i>	-	-	-	-	-
<i>Ototylomys phyllotis</i>	44	93.7	25	92.6	1.8
<i>Peromyscus yucatanicus</i>	-	-	-	-	-
<i>Sigmodon hispidus</i>	-	-	-	-	-
Total :	47	100.0	27	100.0	-

Site n°4 (VB059-VB123)

Species	Total captures	% Total	First captures	% Total	Recapture index
<i>Marmosa mexicana</i>	-	-	-	-	-
<i>Didelphis virginiana</i>	1	0.7	1	1.5	1.0
<i>Heteromys gaumeri</i>	3	2.1	3	4.6	1.0
<i>Otonyctomys hatti</i>	-	-	-	-	-
<i>Ototylomys phyllotis</i>	136	96.5	60	92.4	2.3
<i>Peromyscus yucatanicus</i>	1	0.7	1	1.5	1.0
<i>Sigmodon hispidus</i>	-	-	-	-	-
Total :	141	100.0	65	100.0	-

Site n°5 (VB124-VB144)

Species	Total captures	% Total	First captures	% Total	Recapture index
<i>Marmosa mexicana</i>	-	-	-	-	-
<i>Didelphis virginiana</i>	-	-	-	-	-
<i>Heteromys gaumeri</i>	7	19.4	6	28.6	1.2
<i>Otonyctomys hatti</i>	-	-	-	-	-
<i>Ototylomys phyllotis</i>	29	80.6	15	71.4	1.9
<i>Peromyscus yucatanicus</i>	-	-	-	-	-
<i>Sigmodon hispidus</i>	-	-	-	-	-
Total :	36	100.0	21	100.0	-

Site n°6 (VB145-VB172)

Species	Total captures	% Total	First captures	% Total	Recapture index
<i>Marmosa mexicana</i>	-	-	-	-	-
<i>Didelphis virginiana</i>	-	-	-	-	-
<i>Heteromys gaumeri</i>	3	6.1	3	10.7	1.0
<i>Otonyctomys hatti</i>	-	-	-	-	-
<i>Ototylomys phyllotis</i>	36	73.5	18	64.3	2.0
<i>Peromyscus yucatanicus</i>	-	-	-	-	-
<i>Sigmodon hispidus</i>	10	20.4	7	25.0	1.4
Total :	49	100.0	28	100.0	-

Site n°7 (VB173-VB207)

Species	Total captures	% Total	First captures	% Total	Recapture index
<i>Marmosa mexicana</i>	-	-	-	-	-
<i>Didelphis virginiana</i>	-	-	-	-	-
<i>Heteromys gaumeri</i>	1	1.9	1	2.9	1.0
<i>Otonyctomys hatti</i>	1	1.9	1	2.9	1.0
<i>Ototylomys phyllotis</i>	51	96.2	33	94.2	1.5
<i>Peromyscus yucatanicus</i>	-	-	-	-	-
<i>Sigmodon hispidus</i>	-	-	-	-	-
Total :	53	100.0	35	100.0	-

Site n°8 (VB208-VB231)

Species	Total captures	% Total	First captures	% Total	Recapture index
<i>Marmosa mexicana</i>	-	-	-	-	-
<i>Didelphis virginiana</i>	-	-	-	-	-
<i>Heteromys gaumeri</i>	1	2.4	1	4.2	1.0
<i>Otonyctomys hatti</i>	-	-	-	-	-
<i>Ototylomys phyllotis</i>	40	95.2	22	91.6	1.8
<i>Peromyscus yucatanicus</i>	1	2.4	1	4.2	1.0
<i>Sigmodon hispidus</i>	-	-	-	-	-
Total :	42	100.0	24	100.0	-

Sites n°1-8

Species	Total captures	% Total	First captures	% Total	Recapture index
<i>Marmosa mexicana</i>	1	0.25	1	0.45	1.0
<i>Didelphis virginiana</i>	1	0.25	1	0.45	1.0
<i>Heteromys gaumeri</i>	23	5.55	19	8.15	1.2
<i>Otonyctomys hatti</i>	1	0.25	1	0.45	1.0
<i>Ototylomys phyllotis</i>	376	90.8	200	86.6	1.8
<i>Peromyscus yucatanicus</i>	2	0.5	2	0.9	1.0
<i>Sigmodon hispidus</i>	10	2.4	7	3.0	1.4
Total :	414	100.0	231	100.0	-

Table 3. Capture results per vegetation type. Vegetation types, see paragraph 1.3.

Sites n°1-8													
Species	Total captures	Vegetation types											
		1	2	3	4				5	6	7	8	
				P	L	Pu	Ti	Mu	Ta				
<i>Marmosa mexicana</i>	1	1	-	-	-	-	-	-	-	-	-	-	
<i>Didelphis virginiana</i>	1	-	-	-	-	-	-	-	1	-	-	-	
<i>Heteromys gaumeri</i>	23	6	7	3	-	-	-	-	6	-	-	1	
<i>Otonyctomys hattii</i>	1	1	-	-	-	-	-	-	-	-	-	-	
<i>Ototylomys phyllotis</i>	376	233	24	27	7	-	-	33	12	6	3	31	
<i>Peromyscus yucatanicus</i>	2	1	-	-	-	-	-	-	-	-	-	1	
<i>Sigmodon hispidus</i>	10	-	-	-	-	-	-	-	-	-	9	1	
Total :	414	242	31	30	7	-	-	33	19	6	12	1	33

Table 4. Trapping success. See paragraph 2.7.

Site n°	Trapping periods	No. trap nights	No. captures	% success
1	May 1-11	1600	27	1.7
2	May 19-29	1600	19	1.2
3	June 6-16	1600	47	2.9
4	June 21- July 1	1600	141	8.8
5	July 11-21	1600	36	2.3
6	Aug 28-Sept 7	1600	49	3.1
7	Sept 11-21	1600	53	3.3
8	Sept 26-30	640	42	6.6
Total :		11840	414	3.5

Table 5. Trap response. Trap types, see paragraph 2.3.

Sites n°1-8						
Species	Total captures	Trap types				
		S	T	A1	A2	A3
<i>Marmosa mexicana</i>	1	0	0	1	0	0
<i>Didelphis virginiana</i>	1	0	1	0	0	0
<i>Heteromys gaumeri</i>	23	12	11	0	0	0
<i>Otonyctomys hattii</i>	1	0	0	0	1	0
<i>Ototylomys phyllotis</i>	376	30	169	64	112	1
<i>Peromyscus yucatanicus</i>	2	0	0	2	0	0
<i>Sigmodon hispidus</i>	10	0	10	0	0	0
Total :	414	42	191	67	113	1

Table 6. External measurements. Body (mm) and mass (g) measurements are presented for adults of both sexes. n, sample size. Other abbreviations are defined in paragraph 2.5. Mean and standard error, see paragraph 2.7.

Variable	<i>Marmosa mexicana</i>			<i>Didelphis virginiana</i>		
	Mean ± SE	Range	n	Mean ± SE	Range	n
TL	323	-	1	389	-	1
TV	174	-	1	186	-	1
HF	20	-	1	33	-	1
E	22	-	1	35	-	1
NEB	35	-	1	58	-	1
NEC	16	-	1	26	-	1
V	25	-	1	43	-	1
PA	-	-	1	-	-	1
VA	-	-	0	-	-	0
Weight	66	-	1	170	-	1
SR	35	-	1	-	-	1
Variable	<i>Heteromys gaumeri</i>			<i>Otonyctomys hatti</i>		
	Mean ± SE	Range	n	Mean ± SE	Range	n
TL	266.6 ± 5.58	252-286	5	199	-	1
TV	138.4 ± 3.98	128-147	5	108	-	1
HF	31.13 ± 0.9	25-33	8	19	-	1
E	16.88 ± 0.3	16-18	8	13	-	1
NEB	33.13 ± 0.3	32-34	8	26	-	1
NEC	18.88 ± 0.77	17-24	8	13	-	1
V	45.0 ± 6.0	39-51	2	31	-	1
PA	18.33 ± 5.36	8-26	3	-	-	0
VA	4.25 ± 0.95	3-7	4	6	-	1
Weight	60.22 ± 3.54	50-75	9	24	-	1
SR	9.4 ± 0.24	9-10	5	22	-	1
Variable	<i>Ototylomys phyllotis</i>			<i>Peromyscus yucatanicus</i>		
	Mean ± SE	Range	n	Mean ± SE	Range	n
TL	263.87 ± 1.64	227-295	91	191	-	1
TV	123.76 ± 1.09	97-150	94	92	-	1
HF	23.55 ± 0.1	21-29	95	22	-	1
E	22.2 ± 0.12	19-26	92	19	-	1
NEB	35.9 ± 0.19	29-41	93	28	-	1
NEC	17.05 ± 0.14	11-20	93	15	-	1
V	47.43 ± 1.38	43-52	7	42	-	1
PA	23.0 ± 0.43	17-28	36	-	-	0
VA	12.57 ± 0.28	9-17	56	2	-	1
Weight	65.46 ± 1.15	43-96	102	24	-	1
SR	7.83 ± 0.09	6-10	94	26	-	1

Variable	<i>Sigmodon hispidus</i>		
	Mean ± SE	Range	n
TL	236.2 ± 6.3	220-253	5
TV	97.2 ± 1.93	94-104	5
HF	26.5 ± 0.62	24-28	6
E	17.8 ± 0.58	16-19	5
NEB	34.0 ± 1.03	31-37	6
NEC	16.17 ± 0.7	14-18	6
V	29.0 ± 1.53	27-32	3
PA	26.67 ± 3.18	21-32	3
VA	5.33 ± 0.88	4-7	3
Weight	84.67 ± 3.68	70-92	6
SR	15.0 ± 0.0	15-15	5

Table 7. Cranial measurements (mm), presented for adults of both sexes. n, sample size. Other abbreviations are defined in paragraph 2.5. Mean and standard error, see paragraph 2.7.

Variable	<i>Marmosa mexicana</i>			<i>Didelphis virginiana</i>		
	Mean ± SE	Range	n	Mean ± SE	Range	n
ONL	35.41	-	1	56.99	-	1
CBL	34.42	-	1	55.6	-	1
CIL	33.9	-	1	55.39	-	1
NL	15.27	-	1	26.24	-	1
BN	4.71	-	1	8.85	-	1
PL	18.96	-	1	34.24	-	1
PW	9.53	-	1	17.91	-	1
PPL	13.41	-	1	16.77	-	1
BPS	-	-	0	-	-	0
RL	12.05	-	1	23.19	-	1
RW	5.59	-	1	11.57	-	1
BRJ	10.38	-	1	16.06	-	1
BRF	6.65	-	1	9.91	-	1
LIF	-	-	0	5.52	-	1
BIF	2.31	-	1	3.62	-	1
OL	6.87	-	1	11.22	-	1
LBP	13.7	-	1	26.04	-	1
MPFL	7.67	-	1	11.7	-	1
MPFW	4.0	-	1	6.85	-	1
BOL	4.68	-	1	5.92	-	1
MB	12.68	-	1	18.77	-	1
OCB	7.11	-	1	12.42	-	1
BB	12.65	-	1	19.21	-	1
ZB	20.02	-	1	29.4	-	1
IB	6.1	-	1	11.33	-	1

IOC2	5.97	-	1	9.39	-	1
CD	11.43	-	1	16.66	-	1
BCT	5.43	-	1	11.31	-	1
BM1	1.61	-	1	2.53	-	1
C-M4	13.38	-	1	20.03	-	1
M1-M4	6.38	-	1	12.96	-	1
CLMT	3.29	-	1	14.36	-	1
LM	24.8	-	1	42.31	-	1

Variable	<i>Heteromys gaumeri</i>			<i>Otonyctomys hatti</i>		
	Mean ± SE	Range	n	Mean ± SE	Range	n
ONL	35.46 ± 0.25	34.97-35.75	3	28.67	-	1
CBL	33.27 ± 0.19	32.95-33.62	3	25.77	-	1
CIL	29.49 ± 0.1	29.34-29.67	3	24.81	-	1
NL	14.44 ± 0.34	13.85-15.01	3	9.21	-	1
PL	20.28 ± 0.45	19.44-21.0	3	12.4	-	1
PPL	10.51 ± 0.23	10.12-10.93	3	11.11	-	1
LD	9.22 ± 0.36	8.51-9.63	3	6.75	-	1
RL	15.56 ± 0.18	15.27-15.88	3	9.63	-	1
BR	6.33 ± 0.23	6.07-6.79	3	4.79	-	1
LIF	2.87 ± 0.24	2.62-3.34	3	4.75	-	1
BIF	0.91 ± 0.04	0.84-0.96	3	2.38	-	1
BZP	4.36 ± 0.06	4.29-4.49	3	1.46	-	1
OL	8.81 ± 0.05	8.71-8.89	3	8.76	-	1
LBP	8.0 ± 0.25	7.57-8.42	3	3.88	-	1
BBP	5.34 ± 0.11	5.2-5.56	3	4.95	-	1
MPFL	4.33 ± 0.17	4.06-4.64	3	5.03	-	1
MPFW	2.12 ± 0.12	1.98-2.35	3	2.11	-	1
BOL	4.95 ± 0.1	4.79-5.14	3	4.51	-	1
BL	4.87 ± 0.07	4.75-5.0	3	7.84	-	1
BW	3.54 ± 0.08	3.45-3.69	3	5.54	-	1
MB	14.81 ± 0.27	14.43-15.32	3	12.79	-	1
OCB	6.88 ± 0.22	6.45-7.21	3	6.15	-	1
LB	13.52 ± 0.33	13.13-14.17	3	10.66	-	1
BB	13.51 ± 0.17	13.3-13.85	3	13.1	-	1
ZB	16.41 ± 0.15	16.19-16.7	3	14.29	-	1
IB	8.82 ± 0.06	8.7-8.88	3	4.79	-	1
CD	11.56 ± 0.15	11.32-11.84	3	11.58	-	1
BM1	1.35 ± 0.05	1.3-1.45	3	1.28	-	1
CLM1-3	4.6 ± 0.19	4.32-4.97	3	3.99	-	1
DI	1.45 ± 0.05	1.37-1.55	3	1.33	-	1
HI	5.29 ± 0.15	5.06-5.57	3	3.57	-	1
CLMT	4.79 ± 0.06	4.66-4.87	3	4.16	-	1
LM	15.01 ± 0.14	14.79-15.28	3	13.22	-	1
LR	-	-	0	-	-	0
IPL	4.82 ± 0.12	4.67-5.06	3	-	-	0
IPW	9.03 ± 0.29	8.53-9.53	3	-	-	0
ORB	-	-	0	-	-	0
BPB	-	-	0	-	-	0

LBC	-	-	0	-	-	0
HBC	-	-	0	-	-	0
BIT	-	-	0	-	-	0
	<i>Ototylomys phyllotis</i>			<i>Peromyscus yucatanicus</i>		
Variable	Mean ± SE	Range	n	Mean ± SE	Range	n
ONL	36.81 ± 0.61	33.86-38.86	8	28.8	-	1
CBL	34.37 ± 0.67	30.94-36.84	8	26.86	-	1
CIL	32.08 ± 0.55	29.43-34.18	8	25.49	-	1
NL	12.48 ± 0.29	11.55-13.65	8	11.09	-	1
PL	18.15 ± 0.32	16.44-19.05	8	14.42	-	1
PPL	13.74 ± 0.36	12.27-15.42	8	10.56	-	1
LD	9.02 ± 0.14	8.42-9.55	8	7.98	-	1
RL	12.96 ± 0.31	11.73-13.93	8	11.1	-	1
BR	5.87 ± 0.12	5.36-6.26	8	5.05	-	1
LIF	7.15 ± 0.12	6.4-7.55	8	5.86	-	1
BIF	3.28 ± 0.09	2.97-3.68	8	2.49	-	1
BZP	2.93 ± 0.09	2.69-3.46	8	2.04	-	1
OL	10.79 ± 0.11	10.33-11.13	8	8.92	-	1
LBP	4.62 ± 0.07	4.29-4.82	8	4.09	-	1
BBP	6.2 ± 0.11	5.84-6.67	8	5.18	-	1
MPFL	6.3 ± 0.2	5.65-7.37	8	4.88	-	1
MPFW	2.47 ± 0.04	2.29-2.58	8	1.75	-	1
BOL	5.16 ± 0.14	4.6-5.89	8	3.78	-	1
BL	6.33 ± 0.09	5.81-6.64	8	4.19	-	1
BW	4.47 ± 0.12	4.04-4.98	8	3.38	-	1
MB	13.54 ± 0.14	12.82-14.05	8	11.55	-	1
OCB	7.51 ± 0.14	6.83-7.93	8	6.53	-	1
LB	11.93 ± 0.24	10.76-12.83	8	11.59	-	1
BB	14.33 ± 0.18	13.49-15.13	8	11.87	-	1
ZB	17.82 ± 0.28	16.7-18.78	8	13.04	-	1
IB	5.84 ± 0.16	5.13-6.67	8	4.67	-	1
CD	11.44 ± 0.07	11.22-11.85	8	9.55	-	1
BM1	1.67 ± 0.01	1.61-1.71	8	1.28	-	1
CLM1-3	6.0 ± 0.06	5.68-6.15	8	4.22	-	1
DI	1.65 ± 0.05	1.4-1.81	8	1.37	-	1
HI	3.79 ± 0.16	3.11-4.46	8	3.64	-	1
CLMT	5.96 ± 0.05	5.72-6.08	7	4.29	-	1
LM	17.77 ± 0.3	16.73-18.77	7	14.31	-	1
LR	-	-	0	10.06	-	1
IPL	-	-	0	-	-	0
IPW	-	-	0	-	-	0
ORB	5.55 ± 0.13	4.94-6.03	8	-	-	0
BPB	-	-	0	-	-	0
LBC	-	-	0	13.21	-	1
HBC	-	-	0	-	-	0
BIT	-	-	0	-	-	0

Variable	<i>Sigmodon hispidus</i>		
	Mean \pm SE	Range	n
ONL	32.82 \pm 0.78	31.59-34.26	3
CBL	30.94 \pm 0.74	29.64-32.19	3
CIL	30.55 \pm 0.68	29.3-31.65	3
NL	11.81 \pm 0.37	11.07-12.25	3
PL	17.34 \pm 0.43	16.56-18.05	3
PPL	11.39 \pm 0.34	10.82-11.98	3
LD	9.19 \pm 0.36	8.49-9.64	3
RL	11.81 \pm 0.46	10.9-12.32	3
BR	6.53 \pm 0.2	6.21-6.9	3
LIF	7.75 \pm 0.19	7.41-8.05	3
BIF	2.44 \pm 0.14	2.21-2.69	3
BZP	3.03 \pm 0.1	2.86-3.22	3
OL	10.44 \pm 0.33	10.1-11.11	3
LBP	5.87 \pm 0.11	5.76-6.08	3
BBP	6.67 \pm 0.29	6.14-7.15	3
MPFL	4.66 \pm 0.26	4.4-5.18	3
MPFW	2.07 \pm 0.13	1.82-2.26	3
BOL	5.06 \pm 0.1	4.94-5.27	3
BL	5.86 \pm 0.07	5.73-5.95	3
BW	4.16 \pm 0.01	4.14-4.18	3
MB	12.61 \pm 0.31	12.1-13.16	3
OCB	6.7 \pm 0.16	6.44-7.0	3
LB	11.89 \pm 0.44	11.25-12.73	3
BB	13.14 \pm 0.2	12.86-13.53	3
ZB	18.11 \pm 0.59	16.96-18.87	3
IB	4.88 \pm 0.11	4.72-5.09	3
CD	12.16 \pm 0.25	11.65-12.43	3
BMI	1.74 \pm 0.04	1.68-1.81	3
CLM1-3	5.08 \pm 0.07	4.99-5.23	3
DI	1.89 \pm 0.02	1.86-1.92	3
HI	5.73 \pm 0.14	5.48-5.95	3
CLMT	5.89 \pm 0.17	5.64-6.21	3
LM	17.22 \pm 0.65	16.03-18.26	3
LR	-	-	0
IPL	2.56 \pm 0.13	2.33-2.77	3
IPW	10.38 \pm 0.21	9.97-10.65	3
ORB	-	-	0
BPB	3.06 \pm 0.24	2.59-3.35	3
LBC	-	-	0
HBC	10.05 \pm 0.07	9.92-10.12	3
BIT	2.57 \pm 0.14	2.3-2.71	3

Table 8. Endoparasites. Sampled specimens of each host species are identified by their field number. N, sample size. Ces, class Cestoidea ; Tre, class Trematoda ; Tri, superfamily Trichostrongyloidea. See paragraph 3.2.

Small intestine					
Species	Field n°	Nemata		Platyhelminthes	
		Tri	Others	Tre	Ces
<i>Marmosa mexicana</i>	VB054	1	0	0	0
<i>Didelphis virginiana</i>	VB062	6	4	6	0
<i>Heteromys gaumeri</i>	VB017	178	1	2	0
	VB018	94	0	11	1
	VB021	238	0	0	0
		510	1	13	1
<i>Otonyctomys hatti</i>	VB182	1	0	0	0
<i>Ototylomys phyllotis</i>	VB001	8	0	0	0
	VB002	14	0	0	1
	VB004	81	2	1	0
	VB005	55	0	0	0
		158	2	1	1
<i>Peromyscus yucatanicus</i>	VB225	72	0	0	0
<i>Sigmodon hispidus</i>	VB146	0	1	n	0
	VB147	0	0	n	0
	VB148	0	0	n	n
		0	1	n	n
Total :	N=14	748	8	-	-

Caecum					
Species	Field n°	Nemata		Platyhelminthes	
		Tri	Others	Tre	Ces
<i>Marmosa mexicana</i>	VB054	0	0	0	0
<i>Didelphis virginiana</i>	VB062	0	115	0	0
<i>Heteromys gaumeri</i>	VB017	9	0	0	0
	VB018	0	0	0	n
	VB021	0	0	1	n
		9	0	1	n
<i>Otonyctomys hatti</i>	VB182	0	0	0	0

<i>Ototylomys phyllotis</i>	VB001	0	0	0	0
	VB002	0	2	0	0
	VB004	0	1	0	0
	VB005	3	1	0	0
		3	4	0	0
<i>Peromyscus yucatanicus</i>	VB225	0	0	0	0
<i>Sigmodon hispidus</i>	VB146	0	0	0	0
	VB147	0	0	0	0
	VB148	0	0	0	0
		0	0	0	0
Total :	N=14	12	119	1	-

Rectum (-colon)

Species	Field n°	Nemata		Platyhelminthes	
		Tri	Others	Tre	Ces
<i>Marmosa mexicana</i>	VB054	0	0	0	0
<i>Didelphis virginiana</i>	VB062	0	26	0	0
<i>Heteromys gaumeri</i>	VB017	0	0	0	0
	VB018	0	0	0	0
	VB021	1	0	0	0
		1	0	0	0
<i>Otonyctomys hatti</i>	VB182	0	0	0	0
<i>Ototylomys phyllotis</i>	VB001	5	1	0	0
	VB002	1	2	0	0
	VB004	0	1	0	0
	VB005	3	0	0	0
		9	4	0	0
<i>Peromyscus yucatanicus</i>	VB225	0	0	0	0
<i>Sigmodon hispidus</i>	VB146	0	0	2	0
	VB147	0	0	0	0
	VB148	0	0	3	0
		0	0	5	0
Total :	N=14	10	30	5	0

Table 9. Ecto- and endoparasites. N, sample size (host species). Ces, class Cestoidea; Tre, class Trematoda; Tri, superfamily Trichostrongyloidea. See paragraph 3.2.

Species	N	Endoparasites				Ectoparasites	
		Tri	Others	Tre	Ces	Ticks	Fleas
<i>Marmosa mexicana</i>	1	1	0	0	0	0	0
<i>Didelphis virginiana</i>	1	6	145	6	0	80	0
<i>Heteromys gaumeri</i>	3	520	1	14	n	45	0
<i>Otonyctomys hatti</i>	1	1	0	0	0	0	0
<i>Ototylomys phyllotis</i>	4	170	10	1	1	1	9
<i>Peromyscus yucatanicus</i>	1	72	0	0	0	21	2
<i>Sigmodon hispidus</i>	3	0	1	n	n	112	0
Total :	14	770	157	-	-	259	11

Chapter 9

Appendices :

Appendix 1 - Sympatric diversity in SNR :

This appendix presents a diversity estimate for the small mammal fauna of Shipstern Nature Reserve. The following list is based on geographic expectations, but does not include the sampled and sighted species (see below) :

Gray Four-eyed Opossum	<i>Philander opossum</i>
Central American Woolly Opossum	<i>Caluromys derbianus</i>
Robinson's Mouse Opossum	<i>Marmosa robinsoni</i>
Hispid Pocket Gopher	<i>Orthogeomys hispidus</i>
Forest Spiny Pocket Mouse	<i>Heteromys desmarestianus</i>
Coue's Rice Rat	<i>Oryzomys couesi</i>
Rusty Rice Rat	<i>Oryzomys rostratus</i>
Northern Pygmy Rice Rat	<i>Oligoryzomys fulvescens</i>
Northern Climbing Rat	<i>Tylomys nudicaudus</i>
Slender Harvest Mouse	<i>Reithrodontomys gracilis</i>
Maya Small-eared Shrew	<i>Cryptotis mayensis</i>

This small mammal species list was predicted from range overlap—geographic expectations (Voss and Emmons, 1996)—and is mainly based on distributional data obtained from Reid (1997), Emmons and Feer (1997), and McCarthy et al. (1998). The known ecological requirements for each species was also taken into account, so as to minimize inaccuracy in diversity estimate. Thus, the Water Opossum (*Chironectes minimus*) is probably not present in the Shipstern Nature Reserve—it is semi-aquatic, favoring fast-flowing, rock- or gravel-bottomed streams in hilly country (Reid, 1997)—although its range is seemingly overlapping the area. Inversely, *Marmosa robinsoni* is presently considered as absent from northern Belize, but as discussed in paragraph 4.1, a reappraisal of all specimens of the species in Central America is needed to determine its exact distribution, so that it may well be present throughout Central America. Being a habitat generalist, *M. robinsoni* would therefore be expected in SNR. In the case of the Maya Small-eared Shrew (*Cryptotis mayensis*), information on its known geographic and ecological distribution is complemented by the observation of a non-identified species of shrew in the vicinity of SNR (P. Walker, pers. commun.).

By combining the present list (11 species) with the 7 sampled species of marsupials and myomorph rodents, and 3 sighted species of marsupial and squirrels—*Didelphis marsupialis*, *Sciurus yucatanensis*, and *S. deppei*—a total of 21 small mammal species is expected in SNR. This diversity estimate, however, is subject to several sources of uncertainty (see chapter 4), and is to be considered as a first approximation.

Appendix 2 - Observed mammals in SNR :

This appendix presents an inventory of the mammalian species observed during the fieldwork in Shipstern Nature Reserve. The observations were primarily based on direct sightings (D), but also on indirect indices—e.g. nests (N), sets of tracks (T), scats (Sc), sounds (So). A total of 19 small, medium-sized, and large mammals was thus obtained from SNR and its direct surroundings. In the following list, the numbers are related to the areas—New Trail (1), Main Trail (2), Xo-Pol (3), and Shipstern (4) areas (see paragraph 2.1)—from which the corresponding species were recorded :

Common Opossum	<i>Didelphis marsupialis</i>	D,So/3
Northern Tamandua	<i>Tamandua mexicana</i>	D,So/4
Nine-banded Armadillo	<i>Dasypus novemcinctus</i>	D/2
Yucatán Squirrel	<i>Sciurus yucatanensis</i>	D/3
Deppe's Squirrel	<i>Sciurus deppei</i>	D/3
Mexican Porcupine	<i>Coendou mexicanus</i>	D/1
Central American Agouti	<i>Dasyprocta punctata</i>	D/1,2,4
Paca	<i>Agouti paca</i>	D,So/1
Gray Fox	<i>Urocyon cinereoargenteus</i>	D,So/1,2,3
White-nosed Coati	<i>Nasua narica</i>	D,N/1,3,4
Kinkajou	<i>Potos flavus</i>	D/4
Tayra	<i>Eira barbara</i>	D/3
Puma	<i>Puma concolor</i>	T/3
Jaguar	<i>Panthera onca</i>	T,Sc,So/2,3
Ocelot	<i>Leopardus pardalis</i>	T,So/4
Collared Peccary	<i>Tayassu tajacu</i>	D,So/1
Baird's Tapir	<i>Tapirus bairdii</i>	T/2,3
Red Brocket	<i>Mazama americana</i>	D,T,So/3
White-tailed Deer	<i>Odocoileus virginianus</i>	D,T,So/3