THE TICK SPECIES OF DOMESTIC LIVESTOCK IN THE REPUBLIC OF MALI, WEST AFRICA

Volume I

A Dissertation

by

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ABSTRACT

The Tick Species of Domestic Livestock in the Republic of Mali, West Africa. (May 1984)

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As part of a vector survey program in the Republic of Mali, West Africa from 1977 to 1981, 23,769 ticks were collected mostly from domestic animals. Approximately 98% of the specimens belonged to 20 currently recognized species or subspecies: Amblyomma variegatum, Aponomma flavomaculatum, Ap. latum, Boophilus annulatus, B. decoloratus, B. geigyi, Hyalomma dromedarii, H. impeltatum, H. impressum, H. marginatum rufipes, H. nitidum, H. truncatum, Rhipicephalus cuspidatus, R. evertsi evertsi, R. guilhoni, R. lunulatus, R. muhsamae, R. sanguineus, R. senegalensis, and R. sulcatus. Two groups and a separate single specimen of Rhipicephalus ticks exhibited relatively unique combinations of morphological characters and are described herein as Rhipicephalus group(s) #9 and 10 and specimen #11, respectively. Micrographs of all the aforementioned species and specimen groups were produced by light and electron microscopy. The accepted morphologies of *H. nitidum*, *H. truncatum* and *R. cuspidatus* from Mali were reviewed because some essential characters differed significantly from those currently used in their taxonomy. Supernumerary hypostomal dentition was recorded and discussed in *Boophilus* specimens. Features of female gonopore tissues proved to be characteristic and constant enough to suggest use in distinguishing species of ixodid ticks excepting genus *Ixodes*. Of all species encountered, *A. variegatum*, *B. geigyi*, *H. m. rufipes* and *H. truncatum* had the widest host ranges and occurred, with varying degrees of success, in all areas surveyed. The remaining species showed restricted distributions determined primarily by rainfall, vegetation, topography and host availability. Cattle were readily attacked by most tick species, sheep and goat to lesser extents, and multiple tick species infestations were common to all 3 hosts. The Ndama cattle breed usually carried fewer ticks than the Zebu in the Sudan region of Mali where both breeds were represented by large numbers. Wildlife inspected during the survey usually carried high tick burdens, especially immatures.

DEDICATION

This work is dedicated to my parents, Folorunsho and Adunola Ajidagba. I could not have wished for a better pair of parents.

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TABLE OF CONTENTS

Page

Volume II

LIST OF TABLES

Page

Volume I

LIST OF FIGURES

Figure | Page

Volume I

Figure Page

LIST OF GRAPHS AND SCHEMATIC DRAWINGS

Page

Volume I

LIST OF PLATES

Plate | Page

Volume II

Micrographs of tick species found in Mali

Plates Page

CHAPTER I

INTRODUCTION

Very little information exists on the tick fauna in the Republic of Mali, West Africa. A 1977 compendum - Index Catalogue of Medical and Veterinary Zoology 1977. Tick and Tick-borne Diseases. Part IV: Geographic Distribution of Ticks - lists only 70 citations (in known published works) in which particular tick species have been associated with that area of West Africa. Further, several of the published records were repeat sightings of the same species. For example, of the 70 published citations referred to above, 4 were of *Hyalomma rufipes* Koch and 5 of *Rhipicephalus sanguineus* (Latreille). In addition, many materials treated as separate species by early workers were really synonyms. *Hyalomma brumpti* Delpy, for instance recorded by Rousselot (1951), is a synonym for *H. impeltatum* Schulze and Schlottke (Hoogstraal 1956). This species is known to occur in Mali (Morel 1958).

In recent years, governmental animal health agencies in Mali have suspected mild epidemics of tick-borne cattle diseases such as

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This dissertation follows the style of the Journal of Medical Entomology. All figures and tables are in Appendixes I and II, starting on pages 156 and 203, respectively.

heartwater (etiology: Cowdria ruminantium). Amblyomma variegatum (Fabricius), a tick of tropical wooded savanna of Africa, has been implicated as a carrier of the heartwater agent (Daubney 1930), while Boophilus decoloratus (Koch) is known to be a vector of the agent of redwater disease (Theiler 1909a). Both tick species have been recorded from Mali (Morel 1958). A pressing need therefore arose to build a body of information on the tick fauna of Mali, its species diversities, population dynamics, ecologic preferences and host affinities. Such investigations could serve as a working basis for examining their roles, if any, in the epidemiology of diseases of higher mammals in the country.

In the present study, trained survey teams were sent around the country to collect ticks from domestic livestock between 1977-1981, with particular emphasis on cattle. Relevant data on collected specimens, numbers collected, identifications, hosts, sites and dates of collections, were then collated. Finally, micrographs of identified tick species were made by light and electron microscopy.

These activites were part of a collaborative vector survey program (the Vector-borne Hemoparasites of Livestock and their Vectors Project) in Mali, between the Government of Mali, Texas A&M University and United States Agency for International Development (AID Contract #AFR1262). It is hoped that information gathered through this comprehensive study will serve both as a teaching aid for governmental animal health workers as well as produce the much needed background information for future research into the nature and dynamics of vectors of animal and human diseases in Mali.

CHAPTER II

LITERATURE REVIEW

Background Information on the Republic of Mali. Knowledge of the physiogeography, vegetation, ethnogeography, climate and livestock economy of the Republic of Mali is a necessary requisite to understanding a review of current literature on the tick species occurring in that part of Africa. The following summary, which covers these topics, has been condensed from the 5 sources listed under Supplemental Sources Consulted.

The Republic of Mali (10-25N, 12E-5W) is situated in the interior of West Africa and has an area of 124,014,000 hectares. It is bordered on the north by Mauritania and Algeria, east by the Republic of Niger, south by Upper Volta and Ivory Coast and west by Guinea and Senegambia (Fig. 1).

Most of Mali is covered by low plateaus and basins. Altitude is usually no more than 300 to 400 meters and the plateaus slope both northward (to the basin of the Niger River) and southward. Significant variations in this relief include the gullies of the Niger Valley, the Tosaye Sill between Bourem and Gourma Rharous and scarp relief bluffs created by erosion at Bandiagara near Mopti (Fig. 1). Exceptionally, the Adrar des Iforas range in the northeast rises up to 800 meters in a horst; sculptured into massive blocks by desert wind erosions. From the southwest the Guinean Fouta Djalon mountains extend into Mali as a plateau and then slope eastward to end at Koulikoro, which lies northeast of Bamako, the capital (Fig. 1).

The Niger River is the most conspicuous geographic feature of Mali. After entering the country from the southwest it flows slowly northeastward for about 900 kilometers, through an area of relatively flat terrain, to Tomboctou at the edge of the Sahara Desert. During that trip, and especially between Mopti and Tomboctou, it spreads out into a gigantic inland delta of swamps and lakes. The river turns east after Tomboctou and may be navigated on small river-craft to Gao. Rapids discourage further progress. From Gao the river runs southeastward out of Mali into the Republic of Niger (Fig. 1).

Mali lies between the 10th and 25th parallels north. The southern half of that area is covered by various grades of tropical grassland while that part of the country north of the 17th parallel lies in the southern fringes of the Sahara Desert (Fig. 1,2). A transitional zone exists between the savanna and desert regions from the latitude of Gao to that of Tomboctou. South of the savanna the vegetation grades into the edge of the North Guinean forest as grassland-forest mosaics (Fig. 2).

The grasslands in the southern and central regions of the country - referred to as the south and north Sudanian savanna, respectively - are tropical, wooded types (Fig. 2). Usually the landscape is austere, but many tree species are found, including the Indian butter tree, nere, tamarind and baobab. In the more northern limits of this zone the acacia is predominant. The grassland in the northern regions, the Sahelian steppe, is xerophytic and characterized by stunted vegetation (short, hard, spiny grasses; scattered, small, acacia trees and spiny shrubs). The desert begins fairly abruptly beyond the bend of the Niger River. Vegetation in any form is rare within the desert, except in the scattered oases which are really fossil valleys with underground water near the surface (Fig. 2).

In the Sudanian and Sahelian zones the climate is tropical and based on alternate rainy and dry seasons; the dry season becomes longer as one moves north. Rain falls between June and October and is heaviest around August. The heaviest rainfall (1400mm per annum) occurs in the south. Isohyets then decrease northwards to about 700mm at the limit of the Sudanian zone. The isohyets of the Sahelian steppes lie between 300 and 600mm. The desert extends north of the 200mm isohyet (Fig. 4).

Extremes of temperatures, with the day and night temperatures sometimes differing by as much as 35°C, characterize the desert zone. The situation is less severe however for the rest of the country. The mildest period of the year for the entire country is in the middle of the dry season (December to February), a time when a cool but dry east wind - called harmattan - blows through the country. Figure 5 shows the range of isotherms for the country.

Mali has an estimated population of 5.9 million, most of whom live below the 17th parallel. The society is heterogenous and comprised of some twenty recognizable groups or tribes. These groups include the Bambara, Sarakhole, Malinke, Kassonke, Dialonke, Senoufo, Bobo, Degon and Songhay who traditionally live as farmers in small communities or average sized towns. There are also the Peul or Fulani, who form part of a race of nomads found throughout the West African Sahel, tending cattle for themselves and sometimes for others. Finally there are the Arab—Berbers, represented by the Maures and Tuaregs, who are considered animal breeders.

In recent times, there have been shifts in traditional outlooks and occupations in Malian society consequential upon, and suscribing to, increased urbanization, mild industrialization and tribal intermarriages. Bamako, with 200,000 inhabitants, is the largest urban center. However there are other cities which owe their importance to their rich historic past as centers of culture and commerce, as for examples Kayes (32,000), Mopti (33,000) Segou (32,000), Sikasso (22,000), Gao (20,000), Tomboctou (15,000), and Djenne (10,000). These cities play key roles in north-south trade between the Sahara and West African coastal communities (Fig. 3).

Mali is considered one of the major livestock producers and exporters in West Africa. In 1979, with a total grazing acreage of approximately 63,000,000 hectares, it had 5,000,000 cattle, 10,000,000 sheep and goats, 170,000 camels and about 500,000 horses and donkeys. The cattle population includes 2 major breeds; the predominant, humped Zebu (59%) and the humpless Ndama (29%). Zebu-Ndama crosses (12%) occur but are less common.

Animals are managed under 1 of 3 major management systems; sedentary, nomadic and transhumance husbandry. In the south, where conditions are generally favorable, sedentary husbandry predominates. The severe conditions in the rest of the country, on the other hand, make nomadic and transhumance livestock raising imperative. The Tauregs and the Peul, mentioned previously, are the major ethnic groups involved in the last 2 systems and practice their trade across the Sahelian and Saharan regions. It has been shown that the transhumance method is the preferred mode in cattle management (Dickey 1981).

It is pertinent to note that one of the main socio-economic events in the Malian calendar - the livestock crossing of the Niger at Diafarabe - is caused by the double needs of optimal utilization of pastures, as well as disease prevention under the transhumance and nomadic husbandry. During the rainy season, animals move north of the Niger to seek grazing lands. They thus avoid the humidity and drenched vegetation plus burgeoning parasite populations supposedly characteristic of that period of the year in the south. When the weather becomes too hot, later in the dry season, the herds move back south for more lush pastures. The tiny village of Diafarabe, ideally located at one of the narrowest places along the Niger, serves for this enormous crossing. The crossing itself takes several weeks to complete and provides opportunities for nomadic and transhumance families to reunite. Governmental veterinary workers use the opportunity to vaccinate the crossing herds for common diseases.

The Tick Species of Domestic Livestock in West Africa. A review of the literature of African ixodid ticks is easily approached by considering each genus (and to some extent, each species) separately. This allows for more specific appraisals of ecology and taxonomy.

Genus *Amblyomma* Koch. *Amblyomma* ticks are typically ornate individuals that exhibit 3-host biologies in which adults frequently feed on large domestic animals. Many species have been described from Africa and, due to their characteristically ornate scuta, they usually present few diagnostic difficulties (Rageau & Vervent 1953, Hoogstraal 1956).

Records show that 3 *Amblyomma* "species" have been previously described from Mali. These include *A. rufipes* (Giroud et al. 1957), *A. tholloni* (Santo Dias 1958) and *A. variegatum* (Girard & Rousselot 1945, Rousselot 1951, Lamontellerie 1960, Morel 1958, 1969, 1980). *Amblyomma rufipes* of Giroud et al. (1957) is now recognized as a synonym for *Hyalomma rufipes* Koch (see below). *Amblyomma tholloni* Neumann, the elephant tick, is parasitic on the African elephant, *Loxodonta africana*, and a few other wild animal hosts (Hoogstraal 1956) and will not be discussed further. However, *A. variegatum* (Fabricius), the tropical bont tick, is one of the most commonly encountered ticks of tropical Africa (Hoogstraal 1956, Macleod 1970, Pegram et al. 1981) and will be discussed further.

Amblyomma variegatum has been associated with zones of moderate to heavy rainfall in Africa. A minimum isohyet of 400mm is often required for the establishment of a stable population (Pegram 1976). Further, Centruier & Klima (1979) showed that moderately high temperatures (e.g., 20-30°C), and relative humidities of up to 98% favor the shortest life cycles and highest reproductive rates in the species. The latter authors specifically indicated that at 15°C and/or 70% relative humidities or lower, the life cycle was not completed.

In the drier portions of its range in Africa, where there is only a single rainy season in the year, *A. variegatum* is univoltine. Adults appear at the beginning of, and peak midway through the rainy season. The larvae and then the nymphs become more numerous as the dry season progresses (Wilson 1946, Matthysse 1954). In higher rainfall areas, the species is active throughout the year although adult peak populations still coincide with the height of the rains. In Kenya and Uganda, where there are 2 rainy seasons, 2 generations of *A. variegatum* may occur (Wilson 1953). Bergeon (1968) in Ethiopia, however, reported declines in *A. variegatum* adult populations during the period of heaviest rainfalls from July to September. A possible explanation may have been offered by Smith (1973) who noted the decreased survivability of all stages of the species after (experimental) immersion in water, a condition that may occur in heavily inundated field conditions.

The preferred host of adult _A. variegatum_, in all of its African range, is cattle (Hoogstraal 1956, Morel 1958). Elsewhere other hosts may be preferred, as for example in Yemen where it attacks camels in preference to cattle (Pegram et al. 1982). The species, in French West Africa, has been collected from cattle, sheep, goats, pigs, donkeys, hares, poultry, spurfowls and chamelion among others, although domestic carnivores are reportedly attacked by only nymphs and larvae (Morel 1958). On African cattle, it often occurs in great numbers. For example, an average of 438 adults per cow was obtained in the Jibat and Mecha districts of Ethiopia by Pegram et al. (1981). Immatures feed on a great variety of mammals and birds and, on occasions, reptiles (Hoogstraal 1956).

In Mali, _A. variegatum_ has been collected from "sick animals" at Baguineda (Girard & Rousselot 1945); cattle, sheep, swine, horses, donkeys, goats, _Atelerix adansoni_ and _Ichneumia albicauda_ at Bamako and Segou (Rousselot 1951); Zebu cattle and sheep at Nioro, Koulikoro and Sikasso (Morel 1958); and cattle, dogs, horses and a man at Sikasso, Kapala, Sanzana and Diou (Lamontellerie 1960). Immatures have been recorded from most domestic animals but other infrequent hosts are _Thryonomys swinderianus_, _Numida_ *meleagris* and *Francolinus* sp. (Lamontellerie 1960) as well as the jackal, pintade and man (Morel 1958). Lamontellerie (1960) also reported that his specimens of adult *A. variegatum* were collected between April and August, nymphs in April, May and November and larvae in November.

Genus *Aponomma* Neumann. African *Aponommas* are small, eyeless parasites of lizards and snakes (Hoogstraal 1956). None of the West African species from this genus prefer domestic animals as its primary host but they are discussed here because the tick collecting teams on this project picked specimens off snakes found close to cattle herds.

Aponomma "species" previously collected from Mali included *Ap. exornatum* from *Varanus exanthematicus* at Segou and *V. niloticus* at Sanzana (Lamontellerie 1960). *Aponomma latum* was collected from several snakes of the families Colubridae, Boidae, Elapidae and Viperidae, and in several localities including Sikasso, Kebeni, Diou and Kabiola, while *Ap. transversale* was taken from *Python regius*, along with *Ap. latum*, near the village of Kaboila (Lamontellerie 1960).

Aponomma exornatum Koch, the leguan tick, and *Ap. flavomaculatum* (Lucas), the monitor tick, have very similar scutal ornamentation, however the former can be distinguished by 2 spurs on the 1st coxa whereas the latter has only 1 spur (Tendeiro 1955). Both *Ap. latum* Koch, the snake tick, and *Ap. tranversale* (Lucas), the python tick, are inornate but, for distinctions, the scutum is incompletely chitinized (males) or notched posteriorly (females) in the latter species.

All these species may occur in great numbers and in all developmental stages on the same host (Lewis 1934, Hoogstraal 1956). Members of the genus were once thought to be markedly host specific (Hoogstraal 1956) but the Malian sightings above provided specific contradictions (Lamontellerie 1960). The latter author also reported collecting more than 1 species on the same host. Adults of *Ap. latum* were collected between March and July, nymphs from April to September and larvae in January, July and September (Lamontellerie 1960).

Genus *Boophilus* Curtice. Ticks of the genus *Boophilus* exhibit 1-host life cycles in which all stages, from larva to the engorged mated adult, confine their feeding to the same host. Only the females drop off to oviposit (Hoogstraal 1956). The males are small and yellowish and are frequently overlooked when the heavier pod-shaped females are picked off the hosts (Feldman-Muhsam & Shechter 1970).

There are presently 5 species in this genus worldwide: *Boophilus annulatus* (Say), *B. decoloratus* (Koch), *B. geigyi* Aeschlimann & Morel, *B. kohlsi* Hoogstraal & Kaiser, and *B. microplus* (Canestrini). Three of the 5; *B. annulatus*, *B. decoloratus* and *B. geigyi*; have been reported from West Africa and Mali records included the following: *B. annulatus* (Morel 1958), *B. decoloratus* (Morel 1958; Lamontellerie 1960), *B. palpoboophilus* decoloratus (Rousselot 1951, Santo Dias 1958) and B. geigyi (Aeschlimann & Morel 1965). Reliability on published records of B. decoloratus prior to 1965 are in doubt because Aeschlimann & Morel (1965) discovered that B. decoloratus, previously considered a single species, was actually composed of B. decoloratus (Koch) sensu stricto and B. geigyi Aeschlimann & Morel.

Boophilus annulatus was first described from Africa from Brazzaville, Zaire, under the name B. congolensis by Minning (1934). Hoogstraal (1956) synonymized both "species" under the older name B. annulatus (Say) after examining various collections of African ticks in European museums. Morel (1958) agreed with the synonymy and placed the origin of the species around the Mediterranean basin or near East. Both authors also agreed that the species occur in all African territories bordering the Gulf of Guinea and between the 'Congo' in the south and the Republic of Sudan in the north.

Boophilus annulatus primarily parasitizes cattle (Hoogstraal 1956) but Iwuala & Okpala (1977) reported significant infestations of horses and dogs in Nigeria. Some specimens from the Republic of Sudan came from a giant eland and a donkey (Hoogstraal 1956). In Mali, the species was recorded from cattle at Sotuba and Gouere (Bai) (Morel 1958). Usually the species is present in low numbers on the host but Iwuala & Okpala (1977) obtained figures of "above 20" adults per bovine and between 5 and 9 ticks per horse or dog.

Dipeolu (1975) reported the presence of the species in both wet and dry seasons and in all vegetational zones in Nigeria.

Boophilus decoloratus was thought to exist in all African countries south of the Sahara before the description of *B. geigyi* (Morel 1958). That observation may still be true since *B. decoloratus* have been recorded from several African countries including Tanzania (Yeoman & Walker 1967), Kenya (Walker 1974), Nigeria (Mohammed 1978), Ethiopia (Pegram et al. 1981) and Botswana (Paine 1982) after the description of *B. geigyi*. These records alone covered countries straddling most latitudes of sub-Saharan Africa.

In all these newer records, cattle appeared to be the primary host of the species, but sheep, goats, dogs, horses and donkeys were attacked. In the study in Botswana, South Africa, the numbers of adult ticks per bovine ranged from 1 to 802, with a mean of 64; as many as 426 female ticks were found on a single host (Paine 1982). The species also attacks a wide variety of wild animals including the buffalo, zebra, bushbuck, eland, hartebeest and gazelle (Walker 1974), as well as the warthog and jackal (Morel 1958).

Boophilus geigyi was described from a cow at Minankro, Ivory Coast and differs from *B. decoloratus* principally on its 4:4 hypostomal dentition as compared with the 3:3 arrangement in the latter species (Aeschlimann & Morel 1965). The species, according to the same authors, parasitizes larger livestock, especially cattle, and exists alongside *B. annulatus* in Ivory Coast, Dahomey, Ghana, Guinea, Upper Volta, Mali, Liberia, Nigeria, Senegal, Sierra Leone and Togo, and in Central Africa alongside *B. decoloratus*. Both Dipeolu (1975) and Mohammed (1978) have confirmed its presence in Nigeria, with Dipeolu (1975) noting its absence in the Nigerian arid Sudan savanna zone and predominance in the forest zone.

All 3 *Boophilus* species found in West Africa thus have cattle as the primary host and attack other hosts only infrequently. All 3 species may also be found on the same host, especially during the rainy season (Dipeolu 1975). Infestations of domestic ruminants other than cattle are usually very low in numbers per host and percentage of host population infested (Beaton 1939, Dipeolu 1975).

A definitive picture of the ecological preferences of the 3 species in West Africa cannot be ascertained from current literature. Aeschlimann & Morel (1965) contended that *B. geigyi* replaces *B. decoloratus* in sub-Sudan and Guinea savanna of West Africa, but Dipeolu (1975) reported *B. decoloratus* and B. *annulatus* from both the Sudan and Guinea savanna as well as the forest zones in Nigeria but *B. geigyi* from only, and predominantly in the forest zone. The latter author also found *B. annulatus* in relatively equal incidences in both dry and rainy seasons while the other 2 species were most numerous in the dry season. Before *B. geigyi* was distinguished from *B. decoloratus*, *B. annulatus* used to be found alongside "*B. decoloratus*", although in smaller numbers (Hoogstraal 1956).

Genus Hyalomma Koch. Ticks of this genus inhabit areas of comparatively inhospitable weather and poor vegetation, conditions which also affect host availability and survival (Hoogstraal 1956). A tendency toward intraspecific variation prompted early workers to erroneously create species out of genetically compatible but morphologically disparate materials. Mali records of *Hyalomma* ticks were not spared that trend.

The following *Hyalomma* 'species' have been associated with Mali: *H. brumpti* (Rousselot 1951), *H. dromedarii* (Morel 1958), *H.impeltatum* (Morel 1958, Lamontellerie 1960), *H. impressum* (Rousselot 1951, Morel 1958), *H. rufipes* (Morel 1958, Lamontellerie 1960), *H. rufipes glabrum* (Rousselot 1951), *H. savignyi impressa*, *H. s. intermedia* and *H. s. typica* (Girard & Rousselot 1945), *H. transiens* (Rousselot 1951, Giroud et al. 1957) and *H. truncatum* (Morel 1958).

Feldman-Muhsam (1954) synonymized *H. transiens* Schulze with *H. truncatum* Koch. Hoogstraal (1956) synonymized *H. s. impressa* of Girard & Rousselot (1945) and *H. rufipes glabrum* of Rousselot (1951) with *H. rufipes* Koch, *H. brumpti* of Rousselot (1951) with *H. impeltatum* Schulze & Schlottke and *H. s. intermedia* and *H. s. typica* of Girard & Rousselot (1945) with *H. truncatum* Koch. Later, Hoogstraal & Kaiser (1960) synonymized *H. marginatum* Koch, *H. rufipes* and *H. turanicum* Pomerantzev, arguing that the 3 are all geographical, though closely related, subspecies of *H. marginatum* Koch.

Hyalomma dromedarii Koch is an inhabitant of arid or semi-arid regions. Walker (1974) in Kenya and Liebsch & Sukari (1976) in Syria found the species in regions experiencing less than 250mm of rainfall annually. Delpy & Gouchey (1937) pointed out that the species seemed able to withstand extremes of temperatures of 0°C and 37°C common in desert night and day fluctuations, and Hoogstraal (1956) offered the opinion that it may be the most completely desert-adapted of all ixodid ticks. Morel (1958) considered the dromedary camel its original host but reported collections from Zebu cattle, horses, sheep and warthogs in French West Africa. Immatures are found on rare occasions on camels but, depending on availability, usually infest burrowing mammals such as hedgehogs, hares, rodents and occasionally lizards. Nymphs often attack cattle and horses in large numbers (Hoogstraal 1956). In Mali, adults were collected from Zebu cattle at Nioro, Tomboctou and Gao, warthogs at Niafunke, oryx at Tada and camels in the Adrar des Ifoghas (Morel 1958).

Hyalomma impeltatum Schulze & Schlottke is considered a Near-Eastern species that has extended its range from Iran and Arabia into central, western, northwestern and southeastern Africa (Hoogstraal 1956). Morel (1958) considered it the tick of the Sahel in French West Africa, as it often accounts for the greater proportion of *Hyalommas* collected from that region, and claimed it may be found alongside H. rufipes and H. truncatum in the north Sudan savanna. Unlike H. dromedarii though, it does not show any marked host predilections and adults engorge readily on most large mammals including Zebu cattle, sheep, goats, horses, camels, gazelles, caracals, rhinoceros and wildebeests (Morel 1958, Hoogstraal 1956). As many as 38 adult ticks per bovine were found in Kenya (Yeoman & Walker 1967). Immatures usually feed on rodents, hares, birds and humans (Hoogstraal 1956). In Mali, the species was collected from camels, cattle, sheep and goats at Bamako, Segou and Tomboctou (Rousselot 1951); oxen at Diou (Lamontellerie 1960); and from Zebu cattle and sheep in several places including Nioro, Bamako, Banamba, Segou, Gao and Tomboctou (Morel 1958).

Hyalomma impressum Koch is an authentic West African Hyalomma species that has not been recorded south of the equator or north of the Sahara desert but extended its range eastward into the Republic of Sudan (Hoogstraal 1956). It is common in areas of the French West African savanna experiencing between 500 and 1250mm of rainfall annually, and in close association with H. rufipes (Morel 1958). Cattle are considered the primary host of the adults while immatures prefer smaller mammals and birds (Morel 1958). Mohammed (1978) surmised that the species may be found all year round in Nigeria. In Mali, adults have been collected from cattle at Bamako and sheep and camels at Segou (Rousselot 1951) as well as from warthogs at Bani and Nioro (Morel 1958).

Hyalomma marginatum rufipes (Koch) is a sub-species of *H. marginatum* that prefers moderately xerophytic ranges where annual rainfall is between 300 and 1500mm (Morel 1958). It is often found in environments much drier that those preferred by *H. impressum* and is very abundant in both the Sahel and Sudan savanna (Morel 1958). Adults have been found on African cattle, sheep, goats, horses, donkeys and camels all year round (Macleod 1970, Morel 1980, Norval 1982). Birds may be the preferred host of the immatures of this 2-host tick (Morel 1958) but hares and rodents have been implicated (Norval 1982). In Mali, and under various synonyms mentioned previously, adults have been collected from cattle, sheep, camels, horses and *Myrmecocichla aethiops* at Bamako and Segou (Rousselot 1951); Zebu cattle and horses at Baguineda, Banamba, Niono and Douentza (Morel 1958); and from cattle at Diou (Lamontellerie 1960). Immatures have been collected from *Francolinus* sp. and sparrows at Nioro (Morel 1958). As indicators of its infestation potential, Pegram et al. (1981) collected an average of 60 adults per infested bovine in the Shire lowlands of Tigre, Ethiopia, while Paine (1982) reported 42 of 71 inspected cattle were infested in his Botswana study with from 1 to 25 adult ticks per host.

Hyalomma truncatum Koch is another widely distributed tick with xerophytic preferences in Africa although it appeared in some places, like Ethiopia, to be more tolerant of rainfall and altitude than *H. m. rufipes* (Pegram et al. 1981). In French West Africa, it is highly successful in both the Sahel and Sudan savanna, slightly less than H. impeltatum in the Sahel and more than any other Hyalomma in the Sudan (Morel 1958). Hoogstraal (1956) indicted that the species is rare or absent in forests or areas of year-round precipitation.

The species appears to have a wider host range than H. m. rufipes (Norval 1982). Host range for adult ticks includes cattle, horses, goats, sheep and dogs as well as wild animals (e.g., buffaloes, giraffes and lions) and birds (e.g., ostriches and vultures). Immatures have been reported from a wide variety of large animals, burrowing rodents and birds (Hoogstraal 1956, Morel 1958, Norval 1982). In Mali, adults have been collected from cattle, sheep, camels, donkeys and goats at Bamako and Segou (Rousselot 1951); cattle, sheep and horses at Nioro, Kati and Segou; warthogs at Niafunke and swine at Gao (Morel 1958). Immatures have been reported from dogs at Bamako and Segou (Rousselot 1951) and Francolinus sp. (Morel 1958).

Hyalomma truncatum usually occurs in very light infestations on its hosts. Iwuala & Okpala (1977) obtained 5-9 adults per infested bovine and 1-4 adults per infested horse, sheep or goat in Nigeria. In Ethiopia individual cattle infestations did not exceed 22 adult ticks (Pegram et al. 1981) while the mean infestation per infested bovine was 6 in Botswana (Paine 1982).

Genus Rhipicephalus Koch. Africa is considered the place of origin and/or point of dissemination of the genus Rhipicephalus (Hoogstraal 1956). Most species are endemic in Africa and there are more species in this than in any other ixodid genus present on the continent. Identification within the genus is not easy. Morphological characters (e.g., hypostomal dentitions and coxal spurs) which have been used quite efficiently in the taxonomy of other genera tend to be generalized structurally within this genus. When variations do occur, they are of dubious value since they are often induced by or patterned to combat - when deleterious - the tick's immediate environment.

Hoogstraal (1956) offered the following generalized observations of the genus. Rhipicephalids may be 2- or 3-host ticks in which immatures may parasitize the same hosts as adults or seek smaller or different animals. Host specificity is, usually, fairly wide. Birds and reptiles are rarely preferred. Ecological preferences are often quite restricted with relative humidity the most critical limiting factor. Vegetation type, length of rainy season and proximity to large bodies of water also affect the distributions of Rhipicephalus species.

The following Rhipicephalus 'species' have been previously associated with Mali: R. cuspidatus (Rousselot 1951, Morel 1956, Lamontellerie 1960); R. evertsi (Girard & Rousselot 1945, Rousselot 1951); R. e. evertsi (Morel 1958); R. guilhoni (Morel & Vassiliades 1962); R. lunulatus (Rousselot 1951); R. sanguineus (Rousselot 1951, Giroud et al. 1957, Morel 1958, Morel & Vassiliades 1962); R.

s. sanguineus and R. simpsoni (Lamontellerie 1960); R. simus senegalensis (Rousselot 1951); R. simus simus (Morel 1958, Lamontellerie 1960) and R. sulcatus (Rousselot 1951, Morel & Vassiliades 1962). As will become apparent below, and except for 3 species (R. cuspidatus Neumann, R. evertsi evertsi Neumann, R. simpsoni Nuttall) the true taxonomic statuses of the rhipicephalids cited above are quite unstable.

Rhipicephalus cuspidatus and R. simpsoni are of little importance to the livestock industry since they infest only wild or semi-wild animals. Rhipicephalus cuspidatus attacks, the warthog, Phacochoerus aethiopicus (which is incidentally much-hunted in West Africa), almost exclusively while R. simpsoni prefers cane rats, Thryonomys sp. and Choeromys sp., almost exclusively (Hoogstraal 1956).

Rhipicephalus evertsi evertsi is widely distributed through much of Africa. It has been found in the Sudan and Congo (Rousselot 1951), French West Africa (Morel 1958), Kenya (Yoeman & Walker 1967), Nigeria (Mohammed 1978), Ethiopia (Pegram et al. 1981)and Botswana (Paine 1982). Compared to its presence in eastern and southern Africa, R. evertsi evertsi is relatively uncommon in West Africa where it appears confined to the Sudan savanna zone (Morel 1958). In Botswana, South Africa, for instance, 61 of 71 inspected cattle were infested with from 1 to 47 (mean=13) adult ticks per animal (Paine 1982) whereas Iwuala & Okpala (1977) obtained only 1-4 ticks per infested cattle in Nigeria, although no prevalence figures were given. The preferred host in West Africa is the horse, on which the adults may be found around the perianal area. To lesser extents donkeys, cattle, sheep and goats may be attacked. Wild herbivores are rarely attacked as is usually observed in eastern and southern Africa (Morel 1958). Immatures may be found on the ears on the same horses preferred by adults, but other domestic and wild herbivores are often attacked (Hoogstraal 1956, Morel 1958). In Mali, the species has been collected from "sick animals" at Baguineda (Girard & Rousselot 1945) and cattle, horses, donkeys, goats and dogs at Bamako and Segou (Rousselot 1951).

Rhipicephalus lunulatus Neumann was reported from a cow at Segou by Rousselot (1951). Its taxonomic status was unstable for a while since Neumann (1911), Theiler (1947) and Hoogstraal (1956) have synonymized it with R. triscuspis Donitz. In more recent publications (Morel 1980, Pegram et al. 1981) the species has been resurrected and in a forthcoming publication by Pegram et al. (Hoogstraal 1983 pers. commun.) the distribution of the species has been determined to be most of Africa south of the Sahara.

Rhipicephalus mushamae Morel & Vassiliades, R. simus Koch and R. senegalensis Koch closely resemble each other morphologically, and the 3 species form what is known as the Simus group of ticks (Morel & Vassiliades 1964). Characters common to all males of this group include 4 roughly linear rows of large scutal punctations in a field of very fine interstitials and obsolescent posterior scutal grooves.

According to Morel & Vassiliades (1964), the original descriptors of R. muhsamae, R. simus is endemic in South and East Africa, while the former species replaces it in the Congo basin and west of the Nile, up to Senegal in West Africa. They pointed out that R. muhsamae prefers tropical and sub-tropical savanna zones and at times the southern Sahel steppe, while R. senegalensis, appearing to be more hygrophilic, has a preference for sub-equatorial, Guinean savanna.

Adults of both R. muhsamae (Morel 1980) and R. senegalensis (Hoogstraal 1956) have been collected from a wide variety of ungulates and carnivores in Africa including cattle, donkeys, dogs, jackals and hedgehogs. Immatures feed primarily on rodents. The adults of R. simus simus previously collected in Mali at Nioro and Bamako (Morel 1958) and Sikasso and Bougoula (Lamontellerie 1960) have been re-identified as R. muhsamae (Morel & Vassiliades 1964). Rousselot (1951) collected R. senegalensis from cattle, swine, sheep, dogs, warthogs and Thrynomys swinderianus at Bamako and Segou.

In a treatise on African ticks, Morel & Vassiliades (1962) described what they called the "Rhipicephalus of the Sanguineus group" that included 5 Rhipicephalus species found in Africa; R. sanguineus (Latreille), R. guilhoni Morel & Vassiliades, R. sulcatus Neumann, R. turanicus Pomenrantzev & Matikasvili and R.

pusillus Gil Collado. According to these authors the first species exist in West Africa. Characters shared by all males of this group of ticks include prominent pitlike posterior scutal grooves and 4 roughly linear rows of medium to large scutal punctations that are often obscured by interstitials.

Rhipicephalus sanguineus, the kennel tick, has been regarded for some time now as probably the most widely distributed tick species in the world (Cooley 1946). It inhabits practically all countries between the 50°N and 35°S parallel and its distribution is influenced considerably by human cultural patterns and man-made microhabitats (e.g., buildings) (Hoogstraal 1956, Paine 1982). Morel & Vassiliades (1962) speculated that the locale of the original wild race is probably the peri-saharan steppe of Africa. Adults of this species have been found on domestic cattle, sheep and goats and all stages have been recorded from dogs. More generally, all stages may be found on domestic carnivores. Only adults are found on wild herbivores and carnivores, while immatures develop on myomorph rodents or insectivores (Morel & Vassiliades 1963).

Records of *R. sanguineus* in Mali prior to Morel and Vassiliades' publication in 1962 are of doubtful value since part of what was once considered the homogenous *R. sanguineus* population was then shown to contain a new species, *Rhipicephalus guilhoni*. Records show that Girard & Rousselot (1945) collected *R. sanguineus* specimens from "sick animals" at Banguineda while Rousselot (1951) collected from dogs at Bamako; and swine, horses, sheep, goats, herissons, jackals and gazelles at Segou. Lamontellerie (1960) found the species on dogs, cats, panthers, hares and *Sylvicapra grimmia* at Sikasso, Louloni, Diou and Sanzana. The last author claimed he collected the adults between April and July, nymphs in May and larvae in July. Morel & Vassiliades (1962) reported collections from dogs at Bamako, Tomboctou, Kaore and Bandiagara, and from *Hyaena crocuta* at Mondoro (Douentza).

The type specimens of *R. guilhoni* were described from a collection of ticks from sheep at Nioro, Mali by Morel & Vassiliades (1962). Host preferences for adults were given as wild and domestic ungulates and carnivores while immatures were said to engorge on rodents. The West African Sahelian steppe, corresponding to 250 to 1250mm isohyets, was identified as the prefered habitat, and the species was considered more thermophilous than *R. sanguineus*. Seasonal activity of the species, according to the descriptors, commenced with the rains and diminished during the dry season. The species is said to be univoltine. Mohammed (1978) has since identified the species in Nigeria among tick collections made between June and September from the hooves of bait cattle in the Nigerian Sudan savanna. They occurred in low numbers and in ecological zones parallel to that preferred by *R. sulcatus* which was found in the more humid Guinean savanna.

Hoogstraal (1956) synonymized the *R. sulcatus* previously reported from Mali by Rousselot (1951) with *R. sanguineus* (Latreille). He pointed out that *R. sulcatus* Neumann is a tick in which the scutal punctutations are so regular and uniform that the piliferous series are obscured. This taxonomic definition of *R. sulcatus* was questioned by Morel & Vassiliades (1962) with descriptions of what they believed to be specimens of *R. sulcatus* from Mali, West Africa. They argued that Hoogstraal's (1956) definition is too restrictive for diagnostic description of the species in West Africa since *R. sulcatus* ticks included individuals in which the piliferous series is displayed to varying extents against a background of differently sized interstitials. They contended that while the piliferous series is quite obscured in specimens from carnivores, they are obvious in specimens from large herbivores. In further support of their contention they claimed that the mounted genital apertures of their Mali specimens had massive sclerites similar to those prepared by Feldman-Muhsam (1956) from species of *R. sulcatus*, *sensu* Hoogstraal (1956). Characters of genital apertures, including sclerite features, have been shown to breed true intraspecifically (Adler & Feldman-Muhsam 1948).

The West African *R. sulcatus*, *sensu* Morel & Vassiliades is said to parasitize domestic and wild ungulates and carnivores in Sudanian and Guinean savanna belts that experience rainfalls of 750 to 1500mm annually. Hoogstraal (1956), on the other hand, gave a restricted host list for R. sulcatus Neumann that included only a hare and 2 leopards.

It is quite obvious from the preceeding review that information on the tick fauna in the Republic of Mali lacks a number of essential aspects. Glaringly it lacks coordination and depth both in terms of what is covered and its extent. The number of tick species in Mali on which information is available is deceptively low when compared with comparable parasite data from countries with which Mali either shares common boundaries or trades livestock (Morel 1958, Mohammed 1978). Presumably Mali harbors many tick species now only identified elsewhere among its neighbors. More information needs also to be obtained and consolidated concerning the known fauna; its distributions, ecologic preferences, population dynamics and possible relationships to diseases of animals and humans.

Synonyms in nomenclatures of the tick species known to occur in Mali as seen in the preceeding review suggested a need for updating currently available information. Exact and continuously updated information is a pre-requisite for effective vector control during planning, implementation or evaluation stages.

The review also demonstrated the need for locally available, reference tick collections and literature in Mali for present and future investigators. Most of the ticks previously collected in Mali are in personal or museum colletions in Europe where they are often part of pooled collections from colonial French West Africa.

Many of the available literary works did not specify Mali per se but simply referred to erstwhile geographic communities which encompassed what is currently referred to as the Republic of Mali.

It is therefore the intention of this study to assemble a body of information on the tick fauna in the Republic of Mali (with particular emphasis on species diversity, distribution and ecology), while at the same time producing micrographs of available taxons. In addition, identified specimens will be preserved for reference and teaching purposes. These steps will, hopefully, help in any tick and tick-borne disease investigations and control programs.

CHAPTER III

MATERIALS AND METHODS

The Collection of Ticks in the Republic of Mali. The investigation reported here was part of an intensive research and training program - Vector-borne Hemoparasites of Livestock and Their Vectors Project, 1977-1981 - in Mali. Partners in the program included the Government of the Republic of Mali, Texas A&M University (TAMU) and the United States Agency for International Development. This segment of the program was aimed at documenting the species of ticks parasitizing domestic livestock in Mali.

Between 1977 and 1979, ticks were collected intermittently by members of the project belonging to the Tsetse and Trypanosomiasis Research Division. Later, with the assistance of Drs. P. D. Teel and T. M. Craig from TAMU, an 18-month program of intensive tick collecting beginning January, 1980, was organized in concert with a serological survey of tickborne diseases in cattle. This intensive collecting was carried out by teams trained and directed by Dr. J. G. Matthysse between January and June 1980. Overall, ticks were collected from a total of 114 separate locations by various personnel on the project between June, 1977, and June, 1981 (see Acknowledgements).

During the intensive collecting period, sites were selected to explore as many ecologic variables (vegetation, rainfall, temperature and topography) as possible. A few sites were selected for the simultaneous collection of ticks and blood from the same hosts. Eight sites were selected for routine sampling to provide data on seasonal distributions. Results of the serological analysis and seasonal distribution will not be included in this report.

Cattle were the targeted hosts at the start of the intensive collecting period in Janurary 1980, but other domestic animals including sheep, goats, camels, horses, and dogs were inspected for ticks intermittently throughout the life of the project, 1977-1981. On occasion, wild animals (e.g., warthogs and snakes) and birds (e.g., *Francolinus* sp.) were inspected for ticks. In a few instances ticks were collected from pastures, herd premises and clothing of herdsmen.

In the field, ticks were plucked from animal hosts by hand or with hard brushes. All ticks from individual animals were put together in separate numbered vials containing 70-80% ethyl alchohol and labels were inserted into each vial at the collection site to record the date, host and geographic location. A total of 23,769 preserved tick specimens were then crated and shipped to the Department of Entomology, TAMU, for identification.

Identification and Documentation of Ticks. Materials arriving from the Republic of Mali were unwrapped a "collection" at a time. Each "collection" represented all specimens from a single animal or non-animal source collected on a single visit. Published taxonomic keys (see below) were then used to establish the identity of the specimens using direct visual observations and/or light microscopy. The taxonomic keys used included those prepared for the *Amblyomma* (Rageau & Vervent 1953), *Boophilus* (Feldman-Muhsam & Schechter 1970), *Hyalomma* (Koch 1844, Schulze 1919, Schulze & Schlottke 1929), *Rhipicephalus* (Elbl & Anastos 1966) and the ticks of the Sudan (Hoogstraal 1956). These were supplemented with descriptive information on specific species or related groups of species including essays on the *Hyalomma* (Kratz 1940, Delpy 1949) and the "*Sanguineus*" and 'Simus' groups of *Rhipicephalus* ticks (Morel & Vassiliades 1962). Further taxonomic information was obtained from descriptive reports of investigators who re-examined type specimens as a means of resolving taxonomic problems in closely related species. The reports of Feldman-Muhsam (1954) and Morel & Vassiliades (1962) were in this category.

Taxonomic determinations were compared with reference materials obtained from the United States National Tick Collection formerly located at the Rocky Mountain Laboratory, Hamilton, Montana, and now housed at the Smithsonian Institute, Washington, D. C., and the collections of Dr. Pierre C. Morel of Institut d'Eleveage et de Medecine Veterinaire des Pays Tropicaux, Maisons-Alfort, France. Consultations with Drs. Carleton Clifford and James Keirans at the Rocky Mountain Laboratory, Dr. Pierre Morel of France, Dr. Harry Hoogstraal of the United States Navy Medical Research Unit 3 in Cairo, Egypt, and Professor Manning

Price of the Department of Entomology, TAMU, were invaluable in these determinations.

Adults in each "collection" were sorted to species, with males and females of the same species being put into the same vial, while immatures were sorted to genus. Vials of identified ticks carried their field collection records as well as their TAMU laboratory identification labels. Both field and laboratory data were catalogued and cross-referenced.

Ticks of doubtful taxonomic status from individual hosts were retained in separately labelled vials. Specimens in this category fell into 2 groups: (a) those ticks that had lost anatomical parts considered essential to taxonomic determinations (e.g., hypostomes), and (b) those that did not clearly belong in any established taxonomic category. Specimens in group (a) could generally be determined to genus. Photographs of specimens in group (b) were produced by light and electron microscopy and detailed descriptions prepared.

Preparation and examination of female gonopore tissue (FGT). The FGT of selected females, representing groups determined as species or sub-species, were cleared and mounted on glass slides for examination as follows. A standing clearing solution was made from the following proportions of clearing agents and solvents:

50 parts 25% solution of polyvinyl alcohol in distilled water at room temperature,

25 parts 85% lactic acid and,

25 parts liquidefied phenol.

The female gonopore tissue was obtained by excising the female genital aperture and that part of the genital tube attached tangentially to it and into which it opens. The excised tissue was placed in 2-3 ml of the clearing solution in a glass vial. The tissue was either left overnight at room temperature or heated without boiling, for 2-5 minutes in a fume hood. The length of time, in the latter case, is dependent on the degree of chitinization. Thus poorly chitinized materials (e.g., Boophilus species) required only about 1-2 minutes while the more heavily chitinised Rhipicephalus specimens required up to 5 minutes. The FGT, after clearing, is washed by shaking in distilled water for about 10 seconds and then transfered into a drop of Hoyer's mounting medium. This initial drop of mountant helps to clear the murky white residue left on the tissue by the clearing mixture in contact with water. The FGT may also be trimmed while in this initial mountant, thus avoiding drying or shrivelling of tissue. The specimen is finally mounted in a fresh drop of mountant under a glass coverslip.

Mounted materials were photographed with an Orthomat-W® automatic microscope camera in combination with an Ortholux-1® stereomicroscope.

Scanning electron microscopy (SEM). A well-formed, unengorged, male and female pair, exhibiting clearly the taxonomically important characters of each of the 20 identified species or subspecies, was chosen for SEM examination and photography. A similar representative pair was also chosen from each group of ticks of undetermined taxonomic status. All representative pairs were cleaned, as described by Corwin et al. (1979), using Leech Multi-purpose Glue®.

Cleaned ticks were dehydrated for 2 hours each in a sequence of 80%, 95% and 100% ethyl alcohol. After overnight retention in a reagent grade, absolute ethyl alcohol, they were subjected to critical point drying in a DCP-1® critical point dryer using CO_2 as replacement fluid. Specimens were then coated with gold-palladium in a Technics Hummer 1 sputter coater and photographed with a JEOL JSM-25 scanning electron microscope at 15 KV.

The following features of each specimen were photographed:

1. Overall dorsal view
2. Overall ventral view
3. Gonopore area
4. Dorsal view of capitulum
5. Ventral view of capitulum
6. Legs I-IV, especially the coxae
7. Haller's organ
8. Spiracular plate
9. Posterior area around the anus

A small fly-wheel rotator was developed and used in the scanning electron microscope that allowed for a complete (360°) rotation of the specimen being viewed, along with a 120° tilt on the vertical axis (90° up + 30° down) (Fig. 567-570). This unique arrangement permitted the photographing of both surfaces of the same tick by simple rotation. Previously, since ticks are dorsoventrally flattened, only 1 surface of a tick could be viewed during a single SEM presentation.

CHAPTER IV

RESULTS

General Overview of Ticks Collected from the Republic of Mali. Ticks were collected in Mali between June, 1977, and May, 1981. From that exercise, 23,769 ticks, of all stages, were received at the Department of Entomology, TAMU (Table 1A). All the ticks came from animal hosts except 158 that were obtained from pasture sweeps, ground collections and herdsmen's clothing (Table 1A, under "Other sources").

Distribution of hosts. For the entire survey period in Mali, ticks were collected from 1,248 cattle including 264 Zebu, 267 Ndama and 8 Zebu-Ndama (ZN) cross. No specific information was provided as to the breed of 709 cattle (cattle of unspecified breed or CUB). Other domestic animals from which ticks were taken included 19 sheep, 8 goats, 3 horses, 5 camels and 17 dogs (Table 1A). Wild animals reported with ticks included 7 warthogs, 2 hares, 2 snakes and 2 guinea fowl (Table 1A, 3D).

The distributions of rainfall and vegetational types in Mali run in east-west belts that roughly vary with the latitudes (Fig. 2,4), with rainfall decreasing and vegetation becoming sparser with increasing latitudes. Three broad hygrophytic regions (zones) may be recognized in the areas covered by the collection teams; the areas of Mali below the 12°N (Zone I), the area between the 12 and 14th latitudes (Zone II), and the part of the country between the

14 and 16th latitudes (Zone III). Collecting teams did not venture into the Sahara north of the 16°N latitude as the research objectives centered on ticks and tick-borne diseases of livestock. The arid north supports very few livestock and is sparsely populated (Dickey 1981).

Zone I enjoys moderately high annual rainfall of 1200-1400mm (Fig. 4) and is covered by the North Guinean forest and the Sudano-guinean mosaic vegetation (Fig. 2). Zone II is covered largely by the Sudanian savanna, and has annual rainfall of 800-1200mm (Fig. 4). In western Mali though, either the Sudano-guinean mosaics or the North Guinean forest may be seen (Fig. 2). Zone III is mostly xerophytic and Sahelian, with annual rainfall of 200-800mm (Fig. 4). A narrow belt of Sudano-sahelian transition vegetation exists along the southern limits of the last zone (Fig. 2).

Data pertaining to the collected ticks were considered, in several instances, in 3 separate groups according to the geographic sources of the ticks in Mali and in line with the hygrophytic zone classification above. Two of the instances involved total tick counts (Table 1B-D) and multi-species infestation of cattle by adult ticks (Table 4B-D). The arrangement afforded useful comparisons of, and postulations about, the population dynamics of ticks and tick hosts within the zones.

Zone I had 36 Zebu, 101 Ndama, 8 ZN cross and 119 CUB, for a total of 264 (or 21.15%) cattle. Other major host-types in the zone included 10 sheep, 2 dogs and 4 warthogs. None of the camels or horses reported during the survey came from this zone (Table 1B). Zone II had 76 Zebu, 160 Ndama, 378 CUB (614 or 49.2% of all cattle) and 13 dogs, among other hosts listed in Table 1C. Only the camel, among major domestic animals, was not represented in the zone. Zone III provided 152 Zebu, (370 or 29.65% of all cattle), all 6 camels, 7 goats and 6 sheep. No ZN cross and only 6 of 267 Ndama came from Zone III.

The zonal distribution of cattle breeds reported was not deliberate. It merely reflected 2 important socio-economic trends in the livestock economy of Mali: (a) most of the Zebu cattle in Mali are traditionally associated with the more northern vegetational zones where nomadic or transhumance husbandry predominates while the Ndama has always been associated with the sedentary husbandry of the south, and (b) there is an ongoing introduction of trypano-resistant cattle breeds (e.g., the Ndama from the south) into the Sudan region of Mali in an effort to combat the ravages of tsetse-borne trypanosomiasis (Dickey 1981).

The proportional distributions of the Zebu, Ndama and overall cattle hosts only, by zone and for the survey, are graphically presented in Fig. 18. A breakdown of the more infrequent sources of ticks, as encountered during the survey and by zone, is given in Table 3D.

Total tick count. The total count of ticks, of all stages and from all sources in Mali, was 23,769, with approximately 95% (22,656) from cattle (Table 1A). No more than 250 ticks were picked from all members (combined) of any of the other host-types reported (Table 1A).

For the survey the mean number of ticks (MNT) per animal for the major host-types nationwide included 24.25 (Zebu), 15.64 (Ndama), 19 (ZN cross), 18.55 (cattle), 10.63 (sheep), 9.62 (goat), 6.0 (horse), 11.6 (camel) and 14.71 (dog) (Table 1A). Wild host-types, among which 2 or more individuals were reported, had relatively higher MNT than most domestic hosts. The MNT for the hare, warthog and snake, for example, were 16, 19.85 and 42, respectively (Table 1A, 3D).

More than half of the total tick count, 54.67%, came from Zone II (Table 1C) while Zone I (Table 1B) and Zone III (Table 1D) contributed the remainder almost equally, 21.61% and 23.43%, respectively. In all 3 zones cattle accounted for most of the ticks collected; 4,929 or 95.88%, 12,474 or 95.58% and 5,253 or 94.19% in Zones I, II and III, respectively (Table 1B-D).

The Zebu recorded the highest zonal MNT, 39.81, among all breeds of cattle and in any of the zones, in Zone II (Table 1C) and had its lowest MNT, 17.45, in Zone III (Table 1D). The Ndama recorded lower MNT in Zones II and III than Zone I, 12.43 and 12.3 versus 20.89, respectively (Table 1B-D). The MNT in Zone I for the Zebu, Ndama and ZN cross, 20.06, 20.89 and 19, respectively, were relatively close (Table 1B). Graphic representations of the MNT for cattle and its breeds, nationwide and by zone, are depicted in Fig. 19.

Adult tick counts. Most of the cattle reported during the survey had adult ticks. Adult ticks were collected from 263 Zebu, 261 Ndama, all 8 ZN cross and 689 CUB for a total of 1,221 or 97.84% cattle infestation (Table 1A, Fig. 22). Most other host-types had equally high proportions of their (reported) populations infested by adult ticks, e.g. 17 of 19 sheep, 4 of 5 camels, 6 of 7 warthogs and all dogs and horses. Only 3 of 8 goats had adult ticks (Table 1A).

The mean number of adult (MNA) ticks per individual of the major host-types nationwide included 16.9 (Zebu), 9.6 (Ndama), 19 (ZN cross), 13.1 (cattle), 8.8 (sheep), 22.3 (goat), 6 (horse), 13 (camel), 7.1 (dog) and 8.5 (warthog) (Table 1A). The MNA for the dog and warthog were the only ones less than half of their respective MNT figures, 7.1 and 8.5 to 14.71 and 19.85 respectively, while the other major animal hosts had MNA figures that were at least two-thirds or higher, than their MNT figures.

Zone II accounted for more than half, 8,821 or 52.76%, of all the adult ticks collected in Mali followed by Zones III, 4,792 or 28.52%, and I, 3,151 or 17.89%, respectively (Table 1B-D). The

Zebu had considerably higher zonal MNA, in Zones II and III, 19.18 and 17.15, respectively, than the Ndama, 7.63 and 12.33, respectively (Table 1C,D, Fig. 25). The latter breed enjoyed its lowest zonal MNA, 7.63, in Zone II; a region where the Zebu recorded its highest, 19.18 (Table 1C). Both cattle breeds had relatively close MNA, 12.53 (Ndama) and 11.0 (Zebu) in Zone I (Table 1B).

The zonal MNA for the dog increased from Zone I through III, 4.5, 7.31 and 8.5, respectively, but no clear trends were discernable, zonewise, among other host-types (Table 1B-D).

Immature tick counts. There were 6,312 nymphs and 629 larvae among the 23,769 ticks received from Mali. Most of the immatures, 5,941 nymphs and 438 larvae, were collected from cattle although none were collected from the ZN cross (Table 1A). Tick nymphs were more the commonly found on other domestic animals such as sheep, goats a camels than tick larvae (see below). Wild hosts, especially birds, often carried relatively heavy infestations of immatures without harboring any adult ticks. The lone *Streptonelia senegalensis* examined, for example, had 39 larvae and 34 nymphs and no adult ticks.

Tick nymphs were found on relatively high proportions of the domestic animals that were reported; for example, 35.29% of the dogs, 47.36% sheep and 62.5% goats (Table 1A). Among the cattle breeds, more of the Ndama, 44.56%, harbored immatures than the

Zebu, 28.03% (Table 1A, Fig. 23). High proportions of infestations by nymphs were also encountered among the wild hosts reported, as for example all the hares and guinea fowls and 5 of 7 warthogs had nymphs (Table 1A, 3D). As non-animal sources, collections from 13 pasture sweeps netted 145 nymphs (Table 3D). The mean number of nymphs (MNN) per individual of the major host-type nationwide included 12.58 (cattle), 4.89 (sheep), 2 (goat) and 2.69 (dog). The Zebu had a considerably higher MNN nationwide, 23.41, than the Ndama, 13.32 (Table 1A, Fig. 26).

In Zone I, high and almost equal proportions of the Zebu (69.44%) and Ndama (67.32%) were infested by nymphs, at almost equal MNN 12.96 and 12.01, respectively (Table 1B, Fig. 23). In Zone II the proportion of the Zebu that was infested remained relatively high, 56.58%, while it dropped sharply among the Ndama to 31.25%. In addition, there was a sharp rise to 31.72 MNN in the Zebu while the Ndama experienced only a slight increase to 15.24 MNN (Table 1C, Fig. 23,26). In Zone III only 6 of the 152 Zebu and 1 of the 6 Ndama examined had nymphs and at very low MNN, 7.33 (Zebu) and 6.0 (Ndama). In contrast, most small-sized, non-cattle hosts that were reported from the same Zone had nymphs, including 5 of 8 goats, all 6 sheep, 1 of 2 warthogs and the only hare.

Tick larvae, with 629 specimens, constituted only 2.65% of all the ticks collected from Mali. Cattle, with 438 specimens, accounted for about two-thirds and the dog, with 101 specimens, one-sixth, although no larvae were collected from either host-type in Zone III (Table 1D). Many of the domestic animals reported including the ZN cross, goats, horses and camels had no larvae and relatively few specimens were collected from the lone sheep (7 specimens) and cat (1 specimen) that were found infested (Table 1A, 3D).

Nationwide very low and almost equal proportions of the Zebu, 4.92%, and Ndama, 4.49%, were infested by larvae but the mean number of larvae (MNL) per animal was much higher for the infested Zebu, 17.31, than Ndama, 6.92 (Table 1A. Fig. 24-27). All of the infestations of the Zebu by larvae, except 1, occurred in Zone II; where 15.79% of the breed that were examined was infested at 18.58 MNL. The Ndama had relatively equal proportions of reported animals infested in Zones I, 4.95%, and II, 4.39%, but its MNL in Zone II, 8.0, was far below the Zebu figure for the same zone, and only slightly higher than in Zone I, 6.14 (Table 1B-C, Fig. 24, 27).

<u>Species/Sub-species Identities of Adult Ticks from Mali</u>. All the ticks collected in the Republic of Mali, except for 2 specimens, belonged in 5 genera of the Ixodoidea and were distributed as follows; 10,365 (43.61%) <u>Amblyomma</u>, 7,468 (31.42%) <u>Hyalomma</u>, 4,358 (18.33%) <u>Boophilus</u>, 1,576 (6.63%) <u>Rhipicephalus</u> and 86 (0.36%) <u>Aponomma</u> (Table 2). The 2 different specimens belonged in the

genus Haemaphysalis Koch (a female from a dog) and Argas Latreille (a larva from a bird, Francolinus sp.), respectfully (Table 2).

More males than females were collected in all the genera except Boophilus, with Amblyomma registering the highest male/female ratio, 4.5:1, and Rhipicephalus the lowest, 1.2:1. Boophilus had a 1:2.5 male:female ratio (Table 2).

There were more Hyalomma adult ticks, 44.21%, than any other genus, but the contributions from Amblyomma, 24.69%, and Boophilus, 22.67%, were sizeable and almost equal to one another. The significant observation about Rhipicephalus, which provided 8.51% of all adult ticks, was the almost equal representation of the males (742) to females (629). Aponomma specimens were few, 0.27% of all adults, but they were also collected from only 3 animals (Table 2).

Approximately 90.73% of all the nymphs collected in Mali belonged in the Amblyomma and only the Boophilus, 7.18%, had any other sizeable representation. The Amblyomma also provided the largest proportion of larvae, 79.95%, but larval Rhipicephalus, 18.12%, and Hyalomma, 3.50%, were also sizable (Table 2).

The 5 principal genera of the Ixodoidea yielded 18 species and 2 sub-species that were readily identified by procedures previously enumerated. The species and sub-species were A. variegatum, Ap. flavomaculatum, Ap. latum, B. annulatus, B. decoloratus, B. geigyi, H. dromedarii, H. impeltatum, H. impressum, H. marginatum rufipes, H. nitidum, H. truncatum, R. cuspidatus, R. evertsi evertsi, R.

guilhoni, R. lunulatus, R. muhsamae, R. sanguineus, R. senegalensis and R. sulcatus. There were also 3 groups of rhipicephalid ticks, henceforth referred to as Rhipicephalus group(s) #9 and 10 and specimen #11 respectively, whose group-based combinations of morphological characters appeared to be distinctive.

Based on adult ticks only and excluding the partly classified Rhipicephalus specimens, the following numbers of tick species were collected from the major host-types; 15(Zebu), 15(Ndama), 5(ZN cross), 17(cattle), 12(sheep), 5(goats), 4(horses), 4(camels), 3(dogs) and 5(warthogs) (Table 1A). Rhipicephalus group(s) #9, 10 and specimen 11 were collected from cattle (all 3 group types), sheep (1), goats (1) and a hare (1) (Table 1A, 3D). All other sources of adult ticks encountered during the survey had single species infestations, except for a snake with 3 tick species (Table 3D).

In the following species by species report, references to "main morphological features" are to the list of 9 features of each specimen that were enumerated in the Materials and Methods section and which were consistently photographed by SEM.

Amblyomma variegatum Fig. 6, 18-55, 476. Amblyomma variegatum was the only member of its genus found among the ticks from Mali and its main morphological features are shown in Fig. 38-55. The ornate scuta (not demonstrable in the micrographs) and the relatively large size of both sexes of the species aided in its identification.

The unmounted FGT of A. variegatum has a deep, wide, square-bottomed opening; and a pair of converging, lateral sclerotized bars that may not be clearly visible (Fig. 43). In the cleared and mounted FGT, the atrial commissure is characteristically much wider than the vagina tube and atrial sclerites occur as curved, pigmented, tapering blades. The sclerotized bars, that are often visible externally and lateral to the FGT opening, are the medial edges of the atrial sclerites (Fig. 476).

Amblyomma variegatum was encountered in all vegetational zones covered by the collecting teams in Mali, ranging from the North Guinean forest in the south through the Sudanian grasslands into the northern Sahelian steepes (Fig. 6). This distribution covered areas between 400 and 1400mm isohyets and experiencing between 27 and 29°C average daily temperatures.

More adults of A. variegatum were collected than of any other tick species in Mali, 3,408 males and 746 females or 24.62% of the adult tick count (ATC) (Table 2). Most of the specimens, 3,389 males and 719 females, were collected from cattle at 8.2 MNA and 40.14% prevalence for the period of the survey (Table 3A). The species accounted for 25.24% of all adult ticks collected from cattle, the largest proportion by any of its 17 infesting species. The MNA and prevalence figures obtained from the Zebu, 8.83 and

41.57%, respectively, were considerably higher than those from the Ndama, 4.24 and 34.47%, respectively (Table 3A). Seven of the 8 reported ZN cross carried *A. variegatum* at 9.6 MNA.

Adult *A. variegatum* was found on only 2 other host-types in Mali, sheep and goats, with the respective MNA and prevalence figures of 5.67 and 15.97%, and 11.0 and 25.0%. The species accounted for 11.26% and 32.84% of adult ticks collected from sheep and goats, respectively; the 3rd highest count of adults among 12 tick species infesting sheep and 1st among 5 on goats (Table 3A). A total of 5 males and 2 females were also collected from human clothing and 2 pasture sweeps (Table 3D).

Aponomma flavomaculatum Fig. 7, 56-73, 477. *Aponomma flavomaculatum* specimens were collected from a *Varanus* sp. lizard at Negale (1 male, 2 females) and an unnamed snake at Yebe (6 males, 2 females). Both locations are in the Sudanian savanna in Mali (Fig. 7). The species was 1 of 2 belonging to this genus present in the tick collections and SEM micrographs of its main morphological features are presented in Fig. 56-73. The scuta are ornate in both sexes, but the ornate patterns are not demonstrable in the micrographs.

The unmounted FGT of *Ap. flavomaculatum* has a deep, rather rectilinear opening and a pair of lateral, sclerotized bars (Fig. 61). The cleared, mounted FGT has a wide flat-bottomed atrial commissure and moderately long, tapering, unpigmented atrial sclerites (Fig. 477). The vagina is much narrower than the atrium.

Aponomma latum Fig. 7, 74-91, 478. Aponomma latum specimens were collected from an unnamed snake at Yebe, 23 males and 5 females, and another at Banguineda, 7 males. Both locations are in the Sudanian savanna (Fig. 7). The snake at Yebe also carried Ap. flavomaculatum (see above). Aponomma latum is inornate in both sexes and its main morphological features are presented in Fig. 74-91.

The unmounted FGT in the species has a narrow, smoothly rounded, semicircular opening and thin, inconspicuous, lateral, sclerotized bars (Fig. 79). The cleared and mounted FGT has a smoothly-rounded, shallow, atrial commissure and stubby, unpigmented atrial sclerites (Fig. 478). The atrium is distinctly wider than the vagina.

Boophilus annulatus Fig. 8, 92-109, 479. Boophilus annulatus was 1 of 3 species from this genus found in Mali. Variations observed in its hypostomal dentition (Fig. 547, 548) are discussed elsewhere (page 54) in this report with comparative observations from other Boophilus species from both Mali and North America. The main morphological features of the species are presented in Fig. 92-109.

The unmounted FGT of the species has a wide, semi-circular opening that has lateral cuplike depressions (Fig. 97). The floor of each cup is unstriated and often wrinkled. A central knob exists between the cups on the anterior lip. The cleared and mounted FGT has a narrow commissure that is continuous laterally with the margins of the cups (Fig. 479). The atrium is distinguishable from the distal (vagina) tube but not much wider. The materials of the lateral cups that are visible externally extend inwards to locate laterally on the atrium, more or less like conventional atrial sclerites.

Adults of B. annulatus were not found in great numbers in Mali, 148 males and 384 females, but they were found in a wide variety of vegetational zones (Table 2, Fig. 8), including the North Guinean forest south of Bougouni, Sudano-guinean mosaics and the Sudanian savanna. North of the Sudan, it thrived only along the Niger delta. These regions of Mali have isohyets of between 600 and 1300mm and isotherms of 27-28°C. No specimens were collected west of 10°E longitude.

Except for 3 females from sheep, a male from a dog and a male and 2 females from pasture, all the B. annulatus specimens came from cattle (Table 3A,D) among which its prevalence was 14.9%, at 2.82 MNA. It was, at 3.23%, only the 10th most numerous adult tick of 17 species collected on cattle. Its prevalence and MNA figures were higher among the Ndama, 15.91% and 3.19, respectively, than the Zebu, 8.99% and 2.21, respectively. The species accounted for 5.34% and 1.19% of adult ticks collected from the Ndama and Zebu, respectively (Table 3A).

The main morphological features of B. microplus are presented in SEM micrographs Fig. 146-164. This latter species is closely related to B. annulatus morphologically especially in the features of its FGT and hypostomal dentition (see Literature Review) and is presented here for comparative purposes. Boophilus microplus does not occur in Mali, however, there have been indications that it may be spreading northwards in Africa from its South African habitat (Hoogstraal 1956).

Boophilus decoloratus Fig. 9, 110-127, 480. Boophilus decoloratus was 1 of 2 Old World boophilids, which distinctively possess a setated tubercle on the 1st palpal segment. The other was B. geigyi. Main morphological features of B. decoloratus are presented in Fig. 110-127, and variations seen in its hypostomal dentition (Fig. 541, 542) are discussed elsewhere (page 54) in this report.

The unmounted FGT of B. decoloratus has a narrow, deep, semi-circular opening with a shinning depressed anterior lip (Fig. 115). The cleared and mounted FGT has a slightly thickened, V-shaped atrial commissure and no atrial sclerites. The atrium is only marginally wider than the distal (vagina) tube (Fig. 480).

Adults of B. decoloratus were the least common of the 3 boophilids found in Mali with only 20 males and 55 females collected or 1.97% of the Boophilus specimens (Table 2). They were found in widely scattered locations in both the Sudan and Sahel (Fig. 9) with 500-1500mm isohyets and 27-28^{c} isotherms.

Only 1 host other than cattle, sheep, had B. decoloratus infestations and at a very low prevalence of 5.26%. Proportionately more Zebu, 4.12%, were found infested than the Ndama, 2.65%, and as in the case of B. annulatus, none of the ZN cross carried the species (Table 3A).

Boophilus geigyi Fig. 10, 128-145, 481. Boophilus geigyi was the most abundant of all 3 boophilids found in Mali with 854 males and 2,150 females or 78.74% of all the boophilids (Table 2). It comprised 17.85% of all adult ticks collected and the 3rd most common adult tick of all species encountered in Mali. Its main morphological features are presented in Fig. 128-145, and variations sometimes seen in its hypostomal dentition (Fig. 543, 544) are discussed elsewhere (page 54) in this report.

The unmounted FGT has a squat, semi-circular opening with a depressed anterior lip (Fig. 133). The cleared and mounted FGT has a thickened, squat or semi-circular atrial commissure and no atrial sclerites. The unpigmented atrium is only marginally larger than the distal (vagina) tube (Fig. 481).

Boophilus geigyi was found, with few exceptions, in every location in which A. variegatum was found (Fig. 6) in Mali, although the dates and/or hosts very often differed (Fig. 10). It was thus found in all vegetational zones ranging from the North

Guinean forest to the Sahel, areas with 500-1400mm isohyets and 27-29°C isotherms.

Adults of B. geigyi were found on more host-types than A. variegatum that included cattle, sheep, goats, dogs and snakes. It was the only Boophilus species found on the ZN cross (Table 3A). The species was most common among cattle (42.31%) compared with sheep (21.05%), goats (12.50%) and dogs (5.88%), and more common among the Ndama (46.77%) than the Zebu (37.08%). Five of the 8 reported ZN cross examined were infested (Table 3A). The MNA for the species on the cattle breeds were 5.09 (Zebu), 6.04 (Ndama) and 4.20 (ZN cross). Adult B. geigyi were the most numerous (29.84%) of the 15 species infesting the Ndama, 4th (11.34%) of the 15 infesting the Zebu and 3rd (18.33%) of the 17 found on cattle (Table 3A).

Supernumerary hypostomal dentition in the Boophilus. The linear rows of denticles found on the hypostome of Boophilus ticks have been used extensively in their taxonomy. This characteristic is commonly expressed as a ratio of the number of rows on each half of the hypostome. Boophilus decoloratus is said to have a 3:3 hypostomal dental arrangement while the remaining 4 species, B. geigyi, B. kohlsi, B. annulatus and B. microplus have 4:4 arrangements (Aeschlimann & Morel 1965). Hoogstraal (1956) however reported that B. decoloratus specimens sometimes have a 3.5:3.5 arrangement in which an incomplete row of denticles appear medially on each half of the hypostome.

There were *B. decoloratus* specimens with the 3.5:3.5 hypostomal dentition among the ticks from Mali and they come from widely scattered locations in the country (Fig. 544). Supernumerary dental conditions were also seen among both the *B. geigyi* (Fig. 546) and *B. annulatus* (Fig. 548) specimens again from widely scattered locations in Mali and in the form of 4.5:4.5 dental arrangements. In all cases the numbers of denticles present in the 2 extra (medial) rows are usually unequal and vary between specimens of the same species. All specimens came from cattle with 1 male and 3 females of *B. decoloratus* from 4 animals, 5 males and 19 females of *B. geigyi* from 19 animals and 2 males and 5 females of *B. annulatus* from 7 animals. These specimens constituted about 5.48%, 0.8% and 1.4% of adults of the 3 species respectively that were collected from cattle (Table 3A).

Supernumerary dentitions of the 4.5:4.5 variety were also found in low numbers (no percentage counts were calculated) among collections of *B. annulatus* and *B. microplus* kept at the Acarology Laboratory at TAMU. These laboratory stocks were from North and Central American sources.

Hyalomma dromedarii Fig. 11, 164-181, 482. There were only 4 specimens of *H. dromedarii* in the Mali tick collections, a male each from a Zebu at Tienfala and another at Kayes, along with a male and a female from a camel at Dilly. The locations are in the Sudan and Sahel grasslands (Fig. 11). The main morphological features of this large glossy tick are shown in Fig. 164-181.

The unmounted FGT of the only female in the collection has a very narrow, V-shaped opening with the anterior lip, lying between the arms of the V, slightly raised or convex (Fig. 169). Two converging lobes, covered by unstriated integument, appear lateral to the opening. A female tick (provided by N.I.H. Rocky Mountain Laboratories) was used for our "cleared and mounted FGT" series. It had a very narrow, V-shaped atrial commissure bounded laterally by large, pigmented sclerites. The atrium was distinct, and larger than the distal (vagina) tube.

Hyalomma impeltatum Fig. 11, 182-199, 483. *Hyalomma impeltatum* was 1 of the few tick species with very wide host ranges as based on the results of this survey only. Its identification presented no particular difficulties and its main morphological features are presented in Fig. 182-199.

The unmounted FGT in *H. impeltatum* has a V-shaped opening (Fig. 197) that is broader and shorter-armed than the FGT in *H. dromedarii* (Fig. 169). The area between the arms of the "V" is raised. Two converging lobes, covered by relatively unstriated integument, occur lateral to the opening. The cleared and mounted FGT has U-shaped (as opposed to a V-shaped) atrial commissure with short arms. The atrial sclerites are poorly pigmented, short, moderately wide and shaped like an inverted comma. The atrium is short and only marginally wider than the distal (vagina) tube (Fig. 483).

The species was collected almost exclusively north of latitude 13°N (Fig. 11), in areas of Mali belonging in the north Sudanian savanna and Sahel and experiencing 300-900mm annual rainfall and 30°C isotherms. A few specimens, however, were collected in southern Mali at the Ranch de Madina. Curiously, the species was not collected west of the longitude 10°E.

There were 565 males and 279 females of H. impeltatum in the Mali collection, about 11.34% of all Hyalomma adults and 5.02% of all adult ticks (Table 2). These specimens were collected from cattle, camels, goats, sheep and horses at respective MNAs of 9.43, 7.00, 4.00, 1.00 and 1.00. The species' MNAs on cattle and camel were the highest for any species found on these hosts.

Hyalomma impeltatum was found more among the Zebu, 15.36%, than the Ndama, 2.27%, but the respective MNA figures, 8.95 and 8.33, were similar and among the highest for species infesting both breeds (Table 3A). The ZN cross was not infested. Adults of H. impeltatum were the 4th most numerous adult ticks (8.26%) of 15 species collected from the Zebu, 8th (1.99%) of the 15 from Ndama and 7th (4.87%) of the 17 species from cattle (Table 3A).

Hyalomma impressum Fig. 12, 200-217, 484. Hyalomma impressum is the native West African member of this genus. Its identification posed no particular problems except when mixed with H. marginatum rufipes. Both species possess densely punctate scuta but the circumspiracular pilosity of the latter (as opposed to the relatively glabrous condition of the area in the former) helped in their separation. The main morphological features of H. impressum are shown in Fig. 200-217.

The unmounted FGT in the species has a V-shaped opening in which the anterior lip is depressed (Fig. 205). A wide tubercle lies immediately anterior to the lip depression. The cleared and mounted FGT has a wide, smoothly rounded, semicircular commissure (Fig. 484). The atrial sclerites are pigmented, curved, moderately long and tapering. Both the atrial commissure and the distinctive atrium are much wider than the distal (vagina) tube.

Hyalomma impressum was found in hygrophytic situations similar to H. impeltatum although the preponderance of locations were slightly south and east of (and hence wetter than) the collections of the latter species. Hyalomma impressum was collected more frequently along the delta of the Niger (Fig.12). These areas are Sudano-guinean, Sudanian and Sudano-sahelian in vegetation with 400-1000mm isohyets and 28-30°C isotherms. There were no collections of the species west of the 10°E longitude.

A total of 358 males and 119 females of H. impressum were collected, representing 6.41% of all Hyalomma adults and 2.83% of all adult ticks (Table 2). These specimens were from cattle, sheep and camels, with cattle accounting for all but 3 specimens. The prevalence and MNA figures of the species among cattle were 8.09% and 4.69, respectively. Seventy-seven of 101 infested cattle were

CUB with others being 22 Zebu and 2 Ndama (Table 3A). No collections were recorded from ZN cross. Adults of *H. impressum* were the 6th (2.91%) most numerous 17 species found infesting cattle (Table 3A).

Hyalomma marginatum rufipes Fig. 13, 218-235, 489. Adults of *H. m. rufipes* were the most common *Hyalomma* in the Mali tick collection, both in numbers of specimens collected and hosts infested (see below). Identification was slightly difficult when collections contained *H. impressum* since the scuta in both species are densely punctate. Separation is facilitated by the fact that the circumspiracular area of *H. m. rufipes* is pilose as opposed to the relatively glabrous condition of the area in *H. impressum*. The main morphological features of the species are shown in Fig. 218-235.

The unmounted FGT of the species has a shallow, wide opening with an anterior lip that bears a wide tubercle (Fig. 223). The cleared and mounted FGT has a very wide and shallow atrial commissure with thickened margins (Fig. 489). The wide atrium in truncated towards the vagina tube distally and the atrial sclerites are short, thick and pigmented.

The species was found in all areas of Mali visited by the collecting team, ranging from the North Guinean forest in the south, through the Sudan, to the more northern parts of the Sahel, areas with 300-1400mm isohyets and 27-30°C isotherms (Fig. 13).

There were 2,369 males and 920 females of H. m. rufipes among the Mali ticks, representing 44.19% (1st) of all adult Hyalomma and 19.54% (2nd) of all adult ticks (Table 2). These specimens came from the highest number of host-types, 6, infested by any species encountered during the survey. Hosts included cattle, sheep, goats, horses, camels and warthogs (Table 3A).

Hyalomma m. rufipes infested more cattle, 626 or 50.16%, than any other tick species, but its 5.19 MNA ranked only 4th behind those of H. impeltatum (9.43), A. variegatum (8.2) and B. geigyi (5.65) on the same host. The species had higher respective prevalence and MNA among the Zebu, 59.18% and 8.73, than the Ndama, 48.48% and 3.61 (Table 3A). Half (4) of the reported ZN cross examined were infested at 4.50 MNA. It was the most numerous (31.06%) among adult ticks of the 15 species found on the Zebu and the 2nd most numerous of the 15 found on the Ndama. Hyalomma m. rufipes infested the goat and camel at 7.50 and 6.6 MNA, respectively, figures higher than those for cattle. It infested other host-types with MNAs lower than cattle (Table 3A).

Hyalomma nitidum Fig. 14, 398-415, 488. This species was first described from the Cameroon, West Africa (Schulze 1919), but the type specimens were re-examined and compared with those of H. truncatum by Feldman-Muhsam (1954). The specimens from Mali that have been identified as H. nitidum agree in many morphological respects with these previous descriptions but differed in 2 important features. First, the FGT of the Mali specimens has an opening whose anterior lip is entirely tuberculated (Fig. 403) whereas in H. nitidum and/or H. truncatum, according to Feldman-Muhsam (1954), a depressed area preceeds (i.e., lies posterior to) the tubercle on the anterior lip (Fig. 421). Secondly, leg I in both sexes of the Mali specimens are annulated but were described as unicolorous in the original essays on H. nitidum. Annulations are present in the proximal segments of the other legs, especially in the female, among the Mali specimens. The main morphological features of H. nitidum, as identified from Mali, are shown in Fig. 398-415 and its detailed descriptions are given in the section entitled "Descriptions of Selected Tick Specimens".

Specimens of H. nitidum were found predominantly in southwest Mali from Falea to Farabale (Fig. 14). Other locations included Dialafara, Tienfala, Segou and Madina near Diassa. It obviously survives in the moderately humid North Guinean forest or Sudano-guinean mosaics, with extensions along the Niger waterway into the Sudan. These areas in Mali experience 900-1300mm annual rainfall and 27 or 28°C average daily temperatures.

Only 52 males and 14 females of H. nitidum were collected representing only 0.89% of all adult Hyalomma or 0.39% of all adult ticks (Table 2). They were collected from 13 Ndama, 15 CUB, a Zebu and a warthog. The prevalence and MNA figures among the Ndama were 4.92% and 2.38, respectively (Table 3A).

Hyalomma truncatum Fig. 15, 416-433, 485-487. This species was first described from Senegal, West Africa (Koch 1844) but the holotype and a lectotype female were re-described by Feldman-Muhsam (1954). The specimens from Mali that were identified as *H. truncatum* agreed in many morphological respects with these previous descriptions but differed on the characters of the FGT. The cleared and mounted FGT of the Mali 'species' has (1) a rectilinear atrial commissure that is about twice as wide as the vaginal tube and closely applied to the atrial sclerites and (2) long, moderately thick, pigmented atrial sclerites. A pair of setae are invariably located in the depressed anterior lip of the commissure (Fig. 485-487). In contrast, the FGT of the lectotype female of *H. truncatum* examined by Feldman-Muhsam (1954) and a female obtained by TAMU from the Institut d'Elevage et de Medecine Veterinaire des Pays Tropicaux, Maisons-Alfort, France, have (1) semi-circular commissures that are (a) only marginally wider than the vaginal tube and are (b) located far anterior of the atrial sclerites and (2) short, thin, unpigmented atrial sclerites (Fig. 536). In addition, no setae are found in the depressed anterior lip of the commissures. The main morphological features of *H. truncatum*, as identified from Mali, are shown in Fig. 416-433 and detailed descriptions are given in the section entitled "Descriptions of Selected Tick Specimens".

The "*H. truncatum*" species in Mali was 1 of 4 collected from all the areas of Mali visited by the collecting team. The others were A. variegatum, B. geigyi and H. m. rufipes. It was thus found, albeit with varying degrees of success, in a very floral zone from the North Guinean forest in the south, through the Sudan, to the Sahel in the north (Fig. 15). These regions have isohyets of 300-1400mm and isotherms of 27-30°C.

There were 2,013 males and 748 females of "H. truncatum" in the entire tick collection, accounting for 36.11% of all Hyalomma adults (2nd only to H. m. rufipes) and 16.41% of all adult ticks collected (the 4th most numerous) (Table 2). These specimens were collected from 3 host-types, cattle, sheep and horses, at respective prevalences of 44.79%, 31.58% and 33.33% and respective MNA figures of 4.87, 5.17 and 3 (Table 3A). The respective prevalence and MNA figures among the Zebu, 53.18% and 6.13, were considerably higher than those among the Ndama, 35.98% and 3.96. Seven of the 8 reported ZN cross were infested at 4.14 MNA (Table 3A). Adults of H. truncatum were the 2nd, 3rd and 4th most numerous of the 5, 10 and 15 species infesting the ZN cross, Zebu and Ndama, respectively (Table 3A).

Rhipicephalus cuspidatus Fig. 16, 236-253, 460. Previous descriptions of R. cuspidatus, the West African warthog tick, (Neumann 1906, Theiler 1947, Hoogstraal 1956), did not mention the presence of a sub-adanal shield in the male, a structure that is well-developed in the specimens from Mali. Dr. Carleton Clifford, then Scientist Director of the Rocky Mountain Laboratory, examined and confirmed the existence of the shield on the holotype which is currently housed at the British Museum of Natural History, London. This and other main morphological features of the Mali specimens are presented in Fig. 236-253.

The unmounted FGT of this species has a wide, shallow, semicircular opening whose anterior lip is moderately tuberculated (Fig. 241). The cleared and mounted FGT has a very wide, shallow atrial commissure and rod-like, unpigmented atrial sclerites (Fig. 460). The atrium is much wider than the distal (vagina) tube.

All the *R. cuspidatus* specimens, except a male from an Ndama, were from the warthog. There were 14 males and 18 females, representing only 2.41% of all adult *Rhipicephalus* collected during the survey, although 62.75% of all adult ticks were from the warthog (Table 2, 3A). Six of the 7 warthogs reported in the survey were infested with 5.33 MNA. The warthogs were from 3 sites located south of the 13°N latitude that have 700-1400mm annual rainfall (Fig. 16).

Rhipicephalus evertsi evertsi Fig. 16, 254-271, 491. Specimens of *R. e. evertsi* were collected from only 5 animals (all cattle) for a total of 12 males and 24 females, representing only 2.63% of all adult *Rhipicephalus* (Table 2). The 5 hosts (4 CUB and a Zebu) came from locations within the Sudanian savanna that experience 600-1100mm annual rainfall and 27 or 28°C isotherms (Fig. 16). These hosts carried 7.2 MNA for the species, the highest of any

Rhipicephalus species on cattle (Table 3A). The main morphological features of the adults are shown in Fig. 254-271.

The unmounted FGT of the species has a V-shaped opening with converging sclerotized bars placed laterally (Fig. 259). The anterior lip of the opening, between the arms of the "V", is slightly convex. The cleared and mounted FGT has a flat-bottomed, V-shaped atrial commissure (Fig. 491). The commissure and its distinctive atrium are both much wider than the distal (vagina) tube.

Rhipicephalus guilhoni Fig. 17, 272-289, 492, 493.

Rhipicephalus guilhoni was described as a new species from specimens collected from sheep at Nioro, north-western Mali (Morel & Vassiliades 1962). There is, however, morphological evidence from the materials from Mali suggesting the existence of 2 races of this indigenous rhipicephalid: race I, sensu Morel & Vassiliades, which occurred principallly in the northwest and race II, which was found in the northeast, especially around Sokolo (Fig. 17). Both races were often collected in more southern geographic locations in Mali from trade cattle and slaughtered animals in abatoirs, indicating that this southern distribution is only an extension from the northern regions.

Individuals of race I are relatively small specimens. They have dark-red scuta that may appear two-toned in the male because the darkly toned anterior part of the scutum usually lightens to an orange or burnt-orange color posteriorly, especially on specimens collected from smaller ruminants. The unmounted FGT has a wide, U-shaped opening in which the arms of the U are relatively long. The cleared and mounted FGT also has a wide U-shaped, atrial commissure and a relatively shallow atrium; both structures are much wider than the distal (vagina) tube (Fig. 492). The atrial sclerites are unpigmented, strongly curved externally and excavated medially.

Race II individuals are, on the average, medium sized specimens in which the scuta are invariably unicolorous, dark brown, irrespective of the host. Adanal shields are massive, with very distinctive straight posterior and posterointernal margins that meet at almost perfect right angles (Fig. 288). Legs I to IV, in the male, appear beaded, segment to segment, and become progressively more massive from I to IV (Fig. 274). The spiracular plates, especially in the male, are very wide along their entire lengths (Fig. 286). The main morphological features of Race II are shown in Fig. 272-289. The unmounted FGT has a narrow V-shaped opening in which the posterior portion of the "V" appear pinched (Fig. 277). The cleared and mounted FGT has a U-shaped atrial commissure of about equal width with the distal (vagina) tube. The atrial sclerites are unpigmented, curved externally but not excavated medially (Fig. 493).

Races I and II of *R. guilhoni* totaled 124 males and 102 females in the Mali collection, representing 16.48% of all adult *Rhipicephalus* and the 3rd most numerous *Rhipicephalus* species. The specimens were collected from 4 host-types (cattle, sheep, goats and horses), which represented more host-types infested than any other rhipicephalid.

Roughly 5.13%, 21.1% and 15.0% of reported cattle, sheep and goats were infested with 2.97, 2.25 and 8.0 MNA. One of the 3 horses reported had 8 males and 3 females. No specimens were collected from the ZN cross, and only 1.14% of the Ndama was infested. *Rhipicephalus guilhoni* was collected from 8.61% of the Zebu, the highest percentage infestation by any of the 5 *Rhipicephalus* species found on the breed (Table 3A).

Rhipicephlaus lunulatus Fig. 16, 380-397, 499, 500. This was the 2nd most numerous *Rhipicephalus* species in the Mali collection with 282 specimens (Table 2). Its main morphological features are shown in Fig. 380-397.

The unmounted FGT of *R. lunulatus* has a wide, deeply emarginated, U-shaped opening with a slightly depressed, anterior lip (Fig. 385). The cleared and mounted FGT has a wide, flat-bottomed, shallow atrial commissure and non-pigmented, stubby, sub-triangular sclerites (Fig. 499-500). The vagina is much smaller than both the atrium and (atrial) commissure.

There were 115 males and 167 females of *R. lunulatus* in the Mali collection, representing 20.56% of all adult rhipicephalids (Table 2). The specimens were from 2 host-types, cattle (CUB and Ndama) and sheep, at prevalences of 4.25% and 15.79%, respectively.

The MNA figure was higher for cattle, 5.33, than sheep, 3.33 (Table 3A). Almost all of the infestations by R. lunulatus occurred south of the 13°N latitude in Mali in areas of Sudanian savanna, Sudano-guinean mosaics and North Guinean forest, areas that experience 800-1400mm annual rainfall (Fig. 16).

Rhipicephalus muhsamae Fig. 16, 290-307, 494. This species was 1 of 2 rhipicephalids of the Simus group that were found in the Mali collection (the other was R. senegalensis). The main morphological features of R. muhsamae are shown in Fig. 290-307 and those of R. simus, the 'type' species of the group, are shown in Fig. 344-361 for comparative purposes. Specimens of R. simus which purportedly occurs only east of the Nile in Africa (Morel & Vassiliades 1964), were obtained from the NIH Rocky Mountain Laboratory, Montana (courtesy Dr. C. Clifford), and the collection of East African ticks of Prof. Manning Price at Texas A&M University.

The unmounted FGT of R. muhsamae from Mali has a smoothly rounded, semicircular opening with a pair of converging, sclerotic bars along its lateral arms (Fig. 295). The anterior lip is pinched inwards and therefore convex. The cleared and mounted FGT has a deeply emarginated atrial commissure and a pair of wide, pigmented, divergent atrial sclerites. The medial edges of the sclerites are visible externally in the unmounted gonopore as sclerotic bars. The atrium is distinct and much wider than the vagina (Fig. 494).

There were 197 specimens, 100 males and 97 females, of *R. muhsamae* in the Mali collection, representing 14.37% of all adult rhipicephalids collected and the 5th most numerous *Rhipicephalus* species (Table 2). The specimens were found almost exclusively on cattle, the exception being 4 males and a female collected from 2 warthogs. Infestations of both the Zebu and Ndama were low and similar, with respective prevalence/MNA figures of 3.75%/3.6 and 4.92%/3.38. No specimens were collected from the ZN cross.

Most of the *R. muhsamae* specimens were collected from between the 12 and 15°N latitudes, and from the western to almost the eastern border of Mali (Fig. 16). The vegetational zones include the western portions of the Sudano-guinean mosaic, the Sudan savanna and the Sahel, areas that experience between 500 to 1000mm of rainfall annually.

Rhipicephalus sanguineus Fig. 17, 308-325, 495, 496. The kennel tick, *R. sanguineus*, was collected from dogs in many of the urban centers of southern, central and north-western Mali, and from cattle, sheep and a donkey in locations within the Sudan and Sudano-guinean mosaics having 600-1100mm isohyets (Fig. 17). Its main morphological features are shown in Fig. 308-325.

The unmounted FGT of *R. sanguineus* has a wide U-shaped opening, with sclerotic bars along its lateral arms (Fig. 313). The cleared and mounted FGT has a wide-bottomed U-shaped atrial commissure and stubby, triangular, unpigmented atrial sclerites. The distal (vagina) tube is conspicuously narrower than the atrium and its commissure (Fig. 495). In samples from hosts other than the dog, however, the atrial commissure is slightly narrower and not as wide-bottomed (Fig. 496).

There were 121 males and 77 females of R. sanguineus in the Mali collection, which represented 14.44% of all adult Rhipicephalus and the 4th most numerous among Rhipicephalus species (Table 2). Collections from dogs totaled 59 males and 59 females at 88.24% prevalence and 7.87 MNA. Four of 19 reported sheep were also infested with 12.5 MNA but the infestation of cattle was extremely low at 1.12% prevalence and 1.57 MNA (Table 3A). Six females of R. sanguineus were collected from a donkey and a female each came from a herdsman's clothing and off the ground.

Rhipicephalus senegalensis Fig. 16, 326-346, 497. This species belongs in the Simus group of rhipicephalids and its main morphological features are shown in Fig. 326-346. The unmounted FGT has a wide-mouthed V-shaped opening with sclerotic bars sometimes visible laterally (Fig. 331). The cleared and mounted FGT has a wide, deeply emarginated atrial commissure and pod-shaped, atrial sclerites that taper slightly at their anterior end (Fig. 497). The distal (vagina) tube is much narrower than the atrium and its commissure.

Rhipicephalus senegalensis was the most numerous Rhipicephalus species in the Mali collection, accounting for 22.17% of all adult rhipicephalid. All but 1 collection was obtained south of the

13°N latitude, indicating optimum habitat in the south Sudanian savanna, Sudano-guinean mosaics and North Guinean forest vegetational zones that have isohyets of 800-1400mm (Fig. 16).

A total of 194 males and 110 females were collected from 2 host-types, cattle and warthogs (Table 2). The species was not found on either the Zebu or ZN cross, but infested 8.33% of all the reported Ndama cattle and was the most numerous of the 6 *Rhipicephalus* species found on the breed (Table 3A). Nine males and 2 females were collected from a warthog during the survey.

Rhipicephalus sulcatus Fig. 17, 362-379, 499. There were very few specimens of this species among the ticks collected in Mali; only 4 males and 3 females were collected from sheep at Fonsebougou, which is in the Sudan savanna (Fig. 17). There was, however, a group of specimens, *Rhipicephalus* group #10 (see below), that had some similar morphological features. The features of the cleared and mounted FGT of the Mali specimens of *R. sulcatus* agreed very well with those of the FGT prepared by Feldman-Muhsam (1956) and accepted for the species by subsequent workers including Morel & Vassiliades (1962) who had questioned the current taxonomic status of the species in Africa.

The unmounted FGT of *R. sulcatus* has a very narrow and shallow, U-shaped opening with a pair of sclerotic bars sometimes seen on the lateral arms (Fig. 367). The cleared and mounted FGT has a very narrow U-shaped commissure with large, ovoid and pigmented sclerites (Fig. 499). The distance separating the sclerites medially is much less than their individual width and the length and width of each sclerite are slightly subequal. The distal (vagina) tube is wider than the atrial commissure but less than the atrium. Other main morphological features of R. sulcatus as seen in Mali are presented in Fig. 362-379.

Rhipicephalus group #9 Fig. 17, 434-451, 501-503. This group of partly classified specimens consists of ticks that are morphologically close to R. sanguineus (Latreille) but which differ in some features. Both sexes in this group, for example, possess spiracular plates with long, thin tails (Fig. 448 males, 449 females); whereas in R. sanguineus long, thin tails are seen in males (Fig. 322) and not females (Fig. 323). The atrial commissure of the FGT of the group is also very narrow and the (atrial) sclerites are deeply pigmented, moderately long and wide, and separated by a distance less than their individual width (Fig. 501-503). In contrast, the FGT of R. sanguineus usually possesses a wide atrial commissure and unpigmented, thin and widely separated (atrial) sclerites (Fig. 495). A detailed description of the adults of these specimens is given in the section entitled "Descriptions of Selected Tick Specimens". The main morphological features are shown in Fig. 434-451 and 3 cleared and mounted FGT from the group are presented in Fig. 501-503.

The 1st few specimens of this group, a male and 2 females, were collected from a CUB cow at Sokolo in central northwest Mali. Eventually 11 males and 11 females belonging to the group were collected form 4 host-types, cattle, sheep, goat and hare (Table 2, 3A), and at locations in both the Sudan (Tienfala and Segou) and Sahel (around Niono and Sokolo) (Fig. 17).

Rhipicephalus group #10 Fig. 17, 452-469, 504-506. This group of partly classified specimens consists of ticks that are morphologically close to *R. sulcatus* Neumann but which differ in some details. Uniform, regular scutal punctations in both sexes of these ticks, for example are confined to the central field between the cervical areas only (Fig. 452, 453) whereas such scutal punctations are entire within the marginal and scapulary grooves in *R. sulcatus* (Fig. 362,363). The FGT in *R. sulcatus* also has narrowly separated, massive, ovoid atrial sclerites as well as a very narrow (atrial) commissure (Fig. 499) whereas the FGT in these ticks has widely separated, stubby atrial sclerites and a moderately wide (atrial) commissure (Fig. 504-506). The adanal shields in *R. sulcatus* are also narrow triangles that are elongated at their posterointernal angle (Fig. 378) whereas the shields in these ticks have a relatively wide postanal portion, and all margins smoothly rounded posteriorly (Fig. 468). A detailed description of the adults of these specimens is given in the section entitled "Descriptions of Selected Tick Specimens". The main morphological features are shown in Fig. 452-469 and 3 cleared and mounted FGTs from the group are presented in Fig. 504-506.

There were 45 males and 20 females of Rhipicephalus group #10 among the Mali collection from cattle at 3 locations in southern Mali, Niaradougou, Sikasso and Madina near Diassa (Fig. 17). These areas are within the Sudanian savanna, Sudano-guinean mosaic or North Guinean forest and have annual rainfalls of 800-1300mm.

Rhipicephalus specimen #11 Fig. 16, 470-475. Only a male of this Rhipicephalus material was found, on an Ndama at Falea in southwest Mali. It shares many morphological features with the Ziemanni group of Rhipicephalus ticks (sensu Zumpt 1943 and as reviewed by Hoogstraal 1956), especially Rhipicephalus ziemanni Neumann, R. aurantiacus Neumann and R. cuneatus Neumann. (The last 3 named species have been synonymized, in part or together, by various authors including Hoogstraal 1956, Morel & Mouchet 1958). Among the features this specimen shares with its speculated relations are short and obsolescent marginal grooves and numerous scutal punctations. It differs in having no scapulary grooves and outwardly drawn scapulae and by possessing obsolescent posteromedian and paramedian grooves. Its numerous scutal punctations is also light, not dense regular as in the others. A detailed description of this tick is given in the section entitled "Descriptions of Selected Tick Specimens" and main morphological features are depicted in Fig. 470-475.

<u>Multi-species Infestations of Major Livestock by Adult Ticks</u>. Many of the animals reported during the Mali survey were infested by more than 1 ixodid species based on identifications of adult ticks only. The highest numbers of tick species found infesting a single animal among each domestic host-type were cattle, 7; sheep, 5; goat, 5; horse, 3; dog, 2; and camel 3, and among cattle breeds Zebu, 7; Ndama, 6 and ZN cross, 5.

The highest number of tick species found on an individual Zebu was 7 in Zone III, 6 in Zone II and 4 in Zone I (Table 4B-D). In contrast, the highest number of species found on individual Ndama declined northward through Zones I, II and III with 6, 4 and 3 species, respectively (Table 4B-D). All the ZN-cross cattle, which included an individual with 5 tick species, were inspected in Zone I (Table 4B).

Among cattle, the proprotions of the infested (=reported) population(s) with specific numbers of infesting tick species increased initially with increasing number of species and then declined at still higher levels (i.e., number of infesting tick species). Among Zebu the largest proportion, 32.32%, had 3 tick species, for example, which was preceeded by 22.81% and 28.9% with 1 and 2 species, respectively, and followed by a sharp decline to 11.41% and 3.42% with 4 and 5 species, respectfully (Fig. 20, Table 4A). Among the Ndama, the largest proportion, 39.80%, had 2 tick species followed by sharply lower proportions at higher levels.

Similar distributions of proportions of infested cattle (breeds) populations were observed within the zones in Mali (Table 4B-D) and are depicted graphically in Fig. 28-30.

The mean number of adult (MNA) ticks per individual animal generally increased with increasing number of infesting tick species and among all host-types (Table 4A). The MNA for cattle, for instance, increased from 5.39 with 1 infesting species to 55.8 with 6 species and for sheep from a MNA of 3.00 with 1 infesting species to 21.5 with 4 species. The nationwide data showed that the Zebu usually carried higher MNAs than the Ndama at each level (number) of infesting tick species (Table 4A, Fig. 21) but the zonal data showed that the Zebu carried these higher MNAs (than Ndama) only in Zones II and III (Table 4C&D). Its MNAs in Zone I were either less or close to those of the Ndama (Table 4B). Graphic representations of the MNA for cattle and its breeds are presented in Fig. 21 (nationwide data) and Fig. 31-33 (zone data).

Genus Identities of Immatures of Ticks from Mali. Due to limited research, very little is known about the morphologies of immature ixodids in Africa and uncertainties currently surround the taxonomy of those usually collected in the field or even reared in laboratories (Hoogstraal 1956, Saratsiotis 1977). Classification of immature ticks collected in Mali were therefore determined only to the genus level.

A total of 6,312 nymphs and 629 larvae were collected in Mali in which 6 ixodid genera were represented including *Amblyomma*, *Aponomma*, *Argas*, *Boophilus*, *Hyalomma* and *Rhipicephalus*. Genus *Argas* was represented by a single larva collected from a *Francolinus* sp. bird; otherwise, there were both nymphs and larvae of the other genera.

The genus *Amblyomma* accounted for 5,727 or 90.73% of the nymphs and *Boophilus* 453 or 7.18%, while the other genera had very small representations. Among the larvae, the *Amblyomma* accounted for 76.95% but the *Rhipicephalus* and *Hyalomma* were well represented at 18.2% and 3.05% of the total, respectively (Table 2).

Reported cattle were infested by nymphs from 3 genera, *Amblyomma*, *Boophilus* and *Hyalomma*, at respective prevalences of 34.46%, 8.9% and 0.08% and respective MNNs of 12.76, 4.05 and 3.00. The prevalence of the *Amblyomma* nymphs among the Zebu, 26.22%, was lower than among the Ndama, 38.26%, but the MNN among the former, 23.76, was higher than among the latter, 14.06. A similar situation occurred with the *Boophilus* infestations in which the respective prevalence and MNN among the Zebu were 6.37% and 4.06, and among the Ndama 15.91% and 3.93. The *Hyalomma* infestation was that of CUB host by one nymph (Table 3B).

Both *Amblyomma* and *Boophilus* nymphs were found on sheep at respective prevalences of 36.84% and 10.53%, and respective MNNs of 5.86 and 1.5. The prevalence figures were very close to those achieved among cattle by the 2 genera but the MNNs were considerably lower (Table 3B). Most of the other host-types that carried nymphs had single genus infestations, although the nymphs often occurred in large numbers on the host especially the non-domestic types (Table 3B,D). A snake, for example, carried 36 nymphs and a Streptonelia senegalensis had 34 (Table 3D).

Amblyomma larvae were found in very low strength, 2.56% prevalence, among the cattle reported, but its MNL, 13.65, is sizable. Breedwise, the larvae attacked 4.87% of the Zebu and 4.55% Ndama, with MNLs of 17.31 and 6.92, respectively. Other infestations of non-cattle host-types, by larvae, were of single genus types except for a hare which had a Rhipicephalus and 19 Hyalomma larvae (Table 3C,D).

It is suspected that most, if not all, of the Amblyomma immatures recorded may turn out to be those of A. variegatum since it was the only Amblyomma adult encountered during the survey. It is also possible that the Rhipicephalus immatures from dogs and warthogs include mostly immatures of R. sanguineus and R. cuspidatus, respectively, since both species are known to be unitrophic and their adults were found on the same and respective hosts.

Identification of Ticks Using Female Gonopore Tissue (FGT). Part of the identification procedures used in this study involved distinguishing between species of the Ixodoidea on the basis of the characters of cleared and mounted female gonopore tissures (FGT). The approach proved particularly rewarding after a standard solution and procedure for clearing and mounting of the FGT were formulated, by trial and error, that gave consistent results when used with a wide variety of ticks.

The FGT of several ixodid ticks available in the TAMU laboratory were prepared and photographed as test specimens. The intention was to assess any possible limitations in the use of FGT characters as parameters for species identification by comparing its structures in many individuals of the same species, several species in the same genus and several genera of the Ixodoidea. The potential strength of the standardized clearing solution was also evaluated in different tick species that exhibit different levels of chitinization.

To evaluate the results, a generalized description of structures associated with the FGT in ticks of the genus Rhipicephalus given by Morel & Vassiliades (1962) was used as background information. According to these authors, the external opening of the vaginal tube (in the Rhipicephalus) has a flat-bottomed lip of simple or striated integument. This gonopore leads into a spherical or vial shaped chamber (or cup) called the atrium which is the dilated end of the vaginal tube. The chamber, which has a characteristic width, is tangentially attached to the ventral integument and supported by a pair of laterally placed sclerites, one to a side. The appearance, thickness (width) and curves of the sclerites are said to be constant intraspecifically. Morel & Vassiliades (1962) noted the intraspecies constancy of the

FGT structures and suggested that females be used for the establishment of species within the genus Rhipicephalus using the FGT characters as major parameters. A schematic diagram of the structural arragements of a hypothetical, cleared and mounted FGT is given in Fig. 18. It differs slightly from the description above in 2 respects; (a) in many genera, the medial part of the atrial sclerites is often exposed so that it becomes externally visible as sclerotic bars lateral to the genital opening, and (b) more sclerites may often be found in various positions on the atrium, for example, the circumatrial sclerite shown.

Tick material examined included 6 Amblyomma, 2 Boophilus, 7 Dermacentor Koch, 1 Haemaphysalis Koch, 4 Ixodes Latreille, and 1 Rhipicephalus species (all from continental North America) as well as 2 Amblyomma, 3 Hyalomma and 3 Rhipicephalus species from East African sources (Fig. 507-542).

Genus Amblyomma. Eight species of the Amblyomma were examined including A. americanum Linnaeus, A. cajenensse Fabricius, A. dissimile Koch, A. imitator Kolhs, A. inornatum Banks and A. maculatum Koch, all from North America. The remaining 2 species, A. lepidum Donitz and A. variegatum were from East Africa.

All the Amblyomma specimens follow the format outlined for the Rhipicephalus with respect to structural arrangements, but an extra atrial sclerite is found in A. dissimile. The later sclerite occurs as a narrow, semicircular bar that straddles the space between the 2 standard atrial sclerites on the medial surface of the atrium (Fig. 509).

As was the situation among the rhipicephalids, the width and thickness of the atrial sclerites and commissures in the Amblyomma species are distinctive and characteristic for each. The atrial commissure in A. lepidum (Fig. 531) is V-shaped and very narrow while A. americanum (Fig. 507) and A. cajenensse (Fig. 508) have 2 different shades of the oval. Amblyomma maculatum possess a large tubercle immediately anterior to its atrial commissure (Fig. 512). The externally visible sclerotic bars in A. imitator (Fig. 510) and A. inornatum (Fig. 511) are distinctive and different in the way they are sculptured.

The taxonomic impasse often created by the very close morphologic similarities of females of A. lepidum and A. variegatum in Africa is readily resolved by comparing their cleared and mounted FGT. The former has massive triangular sclerites bounding a very narrow, V-shaped atrial commissure (Fig. 531) while the sclerites in the latter are narrow and recurved and the commissure is a wide oval (Fig. 532).

Genus Boophilus. The FGT of ticks previously identified as B. annulatus, B. decoloratus and B. microplus in the TAMU laboratory were examined. Due to comparatively poor chitinization within the genus, many structures of their FGT appeared to be feeble and were readily overcleared except when the shortest clearing times were employed.

Boophilus decoloratus ticks from East Africa lack any atrial sclerites but have atrial commissures that are characteristically V-shaped and distinct (Fig. 533). Very thin cuticular sheets, however, are found on the atrium of the B. annulatus and B. microplus specimens (Fig. 514 and 515, respectively). Uniquely, the sheets are drawn out over the lateral edge of the atrial lip in thin cup-like extensions that are visible externally as areas of unstriated integument. When large numbers of samples are examined, the average size of these cups appear bigger among the B. microplus specimens than in B. annulatus specimens. The B. annulatus cups however appear to be more poorly chitinized and are more readily overcleared than the former. Both B. annulatus and B. microplus possess a central protruding area or knob between the cup extensions. The knobs have no chitinized base or sub-structure and their width is apparently by the sizes of the enchroaching chitinized cups.

Some Boophilus materials, from an as yet undetermined North American source, with relatively unusual 5:5 hypostomal dentition in both sexes, had mounted FGTs with features slightly different from those described above for B. annulatus and B. microplus. For example, the atrium is pigmented in these ticks whereas it is not in the later species (Fig. 516-518). The main morphological features of representative adults of these specimens are shown in Fig. 549-565 and the features of legs I-IV of nymphs found among the collection of the adults are shown in Fig. 566.

Genus *Dermacentor*. The FGT of 7 representatives of the genus *Dermacentor* were examined including *D. albipictus* Parkard, *D. andersoni* Stiles, *D.* (*Anocentor*) *nitens* Neumann, *D. halli* McIntosh, *D. occidentalis* Marx, *D. parumapterus* Neumann, and *D. variabilis* (Say). The structures in all foregoing species have formats similar to that described for the genus *Rhipicephalus* although their atrial sclerites tend to be thin and unadorned and, in case of *D.* (*Anocentor*) *nitens* (also classified as *Anocentor nitens*) (Fig. 513), reduced to mere thickenings along the lateral arms of its atrial commissure.

The length of the atrial sclerite, however, is particularly characteristic for each species. They are, for instance, short and stubby in *D. parumapterus* (Fig. 523) but long and tapering in *D. halli* (Fig. 521). Females of *D. parumapterus* and *D. halli* have been difficult to distinguish morphologically since their separation has previously been based on the tenuous character of scutal punctation. *Dermancentor occidentalis* (Fig. 522) has the longest and thinnest atrial sclerites among the species examined while the sclerites are long, thin and curved in *D. albipictus* (Fig. 519).

The atrial commissure in all 6 species is U-shaped but the widths appear distinctive for each species. Among these species the U is very narrow in *D. andersoni* (Fig. 520), wide in *D. variabilis* (Fig. 524) and widest in *D. halli* (Fig. 521).

Genus *Haemaphysalis*. The FGT of *Haemaphysalis leporispalustris* (Fig. 525) was examined as the representative and only species available. The FGT followed the *Rhipicephalus* format in structural arrangement with a wide, deep atrium that has 2 narrow, bladelike, unpigmented sclerites and a wide atrial commissure. In the absence of specimens from other species of its genus, it is impossible to ascertain which of the FGT features are specific for the species (or genus), if any.

Genus *Hyalomma*. Three *Hyalomma* species from various African sources were examined; *H. albiparmatum* Schultz and Schlottke, *H. nitidum* Schulze and *H. truncatum*. The 3 species followed the *Rhipicephalus* format, although with modifications, in the structures of their FGT (Fig. 534-539). The 1st modification was seen in a collection of *H. truncatum* from "Rhodesia (now Zambia-Zimbabwe). These specimens have a horseshoe shaped sclerite positioned as an open-ended belt midway down the atrium from the atrial commissure (Fig. 537-539). The open end of the horseshoe is on the medial surface of the atrium, away from the integument. This, probably reinforcing, sclerite has a width equal to about half the width of the vaginal tube proper and is independent of the other atrial scleritles. Atrial commissures in these specimens are wide, roughly rectilinear and deeply located towards the base of the (atrial) sclerites.

The 2nd collection of *H. truncatum*, from South Africa, lack the horseshoe atrial reinforcement in the FGT (Fig. 536) and the atrial commissure appears as a small, smoothly contoured semicircle that is placed far from and anterior of the base of the atrial sclerites (Fig. 536). This latter arrangement creates a deeper atrial chamber and narrower gonopore than in the "Rhodesia" type. The features described for this 2nd group of H. truncatum are similar in detail to those described and photographed for the lectotype of the species by Feldman-Muhsam (1954) which was also obtained from South African sources.

A feature common to the 3 Hyalomma species examined is the presence of a tubercle ((operculum of Feldman-Muhsam (1954)) immediately anterior to the atrial commissure (Fig. 534-539). This however is not a lid-like structure as suggested by the "operculum" terminology used by Feldman-Muhsam (1954) since it does not cover, per se, the female gonopore. The area of integument between the atrial commissure and the tubercule is depressed in all examined specimens except those of H. nitidum. The depression varies in width between species with the depresion in H. albiparmatum being the widest and most rectilinear of all 3 species examined (Fig. 534). Each depression pushes the adjoining tubercle some distance anterior from the commissure. The tubercle in H. nitidum, in contrast, begins at the very edge of its commissure (Fig. 535).

Genus Ixodes. The FGT of 4 Ixodes species, I. affinis Neumann (Fig. 526), I. pacificus Cooley & Kohls (Fig. 527), I. scapularis Say and I. texanus Banks (Fig. 530) were examined. The most significant thing about all these species (and most probably the whole genus) is that none possess atrial sclerities, a situation that considerably reduces the taxonomic value of the FGT. The gonopore lips vary in shape (from flat to wide oval) and width, but the variations are either too subtle or inconsistent to be of any taxonomic value.

Genus *Rhipicephalus*. The FGT of 4 *Rhipicephalus* species, *R. sanguineus* from Oklahoma, and *R. cuspidatus*, *R. lunulatus* and *R. simus* from East African sources were examined. All conform, in structural format, to the description given by Morel & Vassialiades (1962) for the genus.

The characters of the atrial sclerites and commissures (e.g., shape, size, pigmentation) were more constant and distinctive for each of the *Rhipicephalus* species than were found among other genera studied. In the 4 species examined, for example, *R. sanguineus* has unpigmented, stubby or subtriangular sclerites and a shallow atrial commissure (Fig. 530); *R. cuspidatus* a very wide atrial commissure and rod-like, unpigmented sclerites (Fig. 540); *R. simus* pigmented, tear-drop sclerites and narrow atrial commissure (Fig. 542) and *R. lunulatus*, very wide, rectilinear atrial commissure and unpigmented, subquadrate sclerites (Fig. 541).

Descriptions of Selected Tick Specimens.

Hyalomma nitidum (Fig. 398-415)

Male

Medium size; unengorged tick about 4.8 by 2.8 (mm); moderately convex dorsally; oval shape; widest about the third quarter of the scutum; posterior margin rounded; dark-brown to blackish brown dorsally, orange to burnt orange ventrally.

Palps: Long, about 3 times as long as wide. Dorsal surface; segment 1 visible as an uneven-edged, narrow ring; segment II about twice as long as segment III, constricted proximally with a retrograde projection at its proximal median angle; segment III squarish, proximolateral edge drawn out; both segments II and III slightly excavated; segment IV not visible. Ventral surface; palpal setae simple (not fimbriated), segment I a narrow spindle with blunt projections on the proximal and distal ends; segment II about one and one half times as long as segment III; distal portion of article III bevelled ventromedially; segment IV in the bevelled surface of segment III.

Hypostome: Spatulate; slightly shorter than the palps; dentition 3:3, with 9 or 10 denticles per row; corona distinct; rows of denticles grade into (divergent) crenulations posteriorly.

Basis capitulum: Dorsal surface; hexagonal, depressed centrally; auricular (exterior) angle obtuse; posterior margin slightly concave between obsolescent cornuae; anterolateral angle humped; anterolateral margin with a row of 5 or 6 simple hairs; a row of 8 or 9 piliferous punctations stretch between the 2 auricular angles. Ventral surface; rounded-out hexagon; 5 or 6 hairs along the posterolateral margin.

Scutum: Glossy; convex; elongate oval; about 3.7 by 2.8 (mm); anterolateral margin gradually truncate; posterolateral margin rectilinear; posterior margin smoothly rounded; a line of fine, non-piliferous punctations between scapula and first festoon outside of marginal groove and the eyes; scapula sparsely punctated; scapulary groove obsolescent except near cervical pit; cervical groove deep, short and comma shaped; cervical field moderately developed, very superficial at level of eyes; eyes hemispherical, orbited; marginal groove deep, especially in posterior third, gradually superficial and traced anteriorly by a ragged line of non-piliferous punctuations beyond the eyes to the scapular; 1st and 2nd festoons coalesced and raised; area between the fused festoons depressed, heavily punctated, some punctations confluent partially obscuring the posteromedian and paramedian grooves; none of the posterior grooves extend beyond the posterior 3rd of scutum; overall scutal surface impunctate, except posteriorly as noted above.

Ventral body surface: Sparsely covered by simple hairs; operculum at level of coxa II, round-edged pentagon; genital groove immediately divergent posterior to operculum, anus opposite spiracular plate; with 4 pairs of simple setae; anal groove distinct.

Ventral shields: Adanals about 2 times as long as wide, post-anal portion quadrate, free of underlying integument, para-anal section triangular, attached to the integument, with numerous piliferous punctations, hilum angle undifferentiated, not drawn out; accessory shields wide, spatulate, external and posterior margins rounded, free of integument caudally; sub-adanals narrow, short, strongly chitinized, on the same longitudinal axis as the adanals; ventral plaques on festoons, median smallest.

Spiracular plate: Body elongate oval, macula in the anterior end; tail wide proximally, strongly curved and tapering distally; goblets medium-sized in the body, fine in the tail. A structural arrangement in a hypothetical spiracular plate is depicted in Fig. 37.

Legs: Size increases significantly from leg I to IV; leg I annulated, legs II through IV unicolorous (brown); coxa I with two long, parallel spurs - a narrow external and a wider, internal spur bevelled distally; coxa II and III each with a short, sharp external spur and a broad emanance on their posteromedial angle; coxa IV with two short, sharp (external and internal) spurs; tarsals II to IV with a pair of ventral spurs; pulvillus shorter than claws; Haller's organ with 2 pre-, 4 post-, 4 peri- and 6 capsular sensilla. The sensilla distribution in a hypothetical Haller's organ is depicted in Fig. 36.

Female

Medium size; unengorged tick about 5.3 by 2.6 (mm); elongated oval shape with broadly rounded posterior margin; scutum and capitulum dark brown to blackish brown, orange to burnt orange elsewhere.

Palps: Dorsal surface of segments II and III flat to slightly convex, definitely not excavated; posterolateral margin of segment III not drawn out, otherwise all other features similar to males.

Hypostome: Identical to males except for more denticles per row of dentition, actual number 10 to 12.

Basis capitulum: Dorsal surface; hexagonal; depressed centrally; porous areas oval, separated by a ridge less than their individual diameter in width; auricular angle acute; posterior margin nearly straight; cornua obsolescent, anterolateral margin with 3 or 4 simple hairs, anterolateral angle humped. Ventral surface; rounded-out hexagon, row of 5 or 6 hairs at posterolateral margin.

Scutum: Wider than long, about 1.8 by 2.2 (mm); widest at the level of the eyes; posterior margin slightly sinuous, anterolateral margin curved, with a line of punctations between the eye and apex of scapula; scapula otherwise sparsely punctated; scapulary groove deep and sharp anteriorly, rugose or ragged at level of eyes; cervical groove deep, convergent; cervical field deep, divergent at level of eye; central field glossy, impunctate; eyes hemispherical, orbited.

Alloscutum: Marginal groove long, extends from just below the eye to (limit) the 2nd festoon; posteromedian groove deep, extends from just below the fovea dorsalis to touch the median festoon; paramedian grooves slightly shorter than posteromedian; piliferous punctations distributed in rows in the areas between the grooves.

Ventral body surface: Sparsely covered by simple hairs; genital groove forms a constricted oval around the gonopore, genital grooves diverge posteriorly; anus opposite spiracular plate, with 4 pairs of simple setae; anal groove distinct.

Gonopore area: Unmounted FGT; Opening a wide semicircle; posterior lip simple, anterior lip a wide, hemispherical tubercule. Mounted FGT; atrial sclerites pigmented, thin, bladelike, closely applied to atrial commissure; atrium and atrial commissure much wider than distal (vaginal) tube.

Spiracular plate: Body elongate oval, anterior end narrowest, macula in the anterior half; tail moderately long, curved, tapering, with fine goblets.

Legs: Size does not increase significantly from legs I to IV; leg I annulated; annulation infrequent in legs II to IV but may be seen more commonly in the proximal 2 segments; tarsal spurs only moderately developed; pulvilli smaller than claws; coxa spurs as in the male but internal spurs on coxa II to IV not as well developed; Haller's organ as in the male.

Hyalomma truncatum (Fig. 416-433)

Male

Medium size; unengorged tick about 4.5 by 2.5 (mm); moderately convex dorsally; oval shaped; widest about third-quarter of the scutum; posterior margin rounded; brown to dark brown dorsally; orange to light brown ventrally.

Palps: long, about 3 times as long as wide. Dorsal surface; segment I visible as an uneven-edged, narrow ring; segment II about twice as long as segment III, constricted proximally, with a retrograde projection at its proximal median angle; segment III squarish, proximolateral edge drawn out, almost salient; both segments II and III slightly excavated; article IV not visible. Ventral surface; palpal setae simple (not fimbriated), segment I a narrow spindle with blunt projections on the proximal and distal ends segment II; slightly longer than segment III; distal portion of segment III bevelled ventromedially; segment IV in the bevelled surface of segment III.

Hypostome: Spatulate, about equal length with the palps; dentition 3:3, with 9 or 10 denticles; dental rows capped by a distinct corona distally, grade perceptably into (divergent) crenulations posteriorly.

Basis capitulum: Dorsal surface; hexagonal, depressed centrally; auricular angle obtuse; posterior margin slightly concave between obsolescent cornuae; anterolateral margin with a row of 5 or 6 simple hairs; anterolateral angle humped; a few piliferous punctations stretch between the 2 auricular angles; Ventral surface rounded-out hexagon; a row of piliferous punctations along the posterolateral margin.

Scutum: Glossy, especially centrally; slightly convex; elongated oval; about 3.4 by 2.5 (mm); anterolateral margin gradually truncate; posterolateral margin rectilinear; posterior margin smoothly rounded; scapulae moderately punctate, some piliferous; scapulary groove a gradual slope; cervical groove deep, moderately long, convergent; cervical field moderately developed, excavated, anteriorly, eyes hemispherical, orbited; marginal groove deep; long, punctated along its length (from 1st festoon to just below the eye); 1st and 2nd festoons coalesced and slightly raised; area between the fused festoons slightly depressed, heavily punctated, some punctations confluent; posteromedian groove thin, confined to posterior third of scutum; paramedian grooves short, wide; all grooves superficial, obscured proximally by confluent punctations; general scutal appearance impunctate except posteriorly as noted above; specimens from more mesic ecological areas with more widespread, superficial punctations.

Ventral body surface: Sparsely covered by simple hairs; operculum at level of coxa II, subrectangular; genital grooves immediately divergent posterior to operculum, anus opposite spiracular plate; with 4 pairs of simple setae; anal groove distinct.

Ventral shields: Adanals about 2 times as long as wide, post-anal portion quadrate, free of underlying integument, para-anal portion triangular, overall external margin curved, posterior margin straight (often strongly dented), posterointernal margin straight, anterointernal margin concave, hilum angle drawn out medially; accessory shields wide, spatulate, external and posterior margins rounded, free of integument caudally; sub-adanals narrow, short, strongly chitinized, on the same longitudinal axis as the adanals; ventral plaques on festoons, median smallest.

Spiracular plate: Body elongate oval; macula in the anterior end; tail wide proximally sharply curved and tapering distally; goblets medium-sized in the body, fine in the tail.

Legs: All legs annulated; size increases slighty from legs I to IV, coxa I with 2 long, parallel spurs - a narrow external and a wide, distally bevelled internal spur; coxa II and III each with a short, sharp external spur and a broad emanance on the posteromedian angle; coxa IV with two short, sharp (external and internal) spurs; tarsals II to IV with a pair of ventral spurs; pulvillus shorter than claws. Haller's organ with 2 pre-, 4 post-, 4 peri- and 9 capsular sensilla.

Female

Medium size; unengorged tick about 4.7 by 2.5 (mm); oval shaped, smoothly rounded margins; scutum and capitulum brown to dark brown; ventral body surface orange to burnt orange.

Palps: Dorsal surface of segments II and III flat to slightly convex, not excavated; posterolateral margin of segment III not drawn out; otherwise all other features similar to males.

Hypostome: As for males except for more denticles per row of dentition; actual number 10 to 12.

Basis capitulum: Dorsal surface; hexagonal; depressed centrally; porous area small circles separated by a distance about one and one-half of their individual diameter; auricular angle slightly obtuse; anterolateral angle humped; anterolateral margin with 3 or 4 simple hairs; posterior margin nearly straight; cornua obsolescent. Ventral surface; rounded out hexagon; some hairs along the posterolateral margin.

Scutum: Slightly wider than long, about 1.7 by 2.0 (mm); widest at the level of the eyes; posterior margin gradually rounded out, anterolateral margin curved; scapula moderately punctate; curved; scapula moderately punctate; scapulary groove distinct, sometimes, rugose or ragged at level of the eye; cervical groove deep, long, convergent anteriorly divergent afterward; cervical field deeply excavated especially anteriorly, rugose laterally at level of eyes; a few medium-sized punctations in the central field (and along scapulary grooves), otherwise central field impunctate or with very fine punctations.

Alloscutum: Marginal groove long; extends from just below the eye, limits the 2nd festoons; posteromedian groove deep extends from just below fovea dorsalis to touch the median festoon; paramedian groves slightly shorter than the posteromedian; piliferous punctations distributed in rows in the areas between the grooves.

Ventral body surface: Sparsely covered by simple hairs; genital groove diverge immediately posterior of the gonopore; anus opposite spiracular plate, with 4 pairs of simple setae; anal groove distinct.

Gonopore area: Unmounted FGT; opening wide, rectilinear, posterior lip simple, anterior lip depressed, flat; depression bordered anteriorly by a narrow, transverse tubercle. Mounted FGT; atrial sclerites pigmented, thin, long, bladelike; atrial commissure much wider than distal (vagina) tube, rectilinear, located close to the base of sclerites; atrium only slightly wider the distal (vagina) tube; a pair of trichae on the depressed anterior lip of commissure.

Spiracular plate: Body elongate oval, anterior end narrowest macula slightly in the anterior half; tail moderately long, curved, tapering; goblets medium sized in the body, fine in the tail.

Legs: Size does not increase appreciably from legs I to IV; tarsal spurs only moderately developed; internal spurs on coxa II to IV not well developed, otherwise all other characters as in males.

Rhipicephalus group #9 (Fig. 434-451)

Male

Small sized; unengorged tick about 2.7 by 1.4 (mm); slightly convex dorsally; widest at posterior two-thirds gradually, truncate anteriorly; burnt orange to dark brown in color.

Palps: Short, slightly longer than wide; Dorsal surface; segment 1 slightly visible; segment II and III slightly excavated, sub-equal in length and widest at line of apposition; segment IV not visible; Ventral surface; palpal setae fimbriated, segment 1 parasol-shaped; segment II longest; article III compressed ventromedially, bears a ventrally directed projection near its median angle; segment IV in the depressed ventromedian surface of segment III.

Hypostome: Narrow, sub-rectangular, about equal in length to palps; dentition 3:3 with 7 or 8 denticles per row; corona distinct.

Basis Capitulum: Dorsal surface; hexagonal, relatively flat; auricular angle anterior third; posterior margin concave; roughly equidistant hairs in a row around mid-section (auricle to auricle); superficial punctations in the central field; well-developed basidorsal cornuae; Ventral surface; hexagonal; exterior angle anterior third.

Scutum: Elongate oval, about 2.0 by 1.4 (mm), widest at posterior two-thirds; scapulae moderately punctate; scapulary groove marked, traced by a row of 6 to 8 piliferous punctations extending to eye level; cervical groove distinct, short and converging; cervical field moderately developed, superficial posteriorly; eyes flat, slightly convex, hemmed medially by 3 or 4 piliferous punctations; 4 roughly linear rows of piliferous punctations distinct long a scutal length; interstitials medium-sized, regular in the central field, smaller and irregular laterally; marginal groove distinct, long, extends from just below eye level to limit the 1st festoon, heavily punctated along its entire length; conscutum narrow, mildly punctate; posteromedian groove deep wide, slightly shagreened, reaches about a third of scutal length; paramedian grooves deep, wide, shagreened ovals; individual festoons roughly equal in width, not coalesced, unicolorous, slightly punctate.

Ventral body surface: Sparsely covered with simple hairs; operculum at level of coxa II, sub-pentagonal, pointed apex; genital grooves, divergent at base of adanal shields; anus opposite spiracular plate; anal groove distinct; median festoon protruscible.

Ventral shields: Adanals moderately large, subtriangular, mildly punctate, internal margin convex, notched slightly at level of anus, external margin nearly straight, posteroexternal angle obtuse; accessory shields strongly chitinous with pointed caudal projection; ventral plaques on festoons, 1st festoon plaque narrowest, median widest.

Spiracular plate: Body short, sub-oval; macula off-center, surrounded by 2 rows of medium-sized goblets; tail thin, very long, more than 4 times as long as wide, roughly parallel-sided, occupied by only fine goblets, width about equal to half of 1st festoon.

Legs: Size increases from leg I to IV; coxa 1 with two parallel spurs - a narrow external and a wider, distally bevelled, internal spur; coxa II through IV each with a short, sharp external spur; tarsus 1 long; tarsus II through IV each with a pair of recurved spurs; pulvilli longer than claws.

Female

Medium sized; unengorged ticks about 3.0 by 1.9 (mm); slightly convex dorsally, widest at posterior two-thirds, gradually truncated anteriorly; burnt orange to dark brown in color.

Palps: As for males except dorsal surface of segments II and III slightly convex, not excavated.

Hypostome: As for males except greater width and more (actual number 9 or 10) denticles per row of dentition.

Basis capitulum: Dorsal surface; hexagonal; central field depressed; porous areas small, round, separated by a distance double their individual diameter; auricular angle at middle third, slightly curved (at the tip) anteriorly; posterior margin straight between the cornuae; cornua short, sharp; punctations and hairs as in males. Ventral surface; hexagonal; auricular angle middle-third.

Scutum: About as wide as long, 1.2 by 1.2 (mm); widest just below the eye; posterior margin slightly sinuous, gradually rounded out; anterior lateral margin converge gradually towards the scapulae; scapulae mildly punctate; scapulary groove marked, traced by a row of 6 to 8 piliferous punctations to level of the eye; cervical groove distinct, short, converging; cervical field superficial; eyes flat, slightly convex, hemmed by 4 or 5 piliferous punctations; 4 roughly linear, anteriorly converging, rows of piliferous punctations discernible (1 in each of the cervical fields, 2 in the central field); interstitials medium-sized, regular in central field, slightly non-uniform and irregular in the cervical fields.

Alloscutum: Marginal groove long, from just below eye level to (limit) the 2nd festoon; posteromedian groove deep, extends from just below fovea dorsalis to touch the median festoon;

paramedian grooves deep, slightly shorter than the posteromedian; punctations, piliferous and otherwise, distributed in rows in the areas between the grooves.

Ventral body surface: Sparsely covered by simple hairs; genital groove, sub-rectangular around the gonopore, divergent after the anus; anus opposite spiracular plate; anal groove distinct.

Gonopore area: Unmounted FGT; opening very narrow, U-shaped with, short arms. Mounted FGT; pigmented, moderately long (nearly 2 times as long as wide), subtrapezoidal, atrial sclerites; distance between sclerites less than their individual width; lateral margin of atrial sclerite more or less straight, and roughly parallel to, but much longer than the medial margin; atrial commissure very narrow, U-shaped; commissure and atrium marginally wider than vaginal tube.

Spiracular plate: Body moderately large, oval; macula slightly off center, surrounded by 2 rows of medium-sized goblets; tail unusually long, (more than 2 times as long as wide) often very thin, with exclusively fine goblet cells.

Legs: Size does not increase significantly from legs I to IV; tarsal spurs only moderately developed; all other characters as in the male.

Rhipicephalus group #10 (Fig. 452-469)

Male

Medium size: unengorged tick about 2.5 by 1.3 (mm); slightly convex dorsally; slightly truncate anterior of the eye, otherwise oval in outline; orange to burnt orange.

Palps: Short, slightly longer than wide. Dorsal surface; segment 1 slightly visible under high magnifiations; segments II and III slightly excavated, about equal in length, widest at their line of apposition; segment IV not visible. Ventral surface; palpal setae fimbriated; segment 1 parasol-shaped; segments II and III about equal in length; segment III bevelled at ventromedian angle distally; bears a ventrally directed projection near its median angle also distally; segment IV in the bevelled surface of segment III.

Hypostome: Narrow, spatulate, about equal in length to palps; dentition 3:3, 8 or 9 teeth per row; corona distinct; rows of denticles fade out as crenulations posteriorly.

Basis capitulum: Dorsal surface; hexagonal; central field slightly depressed longitudinally; width about twice the length; auricular angle at anterior third; posterior margin roughly straight between sharp, well developed cornuae; auricular edge punctate, including a line of piliferous types. Ventral surface; hexagonal; auricular angle anterior third.

Scutum: Elongate oval, slightly truncate anteriorly, about 2.0 by 1.3 (mm); 8-10 scattered piliferous punctations on scapulae; scapulary groove marked by two rows of punctations (some piliferous) that extend beyond the level of the eye; cervical groove shallow and short; cervical field moderately distinct; eyes flat, slightly convex medially where it is hemmed by 3 or 4 piliferous punctations; 4 roughly linear rows of piliferous punctations apparent along scutal length; interstitials medium-sized, regular and dense around the posteromedian groove and in the central area between the cervical fields, smaller and irregular laterally, fine and few outside of the marginal grooves; marginal groove deep, heavily punctate along its entire length from just below the eye to level of 2nd festoon, anterior punctations piliferous; posteromedian groove deep, wide, shagreened, confined to posterior third of scutal length; paramedian grooves deep, subcircular, shagreened; festoons not coalesced, unicolorous, mildly punctate.

Ventral body surface: Sparsely covered by simple hairs; operculum at level of coxa II, pentagonal, pointed posteriorly; genital groove divergent at base of adanal shields; anus opposite spiracular plate; anal groove distinct.

Ventral shields: Adanal shield moderately long, spatula-shaped, post-anal portion distinctively expanded, gradually rounded margins, hilum notch shallow; accessory shields strongly chitinized, with caudal projection; chitinous plaques on chitinous plaques on festoons, 1st festoon about one-half the width of median festoon; median festoon protruscible.

Spiracular plate: Body long, truncate distally; macula near the wide base; tail very short, arises abruptly at level of ventral plaques of 1st festoon, slightly wider than the 1st festoon; goblets medium-sized in the body, fine along the edge of plate distally and in the tail.

Legs: Size increases only moderately from leg I to IV; coxa I with 2 parallel spurs- a narrow external and a wide, medially bevelled, internal spur; coxa II through IV each with a short, sharp external spur; coxa IV with an additional short, sharp internal spur; tarsus I long; tarsals II through IV each with a pair of recurved spurs; pulvilli longer than claws. Haller's organ with 2 pre-, 4 post-, 3 peri- and 6 capsular sensilla.

Female

Medium sized; unengorged ticks about 2.5 by 1.3(mm); oval, slightly truncate at level of scapulae, slightly convex dorsally; orange to burnt orange.

Palps: As for males except dorsal surface of segments II and III relatively flat, not excavated.

Hypostome: Wider and has 1 or 2 more denticles per row of dentition than the male, otherwise similar in both sexes;

Basis capitulum: Dorsal surface; hexagonal; width more than twice the length; central field depressed longitudinally; porous areas small, round, separated by a distance equal to their combined diameters; auricular angle at middle third, significantly punctate, some piliferous; posterior margin roughly straight between distinct but short cornuae. Ventral surface; hexagonal; auricular angle middle third.

Scutum: About as wide as long, about 1.1 by 1.2 (mm); posterior margin gradually rounded, anterior lateral margin converge gradually towards the scapulae; eyes flat, slightly convex medially where it is hemmed by 4 or 5 piliferous punctations; scapulae punctate; scapulary groove marked, traced out by a mass of small-sized punctations for varying lengths posteriorly; cervical groove distinct, moderately long; cervical field conspicuous, with medium-sized (often dense but usually irregular) interstitials; central field with uniform, medium sized and regular punctations; piliferous series present, but not readily discernible because of equal size of interstitials or the massing of punctations along scapulary grooves.

Alloscutum: Marginal groove long, extends from just below eye to limit the 2nd festoon; posteromedian groove deep, extends from just below the fovea dorsalis to touch the median festoon; paramedian grooves slightly shorter than posteromedian; punctations distributed in rows in the areas between the grooves.

Ventral body surface: Sparsely covered by simple hairs; genital groove sub-circular around gonopore, diverge posteriorly; anus opposite spiracular plate; anal groove distinct.

Gonopore area: Unmounted FGT; Opening moderately wide, U-shaped; triangular area on posterior lip characteristically depressed. Mounted FGT; atrial sclerites pigmented, quadrate, length and width about equal, distance between the sclerites definitely more than their individual width; atrium marginally wider than distal (vagina) tube.

Spiracular plate: Body moderately large, oval; macula slightly off-center, surrounded by moderate size goblets; tail very short, with fine goblets.

Legs: Size does not increase significantly from legs I to IV; tarsal spurs only moderately developed; coxa spurs as in the male but internal spurs on coxa II to IV not well-developed; other characters as in the male.

Rhipicephalus specimen #11 (Fig. 470-475)

(1 male off cattle)

A small tick, unengorged, measuring 2.09 by 1.2 (mm): slightly convex dorsally; truncate anteriorly, widest at scutal middle third; light orange in color.

Palps: Short, rectillinear; slightly longer than wide; strongly pilose, especially laterally. Dorsal surface; article II rectangular, slightly wider than long, flat; article III squarish; flat, anterolateral edge salient; article IV not visible. Ventral surface: Palpal setae fimbriated; article I a wide blunt triangle; article II squarish; article III with lateral salience extended medially: article IV in a depression of the anteromedian surface of article III, with 6 or 7 terminal setae.

Hypostome: Spatulate; length about equal to the palps; dentition 3:3 with 7 or 8 denticles per row; corona distinct.

Basis capitulum: Strongly pilose laterally, about 11 or 12 long hairs in auricular area. Dorsal surface; hexagonal, relatively flat; lightly and superficially punctate especially in the central field; auricular angle anterior third , posterior margin straight between well-developed, moderately sharp, basidorsal cornuae. Ventral suface; hexagonal; non-pilose centrally; auricular angle anterior third.

Scutum: Elongate oval; about 1.6 by 5.4 (mm); widest about two thirds of length posteriorly; scapulary groove absent; cervical groove deep, thin, very short, comma shaped; cervical field abscent; marginal groove nearly obsolete, thinly superficial, short, confined to posterior third of scutum; posteromedian and paramedian grooves obsolete; punctation uniform, medium, regular, but not in any apparent series; festoons relativley uniform in size.

Ventral body surface: Strongly pilose except in the post-anal area posterior to the adanal shields; operculum at levels of coxa II, truncate oval; genital grooves widely divergent posteriorly; anus opposite spiracular plate; anal groove distinct; festoons without chitinous plaques.

Ventral shields: Adanals roughly isosceles triangles, moderately pilose, about 2 times longer than wide, notch of hilum obsolete; accessory adanal represented by a small, chitinous posterior tip; otherwise area lateral to adanal shield strongly pilose.

Spiracular plate: Feminine; large oval body with a wide and very short tail.

Legs: Strongly pilose, not significantly different in sizes from I to IV; coxa I with two parallel - a narrow external, and a wide, distally bevelled, internal-spurs; coxa II through IV each with a short, sharp, external spur; tarsus I long; tarsals II through IV each with a pair of ventral spurs; pulvilli much longer than claws.

CHAPTER V

DISCUSSION

Nationwide and Zonal Counts of Ticks from Mali. The collection of ticks from "Cerce de Sikasso" reported by Lamontellerie (1960) was the 1st and only known instance in which a tick survey had been targeted exclusively for a part of present day Mali. Most other published information on ticks previously sighted in the country may be gathered only from segments of broader investigations into the tick fauna or tick-borne diseases in (especially former French colonial) Africa (e.g., Girard & Rousselot 1945; Rousselot 1951, 1953; Morel 1958, 1969). The present report marks the 1st time data have been collected nationwide and exclusively on the tick fauna in the Republic of Mali.

All of the Mali domestic host-types inspected during the survey including cattle, sheep, goats, dogs, horses, camels, a cat and a donkey had individual(s) with ticks. Tick burden, evaluated by the mean number of ticks (MNT) of all stages per individual animal, varied considerably among the host-types, with cattle having the highest MNT, 18.55 (Table 1A).

For the entire survey data, adult ticks were found on greater proportions of each host-type's infested (= reported) population than either nymphs or larvae. For example, 97.84% of all cattle infested had adult ticks compared to 37.82% with nymphs and 2.64%

with larvae. Tick larvae were not found on many host-types including goats, horses and camels. The low levels of infestations of domestic host-types by immatures might be due to a number of reasons including better resistance by the host-types to infestation by immatures as compared to adults, the immatures' preference for non-domestic host-types or simply because many (immatures of 2 or 3 host ticks) have to drop off their hosts before molting.

There are presumably important alternate hosts (e.g., wildlife) and/or habitats for tick immatures in the Malian ecosystem. These must be identified by a scientific survey before any control programs are instituted. Data from the present study, based on the high MNT figures obtained among the wild host-types reported (e.g., MNT of 16 and 19.85 for hares and warthogs, respectively), suggest that relatively high levels of tick infestations exist among the wildlife (especially bird) populations in Mali. All the infestations found on birds in this survey were entirely by immatures (Table 3D).

Most host-types, and certainly the various breeds of cattle, showed different tick infestations in each of the 3 hygrophytic zones in Mali, fostered in large measure by the relatively distinctive environment (e.g., humidity, vegetation and temperature) in each zone and quite possibly by host husbandry practices.

In Zone I, all the domestic host-types, particularly cattle breeds, proved to be highly (almost equally) susceptible to infestations by adult ticks when judged by the high proportions (90-100%) of their reported populations that were found infested by that tick stage (Table 1B). Infestations by nymphs occurred in much lower but also similar proportions among the host-types while larval infestations were exceptionally low or absent. The observations of similar levels of adult and nymphal infestations between all host types suggest that the environmental conditions in Zone I are probably strong enough to override the innate resistance of each host-type to tick infestations. For instance, the zonal MNA and MNN for the Zebu, 11 and 12.96, respectively, turned out to be very similar to the Ndama's 12.53 and 12.01, respectively. The proportions of reported populations of both breeds found infested by adult ticks and nymphs were also very close (within 2% of each other) (Table 1B).

Very few non-cattle domestic host-types were reported from Zone II, so that legitimate comparisons are limited to cattle data only (Table 1C). In this zone, the Zebu was more successfully attacked by all tick stages than the Ndama based on comparisons of (a) their respective zonal MNA, MNN and MNL figures, which were, in all cases, at least twice as high among the Zebu as the Ndama, and (b) the proportions of their reported populations that were infested by the various tick stages. Further, more tick species (adults only considered) were found on the Zebu (14) than the Ndama

(12). Since substantial numbers of both breeds were reported from the zone and neither breed is considered historically well-established in the zone (Dickey 1981), the tick data suggest that the Ndama may be more tolerant of tick infestations than the Zebu. Controlled investigations that would take into account the age, body sizes and husbandry of both breeds would be needed to test the validity of such a suggestion.

Zone III apparently did not favor the infestation of livestock by larvae and only very slightly so by nymphs. Adult ticks, however, had as much success infesting livestock (excepting the goat) as they did in the other 2 zones based on the high (80-100%) proportions of host populations that were found infested. The fact that the Zebu carried a mean number of adult ticks, 17.15, that was higher than any MNA carried by the Ndama in all 3 hygrophytic zones in Mali suggest again, that the Zebu may be less resistant to tick infestations than the Ndama.

Distributions and Host Ranges of Tick Species. Four of the 20 species encountered in Mali, *A. variegatum*, *B. geigyi*, *H. m. rufipes* and *H. truncatum* (the last as described from Mali) were found in most of the places visited by the survey teams. Such distributions from North Guinean forest through the Sudan to the Sahel include more ecological zones than these species have been associated with elsewhere on the continent. For *B. geigyi*, it represents incursions into xeric zones (in northern Mali) with which it has not been hitherto associated. Dipeolu (1975), for instance, associated the species with mesic enviroments in Nigeria and Aeschlimann & Morel (1965), the descriptors of the species, determined its range in West Africa as the sub-Sudan and guinean savanna. In contrast, for H. m. rufipes and H. truncatum the distributions represented excursions into more hydric enviroments (in southern Mali) than the Sahelian and Sudanian savanna that they have been previously associated with (Morel 1958, Mohammed 1978).

The 4 species combined for nearly four-fifths (78.49%) of all adult ticks collected in the survey by contributing 16-24% each. Each species was also found on 40-50% of the cattle reported. Arguably, their ubiquitous distributions and large numbers could be attributed in part to cattle trade and nomadic husbandry. But the fact that 13 other tick species were found in Mali, each of which infested less than 15% of the cattle reported and had much more restricted distributions, suggest the involvement of factors other than nomadism and cattle trade. One such factor, and a candidate for future research, may be (better) tolerance of these 4 species to wider ranges of enviromental conditions than the other tick species found in Mali.

All of the 4 species above were collected from each of the cattle breeds in Mali. However A. variegatum, H. m. rufipes and H. truncatum infested significantly higher proportions of the Zebu than the Ndama and at higher MNAs (Table 3A). In contrast, B. geigyi infested proportionately more Ndama and at higher MNA than the Zebu. This suggested preference for the Ndama by _B. geigyi_ was probably due to concurrent ecological preferences of both host and parasite since Dipeolu (1975) has shown in Nigeria that _B. geigyi_ thrives better in mesic enviroments as may be found in southern Mali.

For taxonomic considerations, the specimens of _H. truncatum_ from Mali showed morphological features of the species as they were originally described from Senegal (a country with which Mali shares a border) (Koch 1844), but differed significantly from "_H. truncatum_" specimens obtained for comparative studies from both South Africa and former "Rhodesia". The latter, in addition, differed from one another. Two points need to be noted: (a) several _Hyalomma_ species have been described from sub-equatorial Africa, including _H. transiens_ Schulze, _H. planum_ Schulze, and _H. zambesianum_ Schulze and Schlottke that have been included in synonymy with _H. truncatum_ Koch, and (b) _H. truncatum_ in South Africa is currently considered to be composed of 2 strains according to the inability to cause sweating sickness (Bezuidenhout & Malherbe 1981). It is possible that the 3 types of _H. truncatum_ specimens available at TAMU, which so differ in their FGT features are specific varieties of _H. truncatum_ Koch; 1 or all of which might have been previously described. However more specimens from sub-equatorial Africa would need to be examined in order to arrive at a specific conclusion.

Boophilus species. Almost all of the infestations by _B._

annulatus and B. decoloratus occurred on cattle. This is as expected as cattle have been recognized as the preferred host of boophilids in Africa (Hoogstraal 1956). Both species also occurred in very low levels (on cattle) with MNAs of 2.83 and 1.83 for B. annulatus and B. decoloratus, respectively. This may indicate some degree of host resistance as has been seen between B. microplus and Zebu cattle (Hoogstraal 1976). An indication is the fact that in spite of the low MNA, B. annulatus was found on 14.9% of the cattle reported during the survey, the 5th largest proportion of the cattle population infested by any tick species.

The distribution of B. annulatus as seen in this study (Fig. 8), which covered both the Sahel and Sudan savanna, agreed with previous reports from French West Africa (Hoogstraal 1956, Morel 1958, 1969). The concentration of B. decoloratus collections in the northern Sudan and southern Sahel of Mali (Fig. 9) was unusual however considering that B. decoloratus is considered a more mesic species than B. annulatus (Dipeolu 1975). This might be due to the very low numbers of specimens collected or the displacement of the species from its more mesic southern habitats by a more vigorous B. geigyi which also prefers mesic enviroments (Dipeolu 1975). Further investigation is indicated.

The variations seen in the hypostomal dentition in all the 3 Boophilus species found in Mali, B. annulatus, B. decoloratus and

B. geigyi, suggest that the supernumerary dental trait is not unusual in the genus, although it tends to occur in very low proportions of each species population. This appears to be a viable deduction since the trait was also found among Boophilus specimens (at TAMU) that were collected from the New World.

The additional discovery of Boophilus specimens with 5:5 hypostomal dental formula from the TAMU collections adds the possibility that the supernumerary trait could lead to the addition of full lines of denticles to the hypostome of boophilids. Such a scenario, if confirmed by further scientific investigations, would call for a reassessment of Boophilus taxonomy.

Hyalomma species. Six Hyalomma species were found in Mali, H. dromedarii, H. impeltatum, H. impressum, H. m. rufipes, H. nitidum and H. truncatum. Both H. m. rufipes and H. truncatum have been previously discussed. There were too few specimens (4) of H. dromedarii to permit an in-depth appraisal but it must be noted that the specimens were found on camel and Zebu cattle. Since H. dromadarii is noted for its rigid predilection for camels (Hoogstraal 1956), the specimens found on the Zebu could possibly be forced infestations caused by non-availability of the preferred host, especially as the infested Zebu were found in Sudanian locations.

Both H. impeltatum and H. impressum were found principally in the Sahel and Sudan in Mali, distributions that agreed broadly with previous experiences on the Africa continent that had associated them with various savanna vegetational zones (Hoogstraal 1956, Morel 1958, Norval 1982). This survey showed additionally that *H. impeltatum* favored a more xeric (i.e., Sahel-based) distribution than *H. impressum*. Also the species successfully infested more host-types than any other *Hyalomma* except *H. m. rufipes* and its MNA on cattle was the highest by any tick species infesting that host-type. These observations emphasize the potential for escalation inherent in any pathogenic roles that may be played by *H. impeltatum* in its preferred habitat. In contrast, *H. impressum* had a very restricted host range in Mali with all but 3 of its specimens coming from cattle.

Hyalomma nitidum (as described from Mali) differed from the other *Hyalomma* species in thriving in mesic zones in southwest Mali as opposed to the xeric preferences of the others. Collection data suggested 2 foci of strong infestations; the area surrounding Farabale, Mouroukoula and Falea, as well as a ranch at Madina near Diassa. Disseminations have also occurred along cattle trade routes to Dialafara, Tienfala and Segou. This relatively mesic distribution of *H. nitidum* needs to be better defined with more field collections.

Rhipicephalus species. Compared with the other genera, taxonomy within the genus *Rhipicephalus* in Africa is very unstable; creating additional problems of defining ecological and host preferences for "species" for which there are no definitive, taxonomic characters. The rhipicephalid complexes within the Simus and Sanguineus groups are particularly suspect (see below).

Among rhipicephalids encountered in Mali though, both *R. cuspidatus* and *R. evertsi evertsi* have unquestioned taxonomic status. Both occurred in very low numbers, 33 and 36 total specimens respectively, and were collected from 1 host-type each, warthog and cattle, respectively. Generalizations are difficult to make from such small numbers but the host preferences shown and the grassland locations in which the species were found agreed with previous experiences in other African countries (Hoogstraal 1956).

Rhipicephalus lunulatus, whose taxonomic status may likely become stable with the forthcoming publication from Pegram et al. (Hoogstraal 1983 pers. commun.), occurred in relatively large numbers in the Sudan, Sudano-guinean mosaics and North Guinean forest. These mesic to moderately hydric zones appear to be the preferred habitat of the species but confirmation will only come with the stabilization of the its taxonomic status and more field collections.

Among the rhipicephalids belonging to the Sanguineus group, the definitive morphological characters of *R. sanguineus* and *R. guilhoni* (*sensu* Morel & Vassiliades 1962) and *R. sulcatus* (*sensu* Hoogstraal 1956, Feldman-Muhsam 1956) are well exhibited by Mali specimens that were so identified. Only 7 specimens of *R. sulcatus* were found during the survey at a location in the Sudan savanna

(Fig. 17), a vegetational zone similar to the ones the species has been associated with elsewhere in Africa (Elbl & Anastos 1966). Both *R. guilhoni* and *R. sanguineus*, however, were found in relatively substantial numbers - in Sahelian and north Sudanian locations for *R. guilhoni* and Sudanian and urban locations for *R. sanguineus* - that agreed well with previous Malian experiences as summarized by Morel & Vassiliades (1962).

Additionally, this study recognized 2 races of *R. guilhoni* and noted also distinct differences between the FGT of *R. sanguineus* specimens from carnivores and herbivores (see Results). It is possible that the different races of *R. guilhoni*, at least, have different capabilities of vectoring pathogens of livestock and/or human diseases as was the case with the strains of *H. truncatum* in South Africa that have different abilities in causing tick paralysis (Bezuidenhort & Malherbe 1981).

The two partly classified groups of rhipicephalids, *Rhipicephalus* groups #9 and 10, found mostly in the Sahel and Sudan, respectively, appear to be closely related morphologically to members of the Sanguineus group. *Rhipicephalus* group #9 is morphologically close to *R. sanguineus* and *Rhipicephalus* group #10, *R. sulcatus*. Using the detailed descriptions of these specimens that have been given elsewhere in this report, more field collections should be encouraged, starting from the locations in Mali where the original specimens were made. This step should be followed by laboratory rearing and cross-mating between close relatives to determine their true taxonomic status.

The taxonomy of Rhipicephalus species within the Simus complex is currently under review (Pegram et al. 1981). The definitive morphological characters of 2 member species, R. muhsamae, sensu Morel & Vassiliades (1964) and R. senegalensis, sensu Elbl & Anastos (1966), however, are well exhibited by Mali specimens that were identified as such. Both species infested cattle and warthogs only and in fairly sizable numbers, but their distributions were in relatively parallel vegetational zones. Rhipicephalus muhsamae was found in the Sudano-sahel belt between the 12 and 15th latitudes and R. senegalensis in the more hydric Sudano-guinean belt below the 13°N parallel. These distributions agreed well with the known ecological preferences of the 2 species (Morel & Vassiliades 1964). It is possible that the warthog serves as a reservoir host for both tick species in field situations.

The single partly classified Rhipicephalus specimen #11, found at Falea, in southwest Mali, had morphological characters, discussed previously, that have been associated with tick species belonging to the Ziemanni group of rhipicephalids (Zumpt 1943, Hoogstraal 1956). The detailed description given in this report should once again aid in the collection of more specimens from the field for laboratory rearing and mating experiments that should determine their true taxonomic status.

Multi-species Infestation of Major Livestock by Adult Ticks. The occurrence of multi-species infestations on livestock in Mali was not unexpected considering that each tick species may select one or more preferred feeding areas on the host that include the ears, axillae, mane, tail brush and perineum (Hoogstraal 1976). The presence of more species on some hosts (as many as 7 species on an animal) may be partly explained by the conjecture that lead animals in a moving herd (as expected in nomadic husbandry) may usually have more exposures to more ticks (species) as they move through pasture than the rest of the herd. However, this assumption cannot be used to explain the relatively high proportions of host-type populations with 5, 6 or 7 species seen in sedentary herds. Part of the explanation, which must be determined through further studies, may lie in the type and effectiveness of the tick species involved, considered against a background of the densities of the host-types (wild and domestic) in the area.

Both the Zebu and Ndama were shown to be susceptible to high numbered, multi-species infestations, and such host-types as sheep and goats had as many as 5 tick species. The fact that the Ndama and Zebu carried their highest numbers of tick species in Zones I and III, respectively, areas in which they were considered well established, may indicate that multi-species infestations could be due, at least in part, to host-parasite accomodations that have developed over long periods of association especially in situations in which many species exist in the habitat. Factors that may encourage multi-species infestations should be investigated in the future as a prelude to effective tick control programs. Investigations are also called for when considering the nature or dynamics of pathogenic roles (see below) played by the infesting tick species. It is possible that the pathogenic roles of each tick species in multi-species infestations may become additive, complimentary or inhibitory.

In light of the common occurrence of multi-species infestations in Mali, future control programs need to determine and use wide-spectrum control agents (chemical or biological). Agents meant for use on hosts must also be able to reach all tick feeding surfaces on hots, including the axillae and hoof clefts.

Possible Pathogenic Roles for Ticks in Mali. Tick infestations produce many deleterious effects for their hosts including exsanguination, lymph imbibement, paralysis and/or mechanical or biological transmission of disease agents. Many of the tick species found in Africa have long lists of diseases (agents) with which they have been associated (Hoogstraal 1956, Elbl & Anastos 1966, Morel 1980). A referenced compilation that include many, if not all, documented cases of experimental and/or natural associations with disease agents, especially in Africa, is included in the addendum preceeding the micrographs on each tick species found in Mali (see Appendix II). The list should aid workers in Mali to target probable vectors of known or suspected diseases of livestock (e.g., heartwater) and man.

Eight of the 20 species found in Mali, *A. variegatum*, *B.*

decoloratus, H. dromedarii, H.m. rufipes, H. truncatum, R. e. evertsi and R. sanguineus, have each been associated with between 8-20 disease conditions, including paralysis, sweating sickness and transmission of protozoan, bacterial, viral, helminthic and rickettsial agents. These species must be considered as prime targets for further vector research and ultimate control.

The Place of Female Gonopore Tissue in Tick Taxonomy. Adler & Feldman-Muhsam (1946, 1948) pioneered the use of the characters of the FGT in tick taxonomy when they described a method for clearing and mounting the tissue on glass slides and discussed its features in Hyalomma females in Palestine. Subsequently, Kaiser & Hoogstraal (1963, 1964) worked on Hyalomma species from Afghanistan, Pakistan, India and Ceylon; Morel & Vassiliades (1962) on Rhipicephalus species from West Africa, Europe and Israel and Feldman-Muhsam (1951) on several Amblyomma and Dermacentor species from North America. The features of the FGT in all the species studied were shown to be characteristic and relatively constant intraspecifically, and Adler & Feldmand-Muhsam (1948) indicted that the characters also remain constant across generations.

This unique approach to tick taxonomy, however, has not been widely applied for 2 main reasons; (a) currently available procedures for clearing and mounting the FGT are often too cumbersome, time-consuming or harsh (distorting) on the target tissue, and (b) overzealous workers have read too many fine details into what is an simple (FGT) structure that has only 3 significant parts, atrium, sclerites, and an opening.

A standard clearing solution was developed for use in this study with the following distinct advantages. First, the solution is strongly effective on all chitinized tissues at room temperature. Most of the FGT are cleared, enough for photography, within 1-4 hours and will show no deleterous effects when left overnight in the same solution, although a little more clearing presumably would have occurred by then. Heavily chitinized ticks that have been kept in preservatives for long periods (sometimes years) do not clear easily due to poor penetration of tick integument by clearing solution. In such a case and in situations where on-the-spot answers are required, the clearing solution can be warmed (as opposed to boiled) for up to 7 minutes.

Second, the solution does not cause any tissue damage or distortions when used at room temperature. A minimal amount of tissue distortion or over-clearing does occur with heated solutions and is noted as a warping effect in which the integrity of the external surface of the integument becomes lost and tiny tears appear in the epidermal layer (only). Third, the clearing solution is re-usable in its cold application, and over extended periods of time. It is possible to clear up to 8 gonopore materials, at room temperatures, in the same solution (about 2 ml), at different times, over a period of 5 weeks. The solutions preferably should be kept in brown bottles, away from sources of heat when not in use.

The use of the FGT in taxonomy is fully justified and conclusive if the FGT is considered succintly as a simple structure in which the atrium is recognized as the (usually) dilated end of the vagina possessing (at times 2 or more) sclerites and opening to the outside through a slit of the ventral integument. Since all studied ticks have a horizontal plane to the slit (gonopore), each opening has an anterior and a posterior lip (Fig. 34 and 35).

Distinguishing characters are simple to separate. The gonopore may be wide or narrow, V- or U-shaped, shallow or deep. Lips may or may not be depressed or tuberculated, although both characters may occur on a lip, albeit in specific order (e.g., in *H. truncatum* there is always a depression posterior to the tubercle on the anterior lip). The integument lateral to the gonopore may be tuberculated (lobed according to some authors).

The atrium is usually dilated, more so in some species than others; otherwise it remains unadorned. Atrial sclerites, in many genera occur as a pair, 1 to a side, but some species have extras in various locations (e.g., *A. dissimile*). Sclerites may be pigmented, long or short, wide or narrow. Wide sclerites tend to encroach on the space separating them. Shapes of the sclerites do vary, especially among the *Rhipicephalus*, but part of the perspective is due to the fact that the atrium is tangentially attached to the integument and the sclerites are not seen completely flat in their entirety. Atrial commissures are the lips of the atrium per se as seen only in cleared mounts and they may assume various shapes and sizes that are useful only when described broadly. The placement or distance of the commissure from the base of the atrium is characteristic and determines the size or volume of the latter (see Results on _H. truncatum_) and is often a better diagnostic feature than whether or not the atrial sclerite overlaps the commissure. Tensions in the tissues, as well as accidents of preparation, could play important roles in the final placement of the latter feature.

The results of the present study, based solely on species of the Ixodoidea from the collections at TAMU, demonstrated a number of points. First, the 4 _Ixodes_ species that were examined (_I. affinis_, _I. pacificus_, _I. scapularis_ and _I. texanus_) differ significantly from all the other species in not possessing atrial sclerites, thereby denying the other structural features (of their FGT) of definitive reference points. For these species, and most probably for the entire genus, the features of the FGT thus have little or no taxonomic value.

Second, the study confirmed previous observations in the literature that the characters of the FGT are constant and characteristic within each species of the Ixodoidea, excepting genus _Ixodes_, especially when those characters are examined broadly and in a consistent pattern. Although various structural features were variably emphasized among the different genera, no particular feature or group of features was exclusive to any 1 genus.

The question as to why these constant and characteristic structural arrangements exist in the FGT of ticks, and apparently at the species or subspecies but not higher taxonomic level, prompted the speculation that the intraspectic constancy is preventive. The arrangements possibly guard against undesirable mating in the field, e.g., interspecific or intergeneric mating. In this concept, the FGT of each species has evolved to accept and/or facilitate only a structurally compatile male or its spermatophore. Such a male would ideally come only from its own taxon (species or sub-species).

Suggestions for Future Projects in Mali. The study reported here placed emphasis on the tick fauna as it affects cattle, so that other domestic host-types were not adequately represented (numerically). For a more comprehensive data base on the tick fauna in Mali more domestic and wild host-types need to be examined, with each equitably represented (if possible) in the 3 broad hygrophytic zones employed in this study since the zones appear to foster characteristic tick infestation patterns. The emphasis in the selection of candidates for screening among wildlife should be placed on those (especially birds) that frequent peri-urban environments or herd premises since these are possibly the immediate links between domestic and reseivor wild host-types. As a concurrent activity to such surveys, attention should be placed on studying the patterns of activities of identified parasites, on and off hosts, in field situations. These data are pre-requisites for cost-effective tick control programs.

A strong commitment is also needed in Mali to study (including breeding and rearing) immature stages of ticks. Any information gained will help in future identifications, expecially in field situations where and when adults may not be found. There is at present little information on immature stages of ticks in the literature. As a corollary to identification, the true status of tick materials of doubtful taxonomy are often easily estabilished by the characteristic morphology of their immatures. The unclassifed Rhipicephalus materials found in this survey merit such studies in the immediate future. Yet another advantage deriving from such a study is the possible elucidation of the transtadial pathogen survival in many tick species. Obtaining the latter information may, however, involve complimentary facilities for physiological and serological studies.

Any future control program(s) in Mali should consider the following observations from this study: (a) most domestic animals in Mali carry ticks, primarily adult forms, with cattle more readily attacked by most species in all zones, (b) infestations, measured by mean number of ticks per infested individual, varied among host-types and among members of the same host-type in different parts of Mali, (c) among cattle breeds the Zebu appeared to be faring worse than the Ndama, especially in the Sudan zone, in dealing with tick infestations, (d) the wild-life population, especially birds, usually carried high tick burdens, especially immatures, thereby creating reservoir populations for the replenishments of tick infestations of domestic host-types, and (e) multi-species infestation of livestock, especially cattle, was rampant. Any future control programs should be designed in such ways that regional (zones) characters of the tick fauna are not overlooked. Inferences about tickborne disease and disease management programs should consider the multi-species nature of infestations. More than one species may be involved in transmission, and the regional characters of all vectors must be considered.

CHAPTER VI

SUMMARY

As part of a "Vector-borne Hemoparasites of Livestock and their Vectors" survey project in the Republic of Mali, West Africa from 1977 to 1981, 23,769 ticks were collected from various animal and non-animal sources. The sources selected emphasized domestic host-types, especially cattle, and included 1,248 cattle, 19 sheep, 8 goats, 3 horses, 5 camels and 17 dogs. Among cattle, 264 were Zebu, 267 Ndama and 8 Zebu-Ndama crosses. Wild animals reported included 7 warthogs, 2 hares, 2 snakes and 2 guinea fowl; ticks were also collected during 13 pasture sweeps.

Approximately 98% of the specimens belonged to 20 currently recognized tick species or subspecies: *Amblyomma variegatum*, *Aponomma flavomaculatum*, *Ap. latum*, *Boophilus annulatus*, *B. decoloratus*, *B. geigyi*, *Hyalomma dromedarii*, *H. impeltatum*, *H. impressum*, *H. marginatum rufipes*, *H. nitidum*, *H. truncatum*, *Rhipicephalus cuspidatus*, *R. evertsi evertsi*, *R. guilhoni*, *R. lunulatus*, *R. muhsamae*, *R. sanguineus*, *R. senegalensis* and *R. sulcatus*.

Two groups and a separate single specimen of *Rhipicephalus* ticks exhibited relatively unique combinations of morphological characters and are described in this report as *Rhipicephalus* groups #9 and 10, and specimen #11 respectively. Micrographs of the morphological features and the female gonopore tissues of all the aforementioned species and specimen groups were produced by light and electron microscopy. The accepted morphology of *H. nitidum*, *H. truncatum* and *R. cuspidatus* from Mali was reviewed because some essential characters differed significantly from those used in their taxonomy. Supernumerary hypostomal dentition was recorded and noted as a usual trait, occurring in low incidence among *Boophilus* species. Features of the female gonopore tissues were shown to be characteristic and constant enough to suggest use in distinguishing species of ixodid ticks, excepting genus *Ixodes*.

Of all species encountered, *A. variegatum*, *B. geigyi*, *H. m. rufipes* and *H. truncatum* showed the widest host ranges and occurred, with varying degrees of success, in all areas surveyed. The remaining species showed restricted distributions determined primarily by rainfall, vegetation, topography and host availability.

Most domestic animals inspected in Mali carried ticks, primarily adult forms, with cattle more readily attacked by most (adult) tick species, in all zones. Infestation loads (determined by mean number of ticks per infested individual) varied among host-types, without apparent relation to body size, and among members of the same host-type in different parts of the country. Such infestations appeared higher in the Sudan for the Zebu than the Ndama. The wildlife population, especially birds, usually carried high tick burdens, particularly immatures.

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APPENDIX I

Table 1A. Ticks (all stages) from the Republic of Mali (all zones combined)

	CUB	Zebu	Ndama	ZN cross	Cattle	Sheep	Goat	Horse	Camel	Dog	Wart-hog	Other † sources	Totals
# Hosts reported	709	264	267	8	1248	19	8	3	5	17	7	Misc	—
# Host infested	689	263	261	8	1221	17	3	3	4	17	6	Misc	—
% Host infested	97.17	99.62	97.75	100	97.84	89.47	37.5	100	80	100	85.7	—	—
# Males	6011	2832	1351	79	10273	112	26	11	37	59	29	69	10616
# Females	3161	1611	1159	73	6004	39	41	7	15	62	22	22	6212
Total # adults	9172	4443	2510	152	16277	151	67	18	52	121	51	91	16828
Mean # adults/host	13.31	16.89	9.61	19	13.33	8.88	22.3	6	13	7.1	8.5	—	—
# Species (adults)	15(2)††	15(2)††	15(1)††	5(1)††	17(3)††	12(1)††	5(1)††	4	4	3(1)†††	5	6	20(4)†† †††
# Host infested (nymphs)	279	74	119	—	472	9	5	—	1	6	5	Misc	—
% Host infested (nymphs)	39.35	28.03	44.56	—	37.82	47.36	62.5	—	20	35.29	71.43	—	—
Total # nymphs	2624	1732	1585	—	5941	44	10	—	6	28	62	221	6312
Mean # nymphs/host	9.41	23.41	13.32	—	12.58	4.89	2	—	6	4.67	12.4	—	—
# Genera (nymphs)	3	2	2	—	3	2	1	—	1	2	1	4	5
# Host infested (larvae)	8	13	12	—	33	1	—	—	—	2	3	Misc	—
% Host infested (larvae)	1.13	4.92	4.49	—	2.64	5.26	—	—	—	11.76	42.85	—	—
Total # larvae	130	225	83	—	438	7	—	—	—	101	26	57	629
Mean # larvae/host	16.25	17.31	6.92	—	13.27	7	—	—	—	50.5	8.67	—	—
# Genera (larvae)	2	1	1	—	2	2	—	—	—	1	2	3(1)††††	5(1)††††
Total tick count	11926	6401	4177	152	22656	202	77	18	58	250	139	369	23769
% Ticks from host	100	100	100	100	100	100	100	100	100	100	100	100	100
Mean # ticks/host	16.82	24.25	15.64	19	18.55	10.63	9.62	6	11.6	14.71	19.86	—	—

† Full details in Table 3D, "Other sources of the ticks from the Republic of Mali".
†† # in parenthesis indicate specimens or groups of specimens classified to genus, not included in main species count.
††† # in parenthesis indicate additional species (from unidentified *Haemaphyalis* female) not included in main species count.
†††† # in parenthesis indicate additional genus (from unidentified *Argas* larva) not included in main genera count.
CUB Cattle of unspecified breed
ZN Zebu-Ndama
Misc Miscellaneous (animal and non-animal sources)

Table 1B. Ticks (all stages) from the Republic of Mali collected below latitude 12'N (Zone I)

	CUB	Zebu	Ndama	ZN cross	Cattle	Sheep	Goat	Horse	Camel	Dog	Wart-hog	Other † Sources	Totals
# Hosts reported	119	36	101	8	264	10	1	—	—	2	4	Misc	—
# Host infested	110	36	100	8	254	9	1	—	—	2	4	Misc	—
% Host infested	92.44	100	99.99	100	96.21	90	100	—	—	100	100	—	—
# Males	639	198	606	79	1522	77	1	—	—	4	23	2	1629
# Females	571	198	647	73	1489	24	—	—	—	5	3	1	1522
Total # adults	1210	396	1253	152	3011	101	1	—	—	9	26	3	3151
Mean # adults/host	11	11	12.53	19	11.85	11.22	1	—	—	4.5	6.5	—	—
# Species (adults)	12(1)††	6	14(1)††	5(1)††	15(1)††	7	1	—	—	2	4	1	16(1)††
# Host infested (nymphs)	63	25	68	—	156	2	—	—	—	1	2	—	—
% Host infested (nymphs)	52.94	69.44	67.32	—	59.09	20	—	—	—	50	50	—	—
Total # nymphs	730	324	817	—	1871	24	—	—	—	2	24	—	1912
Mean # nymphs/host	11.59	12.96	12.01	—	11.99	12	—	—	—	2	12	—	—
# Genera (nymphs)	2	2	2	—	2	1	—	—	—	2	1	—	3
# Host infested (larvae)	1	1	5	—	7	1	—	—	—	1	2	—	—
% Host infested (larvae)	0.84	2.7	4.95	—	2.65	10	—	—	—	50	50	—	—
Total # larvae	5	2	40	—	47	7	—	—	—	2	13	—	69
Mean # larvae/host	5	2	8	—	6.71	7	—	—	—	2	6.50	—	—
# Genera (larvae)	1	1	1	—	1	1	—	—	—	1	1	—	2
Total tick count	1945	722	2110	152	4929	132	1	—	—	13	63	3	5141
% Ticks from host	16.31	11.28	50.51	100	21.76	65.35	1.32	—	—	11.76	45.32	0.08	21.61
Mean # ticks/host	16.34	20.06	20.89	19	18.67	13.20	1	—	—	6.50	15.75	—	—

† Full details in Table 3D, "Other sources of the ticks from the Republic of Mali".
†† # in parenthesis indicate specimens or groups of specimens classified to genus, not included in main species count.
CUB Cattle of unspecified breed
ZN Zebu-Ndama
Misc Miscellaneous (animal and non-animal sources)

Table 1C. Ticks (all stages) from the Republic of Mali collected between latitudes 12 and 14°N (Zone II)

	CUB	Zebu	Ndama	ZN cross	Cattle	Sheep	Goat	Horse	Camel	Dog	Wart-hog	Other † sources	Totals
# Hosts reported	378	76	160	—	614	3	—	1	—	13	1	Misc	—
# Host infested	374	75	155	—	603	3	—	1	—	13	1	Misc	—
% Host infested%	98.94	98.88	96.88	—	98.21	100	—	100	—	100	100	—	—
# Males	4225	827	690	—	5742	3	—	—	—	47	4	2	5798
# Females	1860	612	493	—	2965	3	—	1	—	48	2	4	3023
Total # adults	6085	1439	1183	—	8707	6	—	1	—	95	6	6	8821
Mean # adults/host	16.27	19.18	7.63	—	14.44	2	—	1	—	7.31	6	—	—
# Species (adults)	14(1)††	14(1)	12(1)††	—	15(2)††	2(1)††	—	1	—	2(1)†††	1	3	17(2)†† †††
# Host infested (nymphs)	132	43	50	—	225	1	—	—	—	2	1	Misc	—
% Host infested (nymphs)	34.92	56.58	31.25	—	36.64	33.30	—	—	—	15.38	100	—	—
Total # nymphs	1250	1364	762	—	3376	2	—	—	—	26	8	218	3630
Mean # nymphs/host	9.47	31.72	15.24	—	15	2	—	—	—	13	8	—	—
# Genera (nymphs)	3	2	2	—	3	1	—	—	—	1	1	3	5
# Host infested (larvae)	7	12	7	—	26	—	—	—	—	1	—	Misc	—
% Host infested (larvae)	1.85	15.79	4.38	—	4.23	—	—	—	—	7.6	—	—	—
Total # larvae	125	223	43	—	391	—	—	—	—	99	—	53	543
Mean # larvae/host	17.86	18.58	6.14	—	15.04	—	—	—	—	99	—	—	—
# Genera (larvae)	2	1	1	—	2	1	—	—	—	1	—	3(1)††††	5(1) ††††
Total tick count	7460	3026	1988	—	12474	8	—	1	—	220	14	277	12994
% Ticks from host	62.55	47.27	47.59	—	55.06	3.96	—	33.33	—	88	10.07	75.06	54.67
Mean # ticks/host	19.74	39.81	12.43	—	20.32	2.67	—	1	—	16.92	14	—	—

† Full details in Table 3D, "Other sources of the ticks from the Republic of Mali".
†† # in parenthesis indicate suspected specimens or groups of specimens classified to genus, not included in main species count.
††† # in parenthesis indicate additional species (from unidentified <u>Haemaphyalis</u> female) not included in main species count.
†††† # in parenthesis indicate additional genus (from unidentified <u>Argas</u> larva) not included in main genera count.
CUB Cattle of unspecified breed
ZN Zebu-Ndama
Misc Miscellaneous (animal and non-animal sources)

Table 1D. Ticks (all stages) from the Republic of Mali collected between latitudes 14 and 16'N (Zone III)

	CUB	Zebu	Ndama	ZN cross	Cattle	Sheep	Goat	Horse	Camel	Dog	Wart-hogs	Other† sources	Totals
# Hosts reported	212	152	6	—	370	6	7	2	5	2	2	Misc	—
# Host infested	205	152	6	—	363	5	2	2	4	2	1	Misc	—
% Host infested	96.70	100	100	—	98.11	83.33	28.57	100	80	100	50	—	—
# Males	1147	1807	55	—	3009	32	25	11	37	8	2	14	3138
# Females	730	801	19	—	1550	12	41	6	15	9	17	4	1654
Total # adults	1877	2608	74	—	4559	44	66	17	52	17	19	18	4792
Mean # adults/host	9.16	17.15	12.33	—	12.56	8.8	33	8.5	13	8.5	19	—	—
# Species (adults)	11(1)††	12(1)††	5	—	12(1)††	7	5(1)††	4	4	1	2	2	13(1)††
# Host infested (nymphs)	84	6	1	—	91	6	5	—	1	—	2	Misc	—
% Host infested (nymphs)	39.62	3.95	16.60	—	24.59	100	71.43	—	20	—	100	—	—
Total # nymphs	644	44	6	—	694	18	10	—	6	—	30	3	761
# Mean # nymphs/host	7.67	7.33	6	—	7.63	3	2	—	6	—	15	—	—
# Genera (nymphs)	2	2	1	—	2	2	1	—	1	—	1	2	4
# Host infested (larvae)	—	—	—	—	—	—	—	—	—	—	1	Misc	—
# Host infested (larvae)	—	—	—	—	—	—	—	—	—	—	50	—	—
Total # larvae	—	—	—	—	—	—	—	—	—	—	13	4	17
Mean # larvae/host	—	—	—	—	—	—	—	—	—	—	13	—	—
# Genera (larvae)	—	—	—	—	—	—	—	—	—	—	1	2	3
Total tick count	2521	2652	80	—	5253	62	17	17	58	17	62	25	5570
% Ticks from host	21.14	41.43	1.92	—	23.28	30.69	98.70	94.44	100	6.80	44.60	6.78	23.43
Mean # ticks/host	11.89	17.45	12.30	—	14.20	10.33	10.86	8.50	11.60	8.50	31	—	—

† Full details in Table 3D, "Other sources of the ticks from the Republic of Mali".
†† # in parenthesis indicate specimens or groups of specimens classified to genus, not included in main species count.
††† # in parenthesis indicate additional species (from unidentified *Haemaphyalis* female) not included in main species count.
†††† # in parenthesis indicate additional genus (from unidentified *Argas* larva) not included in main genera count.
CUB Cattle of unspecified breed
ZN Zebu-Ndama
Misc Miscellaneious (animal and non-animal sources)

Table 2. Species or genera of ticks from the Republic of Mali

Genus +	Species	Adults					Nymphs		Larvae		All stages	
		Males	Females	Total # adults	% Adult ticks from same genus	% All adult ticks	Total # nymphs	% All nymphs	Total # larvae	% All larvae	Total # specimens	% All ticks collected
Amblyomma	A. variegatum	3408	746	4154	100.00	24.69						
	All A. species	3408	746	4154	100.00	24.69	5727	90.73	484	76.95	10,365	43.61
Aponomma	Ap. flavomaculatum	7	4	11	23.91	0.07						
	Ap. latum	30	5	35	76.09	0.21						
	All Ap. specimens	37	9	46	100.00	0.27	36	0.57	4	0.64	86	0.36
Boophilus	B. annulatus	148	384	532	13.94	3.16						
	B. decoloratus	20	55	75	1.97	0.45						
	B. geigyi	854	2150	3004	78.74	17.85						
	B.sp.undeterminable	40	164	204	5.35	1.21						
	All B. specimens	1062	2753	3815	100.00	22.67	453	7.18	4	0.64	4358	18.33
Hyalomma	H. dromedarii	3	1	4	0.05	0.02						
	H. impeltatum	565	279	844	11.34	5.02						
	H. impressum	358	119	477	6.41	2.83						
	H. marginatum rufipes	2369	920	3289	44.19	19.54						
	H. nitidum	52	14	66	0.89	0.39						
	H. truncatum	2013	748	2762	37.11	16.41						
	All H. specimens	5360	2081	7441	100.00	44.21	5	0.08	22	3.50	7468	31.42
Rhipicephalus	R. cuspidatus	15	18	33	2.41	0.20						
	R. evertsi evertsi	12	24	36	2.63	0.21						
	R. guilhoni	124	102	226	16.48	1.34						
	R. lunulatus	115	167	282	20.56	1.68						
	R. muhsamae	100	97	197	14.37	1.17						
	R. sanguineus	121	77	198	14.44	1.18						
	R. senegalensis	194	110	304	22.17	1.81						
	R. sulcatus	4	3	7	0.51	0.04						
	R. group #9	11	11	22	1.60	0.13						
	R. group #10	45	20	65	4.74	0.39						
	R. specimen #11	1	0	1	0.07	0.01						
	All R. specimens	742	629	1371	100.00	8.15	91	1.44	114	18.12	1576	6.23

+ One *Argas* larva was collected from a *Francolinus* sp. bird.

Table 3A. Adult ticks from the Republic of Mali

Host or source	# Host infested	Tick species	Specimens Males	Specimens Females	Specimens Total	% of adult ticks from host-type	Mean # adults /infested animal	% Host-type infested
Unspecified cattle	292	*Amblyomma variegatum*	2306	367	2673	29.14	9.15	41.18
Unspecified cattle	120	*Boophilus annulatus*	94	244	338	3.69	2.82	16.93
Unspecified cattle	22	*Boophilus decoloratus*	14	35	49	0.53	2.23	3.10
Unspecified cattle	300	*Boophilus geigyi*	558	1151	1709	18.63	5.70	42.31
Unspecified cattle	14	*Boophilus* sp. undetermined	3	24	27	0.29	10.14	5.22
Unspecified cattle	37	*Hyalomma impeltatum*	259	116	375	4.09	1.92	1.97
Unspecified cattle	77	*Hyalomma impressum*	295	93	388	4.23	5.04	10.86
Unspecified cattle	336	*Hyalomma marginatum rufipes*	1034	352	1386	15.11	4.13	47.39
Unspecified cattle	315	*Hyalomma truncatum*	1060	388	1448	15.79	4.60	44.43
Unspecified cattle	15	*Hyalomma nitidum*	25	6	31	3.38	2.07	2.12
Unspecified cattle	4	*Rhipicephalus evertsi evertsi*	12	21	33	3.60	8.25	0.56
Unspecified cattle	38	*Rhipicephalus guilhoni*	65	58	123	1.34	3.24	5.36
Unspecified cattle	34	*Rhipicephalus lunulatus*	88	147	235	2.56	6.91	4.80
Unspecified cattle	42	*Rhipicephalus muhsamae*	56	56	112	1.22	2.67	5.92
Unspecified cattle	9	*Rhipicephalus sanguineus*	13	3	16	0.17	1.78	1.27
Unspecified cattle	33	*Rhipicephalus senegalensis*	122	91	213	2.32	6.45	4.65
Unspecified cattle	4	*Rhipicephalus* group # 9	3	4	7	0.08	1.75	0.56
Unspecified cattle	5	*Rhipicephalus* group # 10	4	5	9	0.10	1.80	0.71
Zebu	111	*Amblyomma variegatum*	698	282	980	22.06	8.83	41.57
Zebu	24	*Boophilus annulatus*	18	35	53	1.19	2.21	8.99
Zebu	11	*Boophilus decoloratus*	2	13	15	0.34	1.36	4.12
Zebu	99	*Boophilus geigyi*	120	384	504	11.34	5.09	37.08
Zebu	18	*Boophilus* sp. undetermined	12	65	77	1.73	4.28	6.82

Table 3A. Continued.

Host or source	# Host infested	Tick species	Specimens Males	Specimens Females	Specimens Total	% of adult ticks from host-type	Mean # adults /infested animal	% Host-infested
Zebu	1	Hyalomma dromedarii	2	0	2	0.01	1.00	0.16
Zebu	41	Hyalomma impeltatum	236	131	367	8.26	8.95	15.36
Zebu	22	Hyalomma impressum	62	21	83	1.87	3.77	8.24
Zebu	158	Hyalomma marginatum rufipes	988	392	1380	31.96	8.73	59.18
Zebu	142	Hyalloma truncatum	641	230	871	19.60	6.13	53.18
Zebu	1	Hyalomma nitidum	2	0	2	0.05	2.00	0.37
Zebu	1	Rhipicephalus evertsi evertsi	0	3	3	0.07	3.00	0.37
Zebu	23	Rhipicephalus guilhoni	26	37	63	1.42	2.74	8.61
Zebu	1	Rhipicephalus lunulatus	0	1	1	0.02	1.00	0.37
Zebu	10	Rhipicephalus muhsamae	20	16	36	0.81	3.60	3.75
Zebu	3	Rhipicephalus sanguineus	4	0	4	0.09	1.33	1.12
Zebu	2	Rhipicephalus group # 9	1	1	2	0.05	1.00	0.75
Ndama	91	Amblyomma variegatum	344	42	386	15.38	4.24	34.47
Ndama	42	Boophilus annulatus	35	99	134	5.34	3.19	15.91
Ndama	7	Boophilus decoloratus	4	5	9	0.39	1.29	2.65
Ndama	124	Boophilus geigyi	170	579	749	29.84	6.04	46.97
Ndama	21	Boophilus sp. undetermined	19	71	90	3.59	4.29	7.87
Ndama	6	Hyalomma impeltatum	31	19	50	1.99	8.33	2.27
Ndama	2	Hyalomma impressum	0	3	3	0.12	1.50	0.76
Ndama	128	Hyalomma marginatum rufipes	310	152	462	18.41	3.61	48.48
Ndama	95	Hyalomma truncatum	268	108	376	14.98	3.96	35.98
Ndama	13	Hyalomma nitidum	23	8	31	1.24	2.38	4.92

Table 3A. Continued.

Host or Source	# Host infested	Tick species	Specimens Males	Females	Total	% of adult ticks from host-type	Mean # adults /infested animals	% Host-infested
Ndama	1	Rhipicephalus cuspidatus	1	0	1	0.04	1.00	0.38
Ndama	3	Rhipicephalus guilhoni	4	0	4	0.15	1.33	1.14
Ndama	18	Rhipicephalus lunulatus	19	18	37	1.47	2.06	6.82
Ndama	13	Rhipicephalus muhsamae	20	24	44	1.75	3.38	4.92
Ndama	1	Rhipicephalus sanguineus	1	0	1	0.04	1.00	0.38
Ndama	22	Rhipicephalus senegalensis	63	17	80	3.19	3.64	8.33
Ndama	4	Rhipicephalus group # 10	38	14	52	2.07	13.00	1.52
Ndama	1	Rhipicephalus group # 11	1	0	1	0.04	1.00	0.38
Zubu X Ndama	7	Amblyomma variegatum	41	28	69	45.39	9.86	87.50
Zebu X Ndama	5	Boophilus geigyi	3	18	21	13.82	4.20	62.50
Zebu X Ndama	6	Boophilus sp. undetermined	6	4	10	6.58	1.80	75.00
Zebu X Ndama	4	Hyalomma marginatum rufipes	11	7	18	11.84	4.50	50.00
Zebu X Ndama	7	Hyalomma truncatum	14	15	29	19.08	4.14	87.50
Zebu X Ndama	1	Rhipicephalus sanguineus	1	0	1	0.66	1.00	12.50
Zebu X Ndama	2	Rhipicephalus group # 10	3	1	4	2.63	2.00	25.00
Cattle	501	Amblyomma variegatum	3389	719	4108	25.24	8.20	40.14
Cattle	186	Boophilus annulatus	147	378	525	3.23	2.82	14.90
Cattle	40	Boophilus decoloratus	20	53	73	0.45	1.83	3.21
Cattle	528	Boophilus geigyi	851	2132	2983	18.33	5.65	42.31
Cattle	54	Boophilus sp. undetermined	40	164	204	1.25	3.78	4.33
Cattle	2	Hyalomma dromedarii	2	0	2	0.01	1.00	0.16
Cattle	84	Hyalomma impeltatum	526	266	792	4.87	9.43	6.73

Table 3A. Continued.

Host or source	# Host infested	Tick species	Specimens Males	Specimens Females	Specimens Total	% of adult ticks from host-type	Mean # adults /infested animals	% Host-infested
Cattle	101	*Hyalomma impressum*	357	117	474	2.91	4.69	8.09
Cattle	629	*Hyalomma marginatum rufipes*	2343	903	3246	19.94	5.19	50.16
Cattle	29	*Hyalomma nitidum*	50	14	64	0.39	2.21	2.32
Cattle	559	*Hyalomma truncatum*	1983	741	2724	16.73	4.87	44.79
Cattle	1	*Rhipicephalus cuspidatus*	1	0	1	0.01	1.00	0.08
Cattle	5	*Rhipicephalus evertsi evertsi*	12	24	36	0.22	7.20	0.40
Cattle	64	*Rhipicephalus guilhoni*	95	95	190	1.17	2.97	5.13
Cattle	53	*Rhipicephalus lunulatus*	107	165	272	1.67	5.13	4.25
Cattle	65	*Rhipicephalus muhsamae*	96	96	192	1.17	2.95	5.21
Cattle	14	*Rhipicephalus sanguineus*	19	3	22	0.14	1.57	1.12
Cattle	55	*Rhipicephalus senegalensis*	185	108	293	1.80	5.33	4.41
Cattle	6	*Rhipicephalus* group # 9	4	6	10	0.06	1.67	0.48
Cattle	11	*Rhipicephalus* group # 10	45	20	65	0.39	5.19	0.88
Cattle	1	*Rhipicephalus* specimen # 11	1	0	1	0.01	1.00	0.08
Sheep	3	*Amblyomma variegatum*	13	4	17	11.26	5.67	15.79
Sheep	2	*Boophilus annulatus*	0	3	3	1.99	1.50	10.53
Sheep	1	*Boophilus decoloratus*	0	2	2	1.32	2.00	5.26
Sheep	4	*Boophilus geigyi*	3	8	11	7.28	2.75	21.05
Sheep	4	*Hyalomma impeltatum*	4	0	4	2.65	1.00	21.05
Sheep	1	*Hyalomma impressum*	0	1	1	0.66	1.00	5.26
Sheep	1	*Hyalomma marginatum rufipes*	2	1	3	1.99	3.00	5.26
Sheep	6	*Hyalomma truncatum*	25	6	31	20.53	5.17	31.58

Table 3A. Continued.

Host or source	# Host infested	Tick species	Specimens Males	Specimens Females	Specimens Total	% of adult ticks from host-type	Mean # adults /infested animals	% Host-infested
Sheep	4	*Rhipicephalus guilhoni*	8	1	9	5.96	2.25	21.05
Sheep	3	*Rhipicephalus lunulatus*	8	2	10	6.62	3.33	15.79
Sheep	4	*Rhipicephalus sanguineus*	43	7	50	33.11	12.50	21.05
Sheep	2	*Rhipicephalus sulcatus*	4	3	7	4.64	3.50	10.52
Sheep	1	*Rhipicephalus* group # 9	2	1	3	1.99	3.00	5.26
Goat	2	*Amblyomma variegatum*	1	21	22	32.84	11.00	25.00
Goat	1	*Boophilus geigyi*	0	8	8	11.94	8.00	12.50
Goat	1	*Hyalomma impeltatum*	4	0	4	5.97	4.00	12.50
Goat	2	*Hyalomma marginatum rufipes*	7	8	15	22.39	7.50	25.00
Goat	2	*Rhipicephalus guilhoni*	13	3	16	23.88	8.00	25.00
Goat	1	*Rhipicephalus* group # 9	1	1	2	2.99	2.00	12.50
Horse	1	*Hyalomma impeltatum*	0	1	1	5.56	1.00	33.33
Horse	2	*Hyalomma marginatum* rufipes	1	2	3	16.67	1.50	66.67
Horse	1	*Hyalomma truncatum*	2	1	3	16.67	3.00	33.33
Horse	2	*Rhipicephalus guilhoni*	8	3	11	61.11	5.50	66.67
Donkey	1	*Rhipicephalus sanguineus*	0	6	6	100.00	6.00	100.00
Dog	1	*Boophilus* annulatus	0	1	1	0.83	1.00	5.88
Dog	1	*Boophilus geigyi*	0	1	1	0.83	1.00	5.88
Dog	1	*Haemaphysalis* female	0	1	1	0.83	1.00	5.88
Dog	15	*Rhipicephalus sanguineus*	59	59	118	97.52	7.87	88.24
Camel	1	*Hyalomma dromedarii*	1	1	2	3.85	2.00	20.00
Camel	4	*Hyalomma impeltatum*	20	8	28	53.85	7.00	80.00
Camel	2	*Hyalomma impressum*	1	1	2	3.85	1.00	40.00

Table 3A. Continued,

Host or source	# Host infested	Tick species	Specimens Males	Females	Total	% of adult ticks from host-types	Mean # adults /infested animal	% Host-infested
Camel	3	Hyalomma marginatum rufipes	15	5	20	38.46	6.67	60.00
Warthog	1	Hyalomma marginatum rufipes	0	1	1	1.96	1.00	14.29
Warthog	1	Hyalomma nitidum	2	1	1	3.92	2.00	14.29
Warthog	6	Rhipicephalus cuspidatus	14	18	32	62.75	5.33	85.71
Warthog	2	Rhipicephalus muhsamae	4	1	5	9.80	2.50	28.57
Warthog	1	Rhipicephalus senegalensis	9	2	11	21.57	11.00	14.29
Other sources†	—	Amblyomma variegatum	5	2	7	—	—	—
Other sources†	—	Aponomma flavomaculatum	7	4	11	—	—	—
Other sources†	—	Aponomma latum	30	5	35	—	—	—
Other sources†	—	Boophilus annulatus	1	2	3	—	—	—
Other sources†	—	Boophilus geigyi	0	1	1	—	—	—
Other sources†	—	Hyalomma impeltatum	11	4	15	—	—	—
Other sources†	—	Hyalomma marginatum rufipes	1	0	1	—	—	—
Other sources†	—	Hyalomma truncatum	3	0	3	—	—	—
Other sources†	—	Rhipicephalus sanguineus	0	2	2	—	—	—
Other sources†	—	Rhipicephalus group # 9	4	3	7	—	—	—

† Full details in Table 3D, "Other sources of the ticks from the Republic of Mali".

Table 3B. Tick nymphs from the Republic of Mali.

Host or source	# Host infested	Genus of nymph	# Specimens	% of tick nymphs from host-type	Mean # nymphs /infested animal	% Host-type infested
Unspecified cattle	259	Amblyomma	2405	91.65	9.29	36.53
Unspecified cattle	52	Boophilus	216	8.23	4.15	7.33
Unspecified cattle	1	Hyalomma	3	0.11	3.00	0.14
Zebu	70	Amblyomma	1663	96.02	23.76	26.22
Zebu	17	Boophilus	69	3.98	4.06	6.37
Ndama	101	Amblyomma	1420	89.59	14.06	38.26
Ndama	42	Boophilus	165	10.41	3.93	15.91
Cattle	430	Amblyomma	5488	92.38	12.76	34.46
Cattle	111	Boophilus	450	7.57	4.05	8.90
Cattle	1	Hyalomma	3	0.05	3.00	0.08
Sheep	7	Amblyomma	41	93.18	5.86	36.84
Sheep	2	Boophilus	3	6.82	1.50	10.53
Goat	1	Amblyomma	10	100.00	10.00	12.50
Dog	1	Amblyomma	1	3.57	1.00	5.88
Dog	3	Rhipicephalus	27	96.43	9.00	17.65
Camel	1	Amblyomma	6	100.00	6.00	20.00
Warthog	5	Rhipicephalus	62	100.00	12.40	71.43
Other sources†	—	Amblyomma	181	—	—	—
Other sources†	—	Aponomma	36	—	—	—
Other sources†	—	Hyalomma	2	—	—	—
Other sources†	—	Rhipicephalus	2	—	—	—

† Full details in Table 3D, Other sources of the ticks from the Republic of Mali.

Table 3C. Tick larvae from the Republic of Mali.

Host or source	# Host infested	Genus of larvae	# Specimens	% of tick larvae from host-type	Mean # larvae /infested animal	% Host-type infested
Unspecified cattle	7	*Amblyomma*	126	96.92	18.00	0.99
Unspecified cattle	1	*Boophilus*	4	3.08	4.00	0.14
Zebu	13	*Amblyomma*	225	100.00	17.31	4.87
Ndama	12	*Amblyomma*	83	100.00	6.92	4.55
Cattle	32	*Amblyomma*	434	99.09	13.56	2.56
Cattle	1	*Boophilus*	4	0.90	4.00	0.08
Sheep	1	*Amblyomma*	7	100.00	7.00	5.26
Dog	2	*Rhipicephalus*	101	100.00	50.50	11.76
Cat	1	*Amblyomma*	1	100.00	1.00	100.00
Warthog	1	*Amblyomma*	13	50.00	13.00	14.29
Warthog	2	*Rhipicephalus*	13	50.00	6.50	28.57
Other sources†	—	*Amblyomma*	29	—	—	—
Other sources†	—	*Aponomma*	4	—	—	—
Other sources†	—	*Argas*	1	—	—	—
Other sorucest†	—	*Hyalomma*	22	—	—	—

† Full details in Table 3D, Other sources of the ticks from the Republic of Mali.

Table 3D. Other sources of ticks from the Republic of Mali

Zone	Host/sources (#)	# Collections	Tick species	Males	Females	Nymphs	Larvae
1	Ground collection (1)	1	A. variegatum	—	1	—	—
1	Herdman's clothing (1)	1	A. variegatum	2	—	—	—
2	Cat (1)	1	Amblyomma larva	—	—	—	1
2	Donkey (1)	1	R. sanguineus	6	—	—	—
2	Guinea fowl (1)	1	Amblyomma nymphs	—	—	2	—
2	Ground collection (1)	1	R. sanguineus	—	1	—	—
2	Ground collection (1)	1	H. marginatum rufipes	1	—	—	—
2	Hare (1)	1	Hyalomma nymph	—	—	1	—
			Hyalomma larvae	—	—	—	19
2	Herdsman's clothing (1)	1	R. sanguineus	—	1	—	—
2	Pasture sweeps (13)	4	A. variegatum	3	1	—	—
		1	B. annulatus	1	2	—	—
		13	Amblyomma nymphs	—	—	145	—
2	Snakes (2)	1	Ap. flavomaculatum	6	2	—	—
		2	Ap. latum	30	5	36	4
		1	B. geigyi	1	—	—	—
2	Streptonelia senegalensis (1)	1	Amblyomma nymphs	—	—	34	—
			Amblyomma larvae	—	—	—	39
2	Varanus sp. (1)	1	Ap. flavomaculatum	1	2	—	—
3	Francolinus sp. (1)	1	Argas larva	—	—	—	1
3	Guinea fowl (1)	1	Hyalomma larva	—	—	—	1
3	Hare (1)	1	Rhipicephalus group # 9	4	3	—	—
			Rhipicephalus nymphs	—	—	2	—
			Rhipicephalus larva	—	—	—	1
3	Sheep/goats (?)	Not known	H. impeltatum	11	4	—	—
		Not known	H. truncatum	3	—	—	—

Table 4A. Multi-species infestation of major hosts by adult ticks in the Republic of Mali.

Host	# Tick species in infestation	# Host infested	Total # hosts	% host-type infested	Specimens Males	Specimens Females	Specimens Total	Total # ticks from the same host-type	Mean # ticks/infestation	% Total tick count from host-type
Unspecified cattle	1	186	687	27.07	658	346	1004	9145	5.40	10.98
Unspecified cattle	2	196	687	28.53	1025	765	1790	9145	9.13	19.57
Unspecified cattle	3	174	687	25.33	1975	930	2905	9145	16.70	31.77
Unspecified cattle	4	86	687	12.52	1157	534	1691	9145	19.66	18.49
Unspecified cattle	5	33	687	4.80	658	365	1023	9145	31.00	11.19
Unspecified cattle	6	10	687	1.46	430	173	603	9145	60.30	6.59
Unspecified cattle	7	2	687	0.29	105	24	129	9145	64.50	1.41
Zebu	1	60	263	22.81	257	201	458	4366	7.63	10.49
Zebu	2	76	263	28.90	498	357	855	4366	11.25	19.48
Zebu	3	85	263	32.32	1254	675	1929	4366	22.69	44.18
Zebu	4	30	263	11.41	478	193	671	4366	22.37	15.37
Zebu	5	9	263	3.42	218	72	290	4366	32.22	6.64
Zebu	6	2	263	0.76	93	39	132	4366	66.00	3.02
Zebu	7	1	263	0.38	22	9	31	4366	31.00	0.71
Ndama	1	79	261	30.27	153	131	284	2420	3.59	11.74
Ndama	2	102	261	39.08	534	410	944	2420	9.25	39.01
Ndama	3	43	261	16.48	282	226	508	2420	11.81	20.99
Ndama	4	29	261	11.11	215	234	449	2420	15.48	18.55
Ndama	5	5	261	1.92	81	52	133	2420	26.60	5.50
Ndama	6	3	261	1.15	67	35	102	2420	34.00	4.21
Zebu X Ndama	1	2	8	25.00	13	5	18	142	9.00	12.68
Zebu X Ndama	3	1	8	12.50	4	7	11	142	11.00	7.75
Zebu X Ndama	4	4	8	50.00	42	42	84	142	21.00	59.15
Zebu X Ndama	5	1	8	12.50	14	15	29	142	29.00	20.42
Cattle	1	327	1219	26.83	1081	683	1764	16073	5.39	10.97
Cattle	2	374	1219	30.68	2057	1532	3589	16073	9.60	22.33
Cattle	3	303	1219	24.86	3515	1838	5353	16073	17.66	33.30
Cattle	4	149	1219	12.22	1892	1003	2895	16073	19.43	18.01
Cattle	5	48	1219	3.90	971	504	1475	16073	30.73	9.18
Cattle	6	15	1219	1.23	590	247	837	16073	55.8	5.21
Cattle	7	3	1219	0.24	127	33	160	16073	53.3	1.00

Table 4A. Continued,

Host	# Tick species in infestation	# Host infested	Total # hosts	% host-type infested	Specimens: Males	Specimens: Females	Specimens: Total	Total # ticks from the same host-type	Mean # ticks/infestation	% Total tick count from host-type
Sheep	1	8	17	47.06	13	11	24	151	3.00	15.89
Sheep	2	3	17	17.65	34	7	41	151	13.67	27.15
Sheep	3	3	17	17.65	26	11	37	151	12.33	24.50
Sheep	4	2	17	11.76	36	7	43	151	21.50	28.48
Sheep	5	1	17	5.88	3	3	6	151	6.00	3.97
Goat	1	1	3	33.33	1	0	1	67	1.00	1.49
Goat	3	1	3	33.33	12	2	14	67	14.00	20.90
Goat	5	1	3	33.33	13	39	52	67	52.00	77.61
Horse	1	1	3	33.33	0	1	1	18	1.00	5.56
Horse	2	1	3	33.33	1	2	3	18	3.00	16.67
Horse	3	1	3	33.33	10	4	14	18	14.00	77.78
Dog	1	16	17	94.12	57	57	114	121	7.13	94.12
Dog	2	1	17	5.88	2	5	7	121	7.00	5.79
Camel	2	2	4	50.00	13	3	16	52	8.00	30.77
Camel	3	2	4	50.00	24	12	36	52	18.00	69.23
Warthog	1	3	6	50.00	7	2	9	51	3.00	17.65
Warthog	2	2	6	33.33	4	17	21	51	10.50	41.18
Warthog	4	1	6	16.67	18	3	21	51	21.00	41.18

Table 4B. Multi-species infestation of cattle by adult ticks observed below latitude 12°N (Zone I).

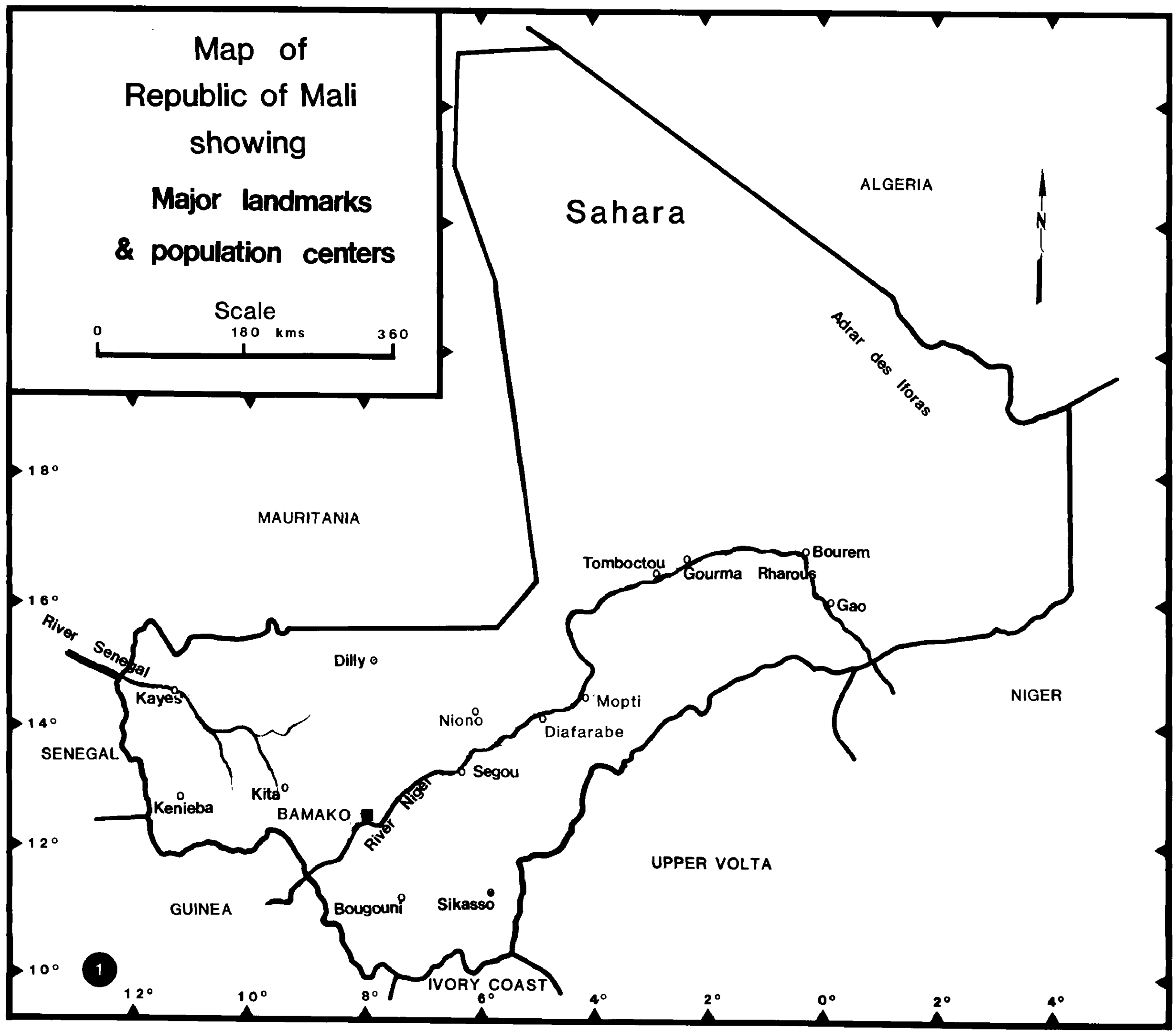
Host	# Tick species in infestation	# Host infested	Total # hosts	% host-type infested	Specimens Males	Specimens Females	Specimens Total	Total ticks from the same host-type	Mean # ticks/ infestation	% Total tick count from host-type
Unspecified cattle	1	39	110	35.45	75	77	152	1194	3.90	12.73
Unspecified cattle	2	35	110	31.82	158	192	350	1194	10.00	29.31
Unspecified cattle	3	18	110	16.36	236	137	373	1194	20.72	31.24
Unspecified cattle	4	11	110	10.00	84	66	150	1194	13.64	12.56
Unspecified cattle	5	6	110	5.45	80	75	155	1194	25.83	12.98
Unspecified cattle	6	1	110	0.91	4	10	14	1194	14.00	1.17
Zebu	1	5	36	13.89	8	9	17	390	3.40	4.36
Zebu	2	8	36	22.22	21	32	53	390	6.63	13.59
Zebu	3	18	36	50.00	140	123	263	390	14.61	67.44
Zebu	4	5	36	13.89	29	28	57	390	11.40	14.62
Ndama	1	13	100	13.00	15	50	65	1248	5.00	5.21
Ndama	2	39	100	39.00	192	234	426	1248	10.92	34.13
Ndama	3	24	100	24.00	135	134	269	1248	11.21	21.55
Ndama	4	16	100	16.00	116	137	253	1248	15.81	20.27
Ndama	5	5	100	5.00	81	52	133	1248	26.60	10.66
Ndama	6	3	100	3.00	67	35	102	1248	34.00	8.17
Zebu X Ndama	1	2	8	25.00	13	5	18	142	9.00	12.68
Zebu X Ndama	3	1	8	12.50	4	7	11	142	11.00	7.75
Zebu X Ndama	4	4	8	50.00	42	42	84	142	21.00	59.15
Zebu X Ndama	5	1	8	12.50	14	15	29	142	29.00	20.42
Cattle	1	59	254	23.23	111	141	252	2974	4.27	8.47
Cattle	2	82	254	32.28	371	458	829	2974	10.10	27.87
Cattle	3	61	254	24.02	515	401	916	2974	15.02	30.80
Cattle	4	36	254	14.17	271	273	544	2974	15.11	18.29
Cattle	5	12	254	4.72	175	142	317	2974	26.41	10.66
Cattle	6	4	254	1.57	71	45	116	2974	29	3.90

Table 4C. Multi-species infestation of cattle by adult ticks observed between latitudes 12 and 14°N (Zone II)

Host	# Tick species in Infestation	# Host infested	Total # hosts	% host infested	Specimens			Total ticks from the same host-type	Mean # ticks/ infesta-tion	% Total tick count from host-type
					Males	Females	Total			
Unspecified cattle	1	72	373	19.30	382	120	502	6077	6.97	8.26
Unspecified cattle	2	103	373	27.61	556	356	912	6077	8.85	15.01
Unspecified cattle	3	111	373	29.76	451	600	051	6077	18.48	33.75
Unspecified cattle	4	57	373	15.28	919	359	278	6077	22.42	21.03
Unspecified cattle	5	22	373	5.90	463	244	707	6077	32.14	11.63
Unspecified cattle	6	7	373	1.88	387	152	539	6077	77.00	8.87
Unspecified cattle	7	1	373	0.27	67	21	88	6077	88.00	1.45
Zebu	1	12	75	16.00	16	88	84	1380	7.00	6.09
Zebu	2	25	75	33.33	87	126	213	1380	8.52	15.43
Zebu	3	20	75	26.67	316	192	508	1380	25.40	36.81
Zebu	4	11	75	14.67	171	93	264	1380	24.00	19.13
Zebu	5	5	75	6.67	140	39	179	1380	35.80	12.97
Zebu	6	2	75	2.67	93	39	132	1280	66.00	9.57
Ndama	1	64	155	41.29	123	76	199	1098	3.11	18.12
Ndama	2	60	155	38.71	316	167	483	1098	8.05	43.99
Ndama	3	18	155	11.61	133	87	220	1098	12.22	20.04
Ndama	4	13	155	8.39	99	97	196	1098	15.08	17.85
Cattle	1	148	608	24.34	521	264	785	8555	5.30	24.34
Cattle	2	188	608	30.92	953	655	608	8555	8.55	30.92
Cattle	3	149	608	24.30	900	879	779	8555	18.65	24.50
Cattle	4	81	608	13.32	189	549	738	8555	21.46	13.32
Cattle	5	27	608	4.44	603	283	886	8555	32.81	4.44
Cattle	6	9	608	1.48	480	191	671	8555	74.56	1.48
Cattle	7	1	608	0.16	67	21	88	8555	88.00	0.16

Table 4D. Multi-species infestation of cattle by adult ticks observed between latitudes 14 and 16°N (Zone III)

Host	# Tick species in infestation	# Host infested	Total # hosts	% host-type infested	Specimens			Total ticks from the same host-type	Mean # ticks/ infestation	% Total tick count from host-type
					Males	Females	Total			
Unspecified cattle	1	75	204	36.76	201	149	350	1874	4.67	18.68
Unspecified cattle	2	58	204	28.43	311	217	528	1874	9.10	28.18
Unspecified cattle	3	45	204	22.06	288	193	481	1874	10.69	25.67
Unspecified cattle	4	18	204	8.82	154	109	263	1874	14.61	14.03
Unspecified cattle	5	5	204	2.45	115	46	161	1874	32.20	8.59
Unspecified cattle	6	2	204	0.98	39	11	50	1874	25.00	2.67
Unspecified cattle	7	1	204	0.49	38	3	41	1874	41.00	2.19
Zebu	1	43	152	28.29	233	124	357	2596	8.30	13.75
Zebu	2	43	152	28.29	390	199	589	2596	13.70	22.69
Zebu	3	47	152	30.92	798	360	158	2596	24.64	44.61
Zebu	4	14	152	9.21	278	72	350	2596	25.00	13.48
Zebu	5	4	152	2.63	78	33	111	2596	27.75	4.28
Zebu	7	1	152	0.66	22	9	31	2596	31.00	1.19
Ndama	1	2	6	33.33	15	5	20	74	10.00	27.03
Ndama	2	3	6	50.00	26	9	35	74	11.67	47.30
Ndama	3	1	6	16.67	14	5	19	74	19.00	25.68
Cattle	1	120	362	33.15	449	278	727	4544	6.06	16.00
Cattle	2	104	362	28.73	727	425	152	4544	11.08	25.35
Cattle	3	93	362	25.69	100	558	658	4544	17.82	36.49
Cattle	4	32	362	8.84	432	181	613	4544	19.16	13.49
Cattle	5	9	362	2.49	193	79	272	4544	30.22	5.98
Cattle	6	2	362	0.55	39	11	50	4544	25.00	1.10
Cattle	7	2	362	0.55	60	12	72	4544	36.00	1.58


Map of
Republic of Mali
showing
Major landmarks
& population centers
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360
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Sahara
Adrar des Iforas
MAURITANIA
NIGER
UPPER VOLTA
SENEGAL
GUINEA
IVORY COAST
River Senegal
River Niger
Tombocto u
Gourma
Rharous
Bourem
Gao
Mopti
Diafarabe
Niono
Segou
Dilly
Kayes
Kenieba
Kita
BAMAKO
Bougouni
Sikasso
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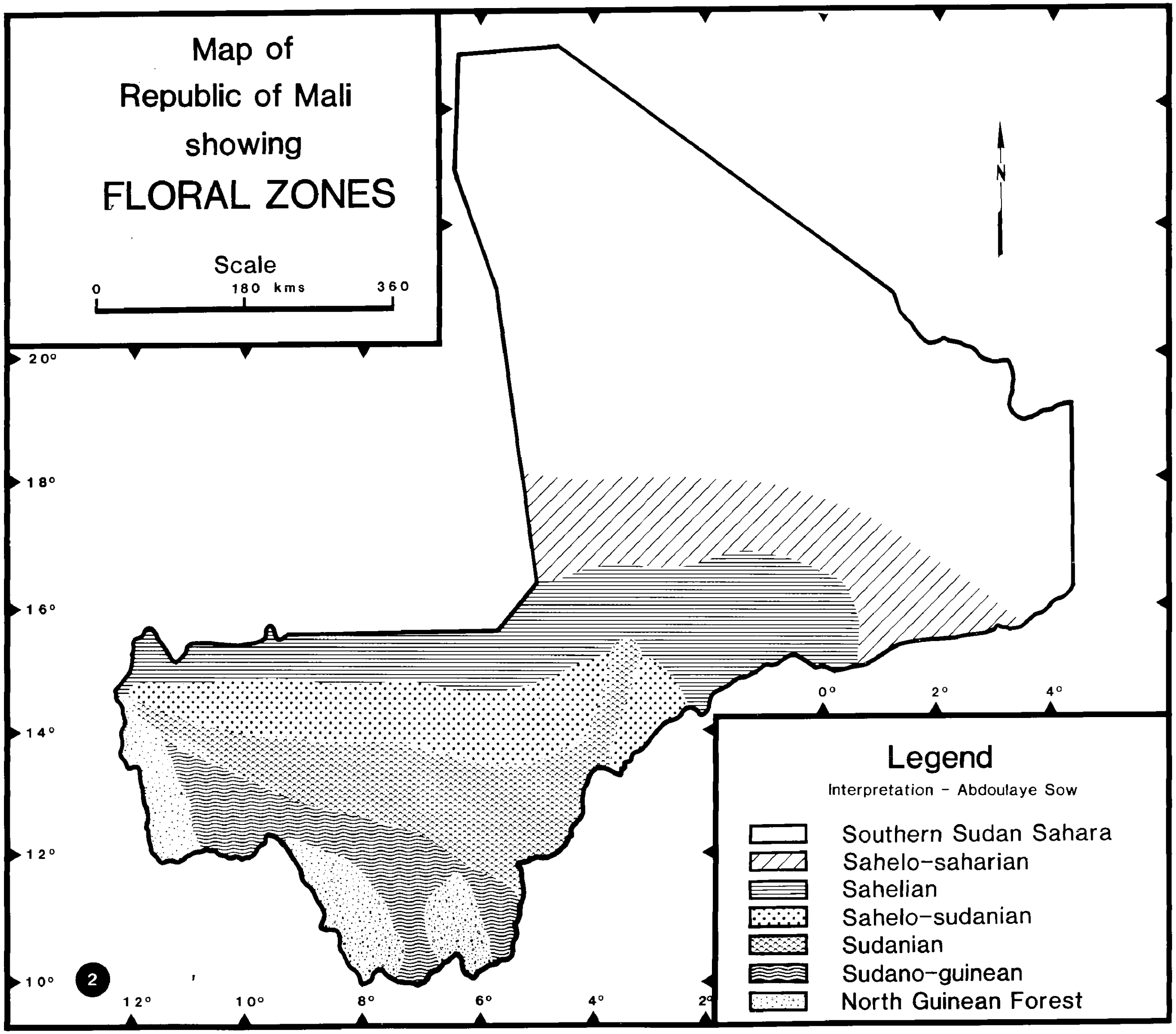
Map of
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2
Legend
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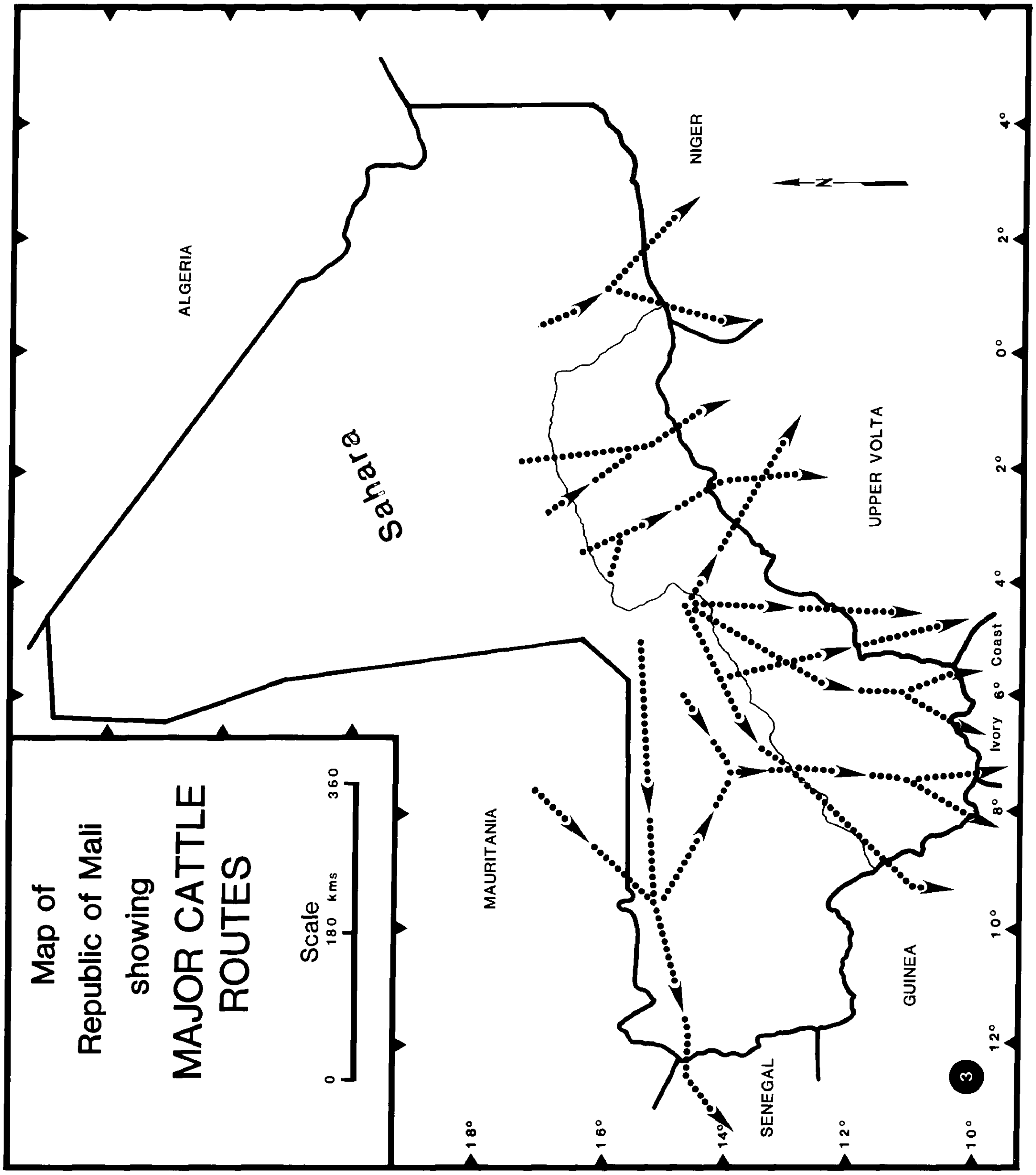
Southern Sudan Sahara
Sahelo-saharian
Sahelian
Sahelo-sudanian
Sudanian
Sudano-guinean
North Guinean Forest



Map of
Republic of Mali
showing
MAJOR CATTLE
ROUTES
Scale
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180 kms
360
ALGERIA
Sahara
NIGER
N
UPPER VOLTA
MAURITANIA
SENEGAL
GUINEA
Ivory Coast
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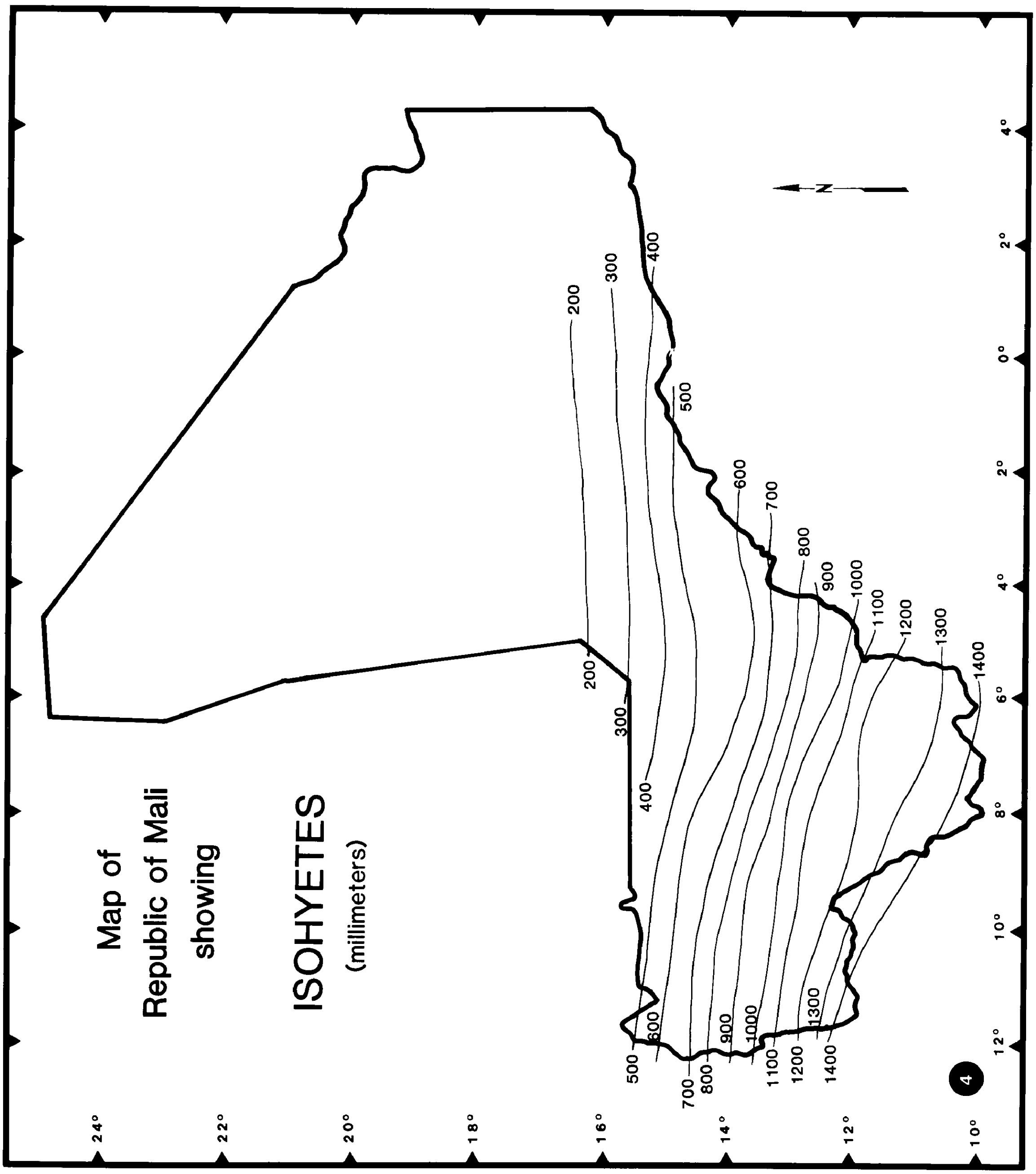
Map of
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showing
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(millimeters)
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300
400
500
600
700
800
900
1000
1100
1200
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1400
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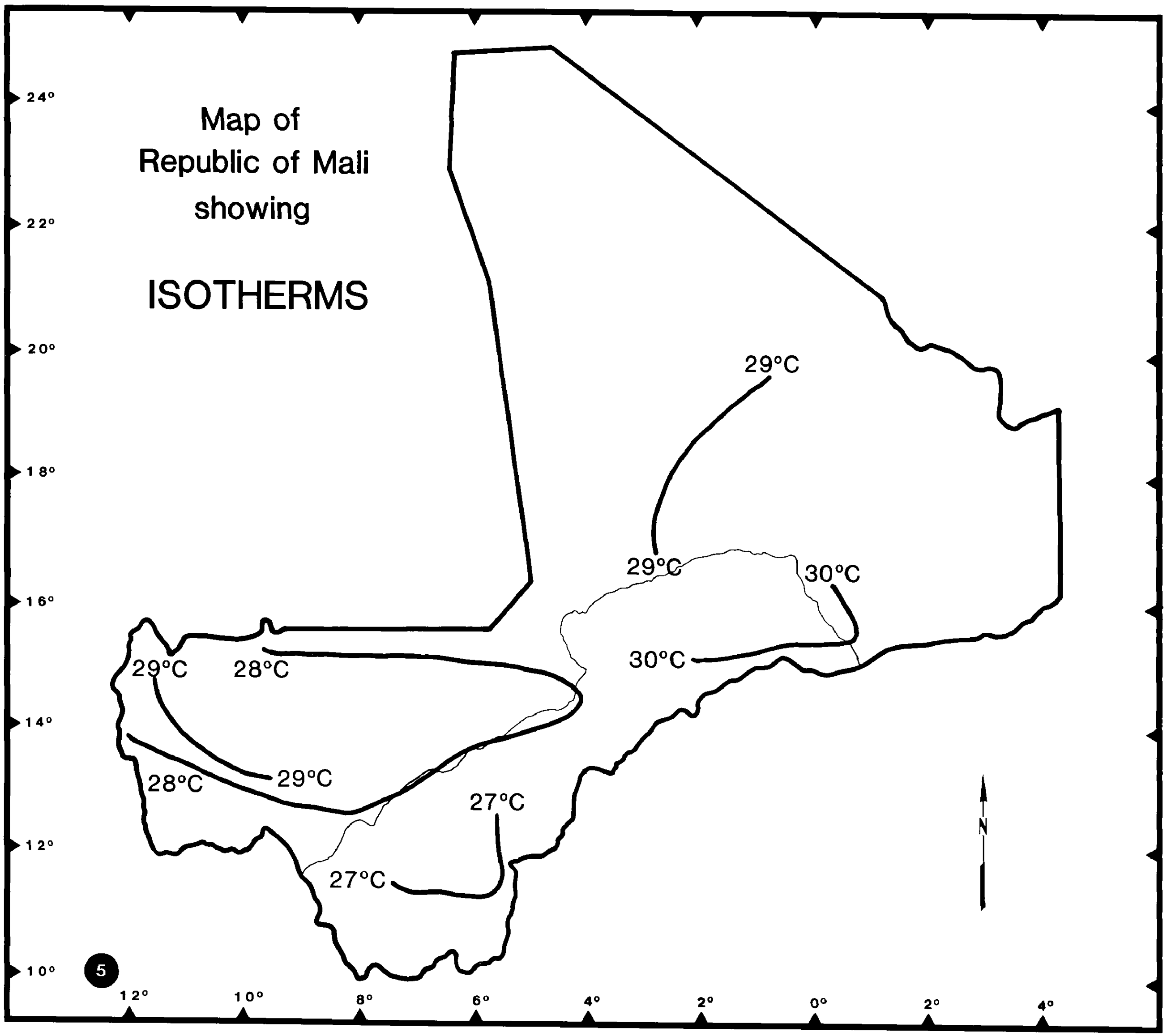
Map of
Republic of Mali
showing
ISOTHERMS
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29°C
30°C
30°C
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28°C
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27°C
27°C
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5
24°
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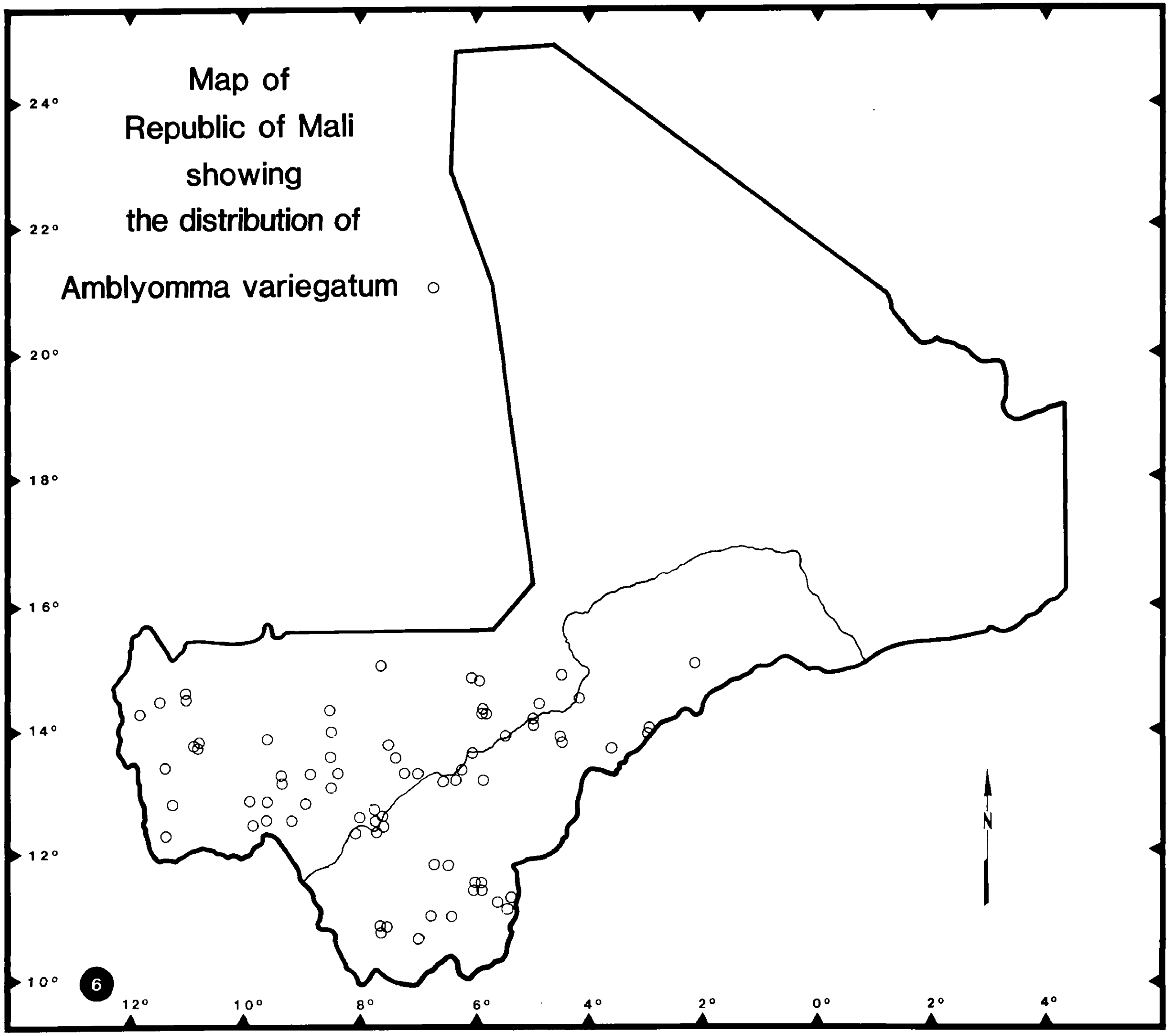
Map of
Republic of Mali
showing
the distribution of
Amblyomma variegatum
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22°
20°
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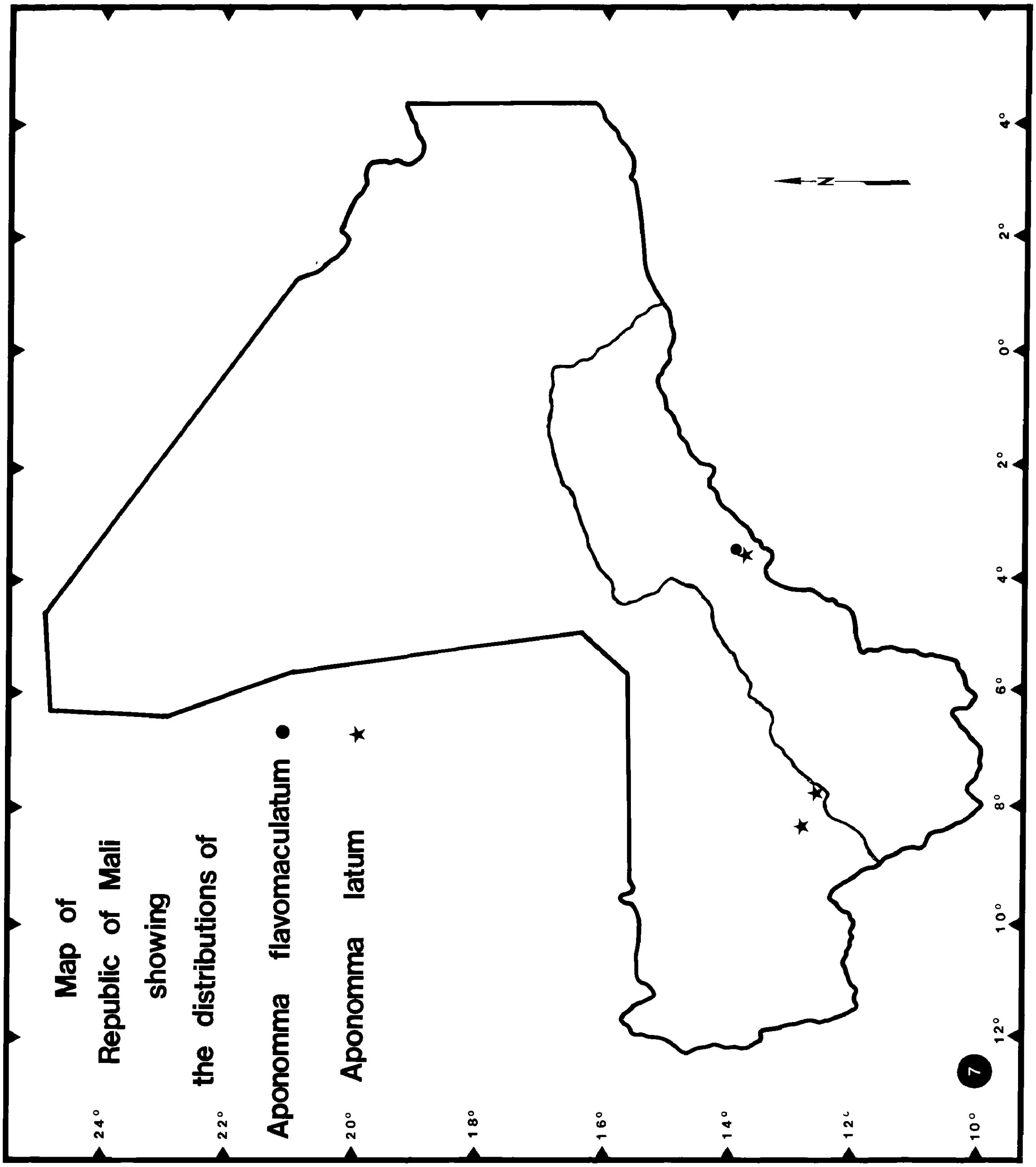
Map of
Republic of Mali
showing
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Aponomma flavomaculatum ●
Aponomma latum ★
7
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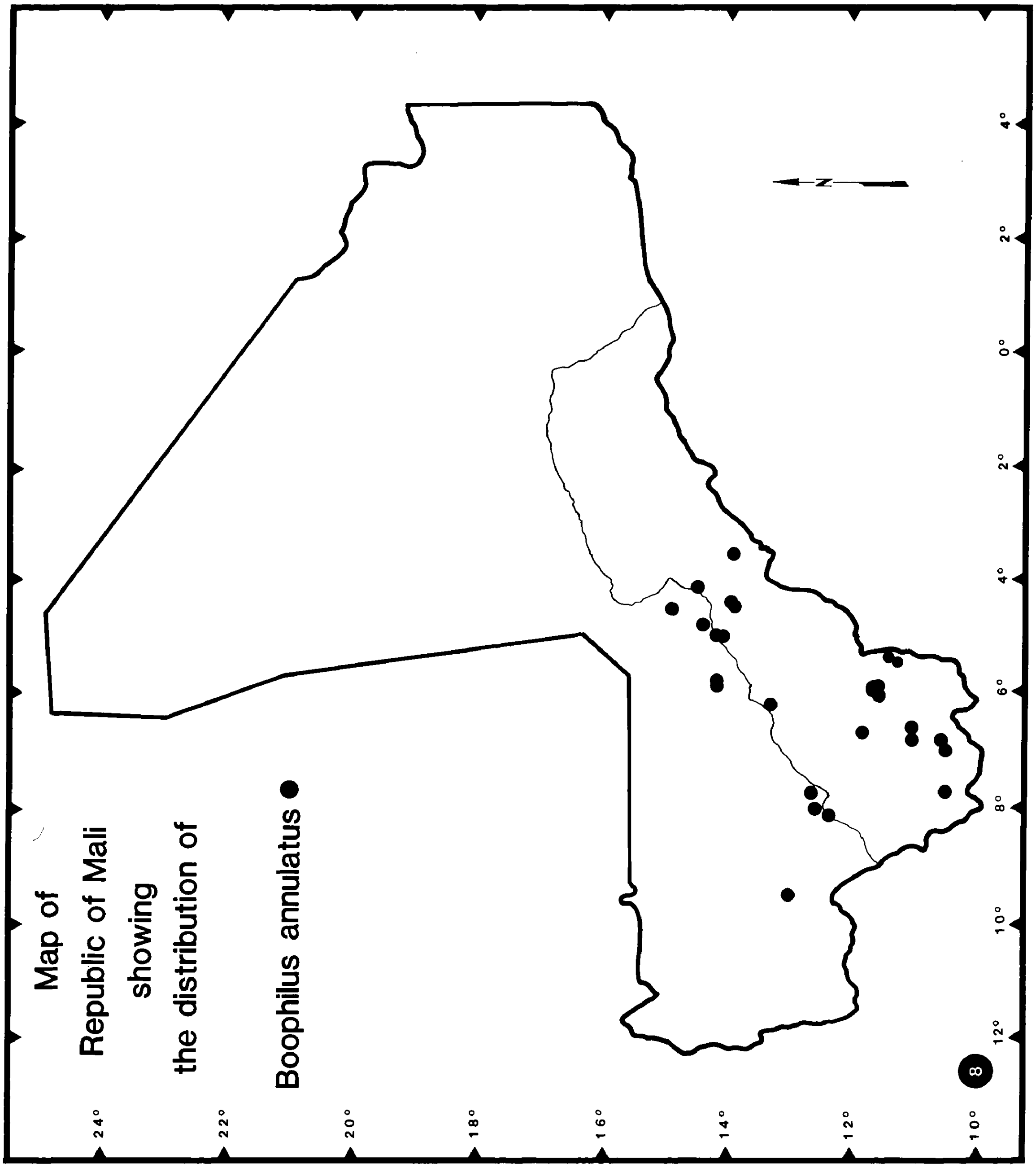
Map of
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showing
the distribution of
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8
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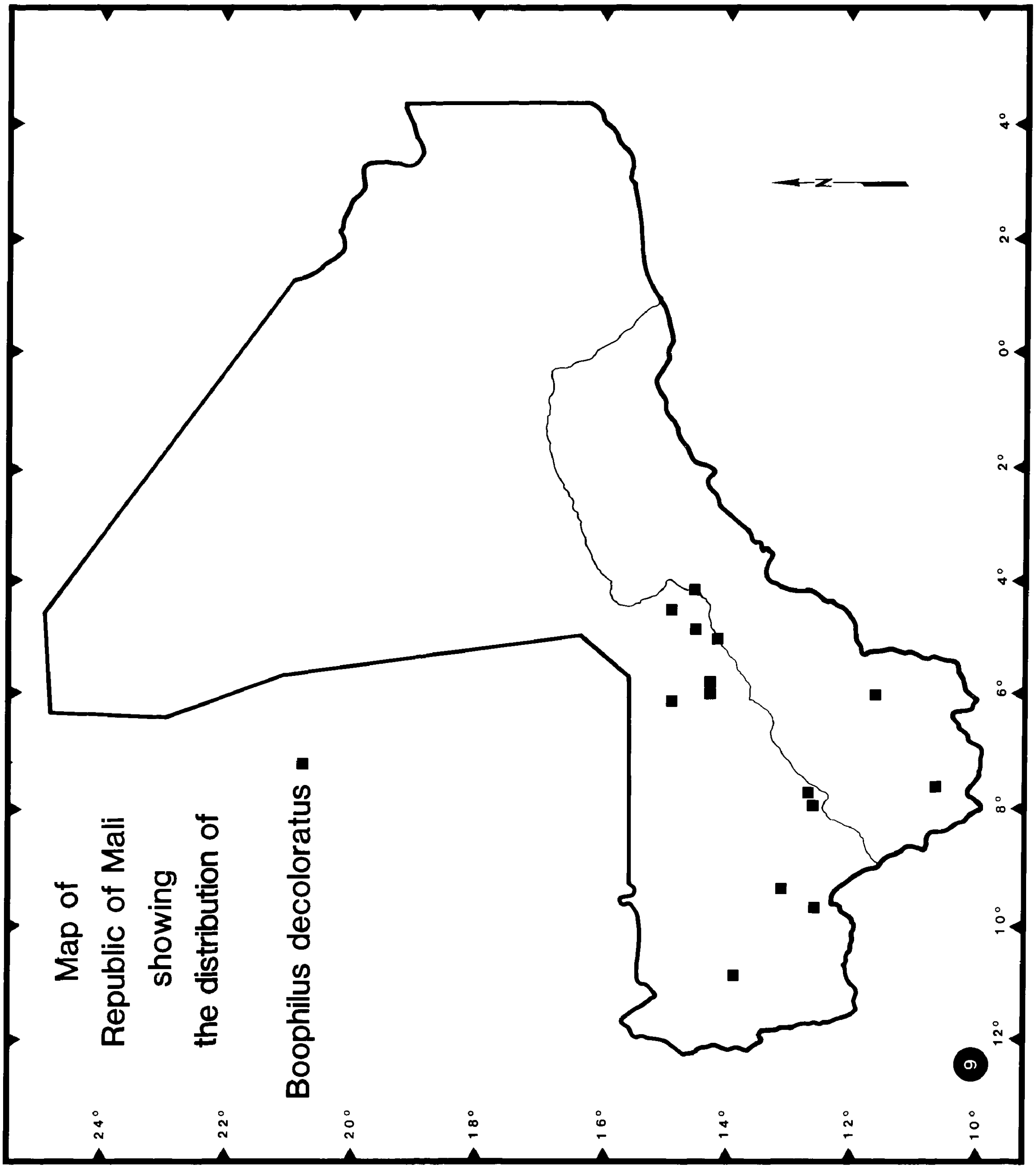
Map of
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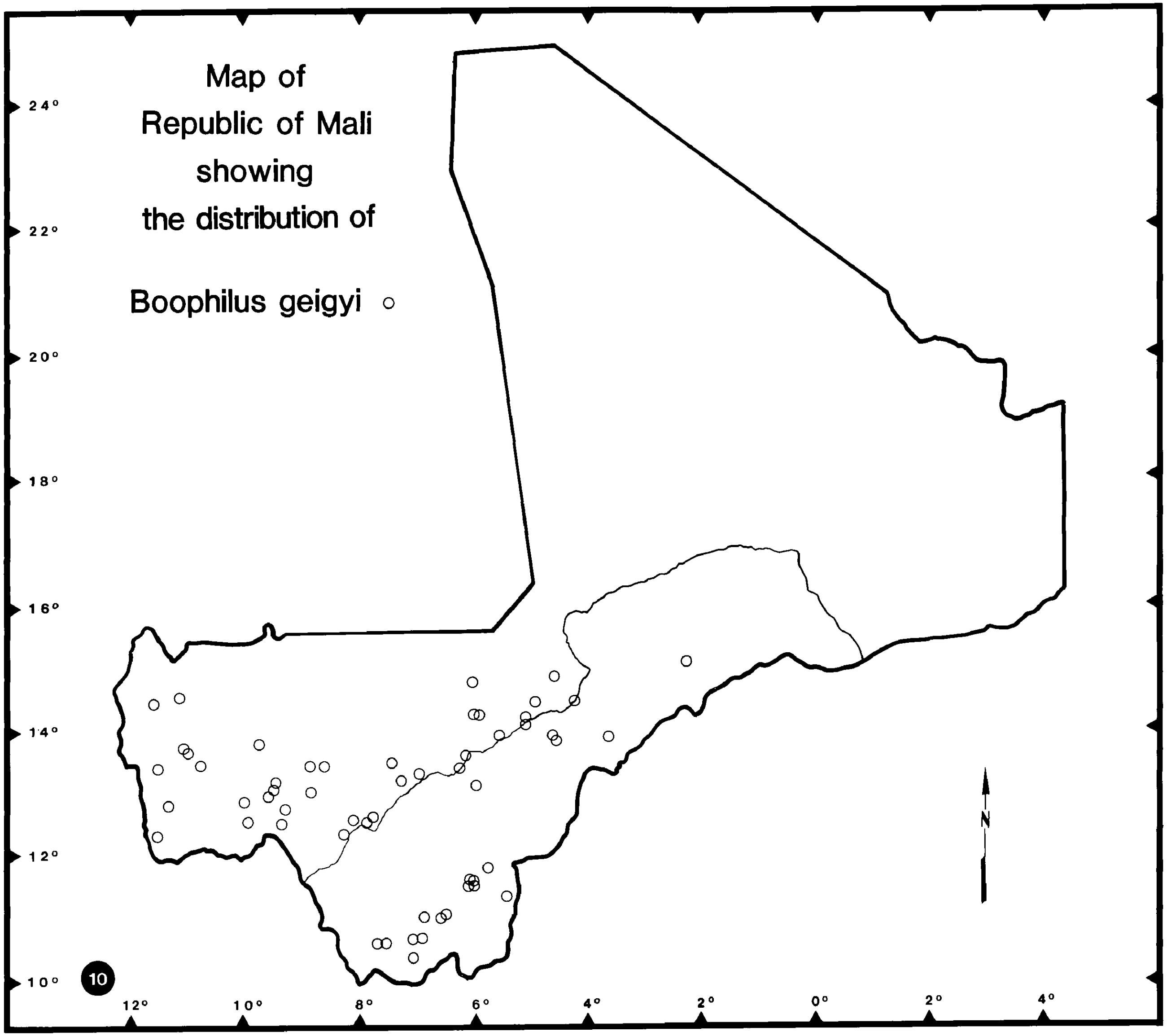
Map of
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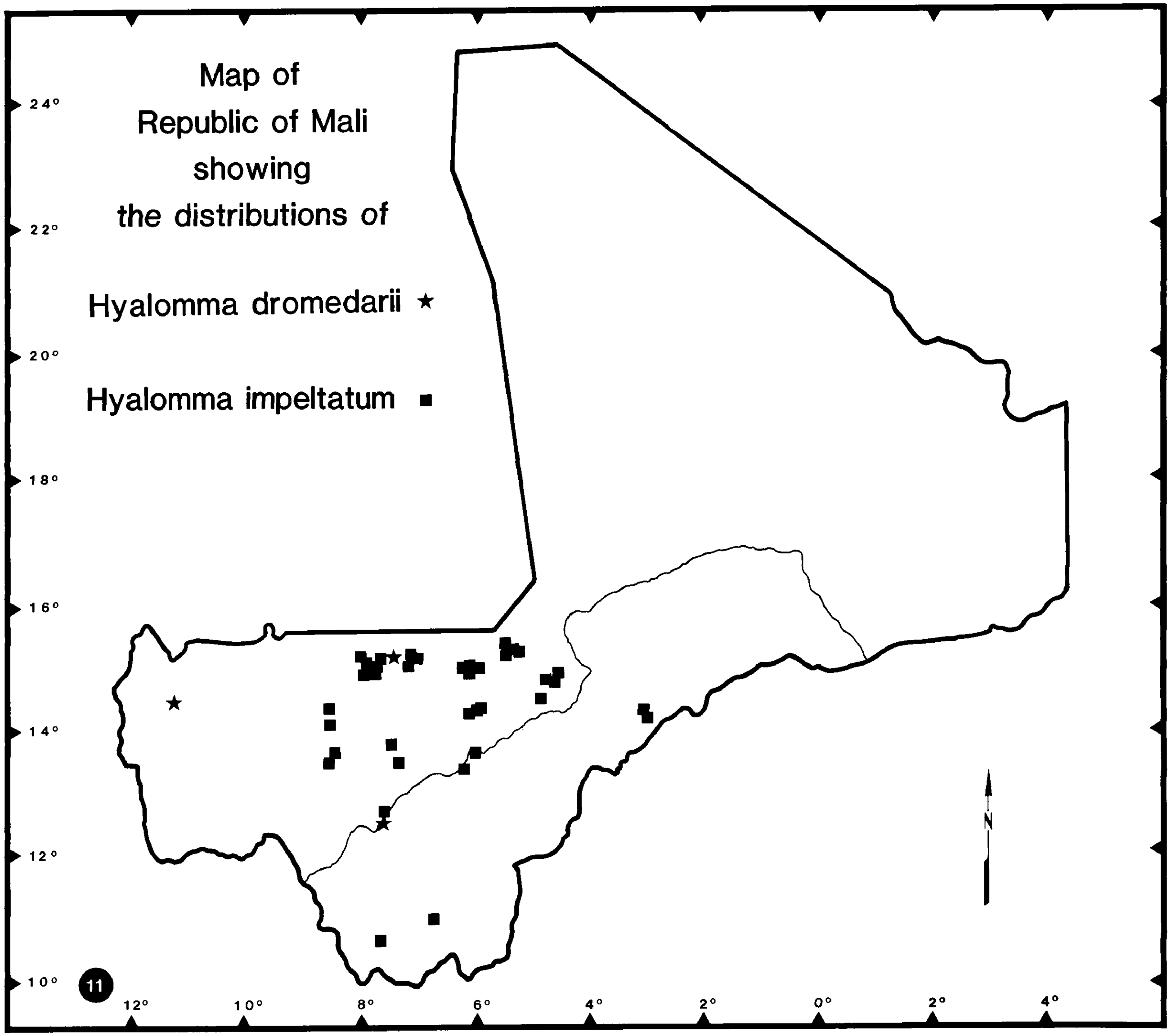
Map of
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showing
the distributions of
Hyalomma dromedarii ★
Hyalomma impeltatum ■
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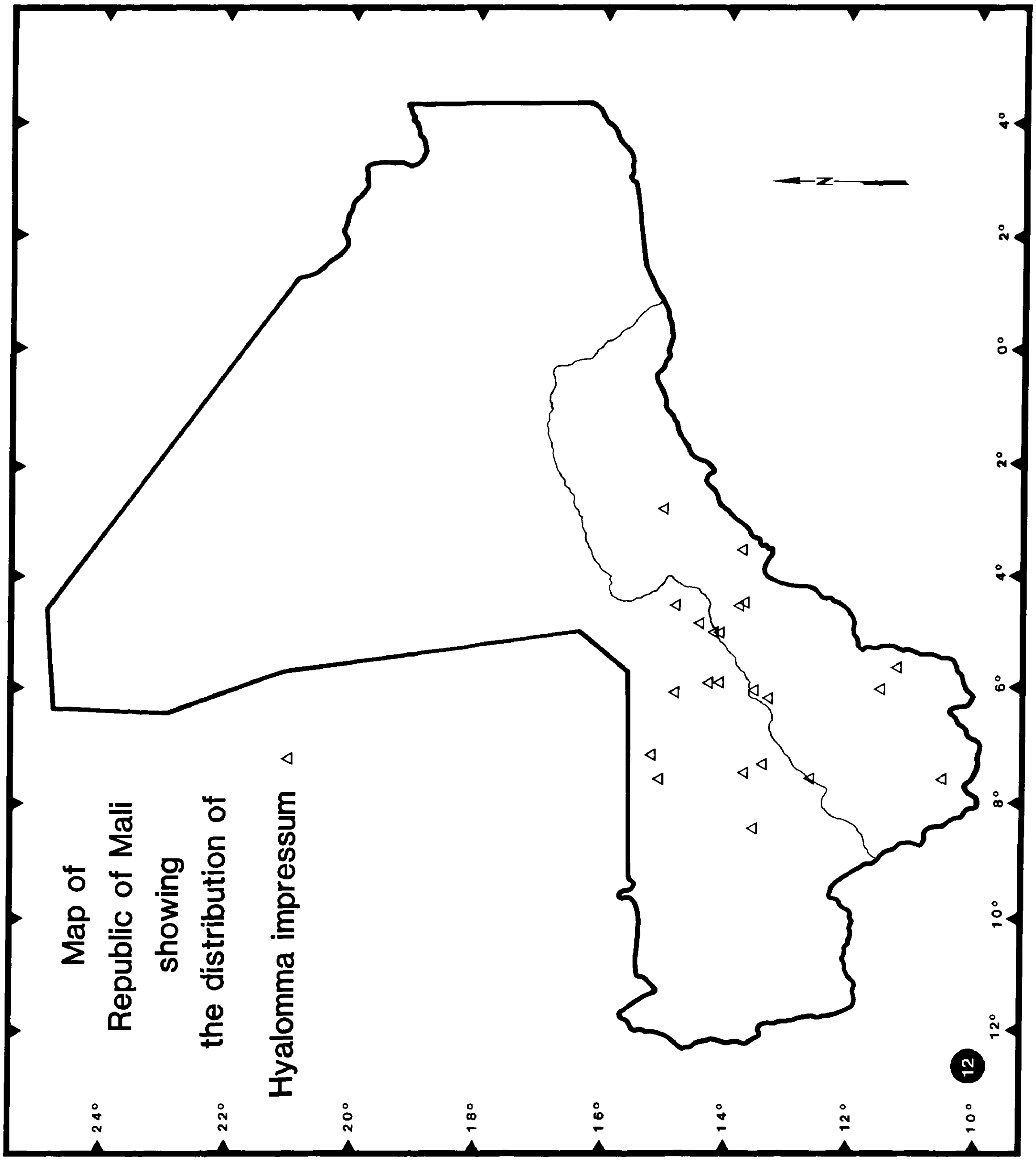
Map of
Republic of Mali
showing
the distribution of
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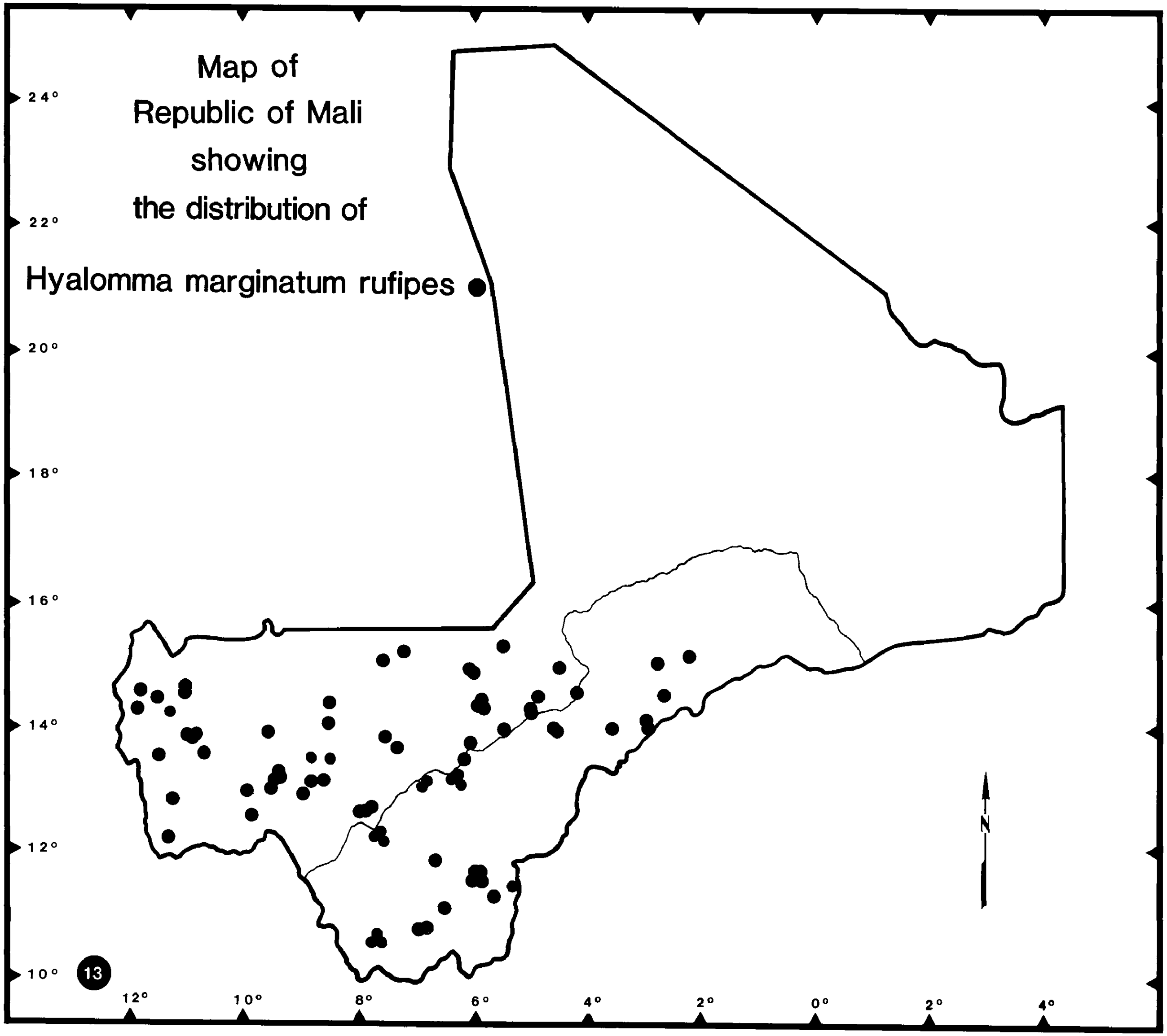
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showing
the distribution of
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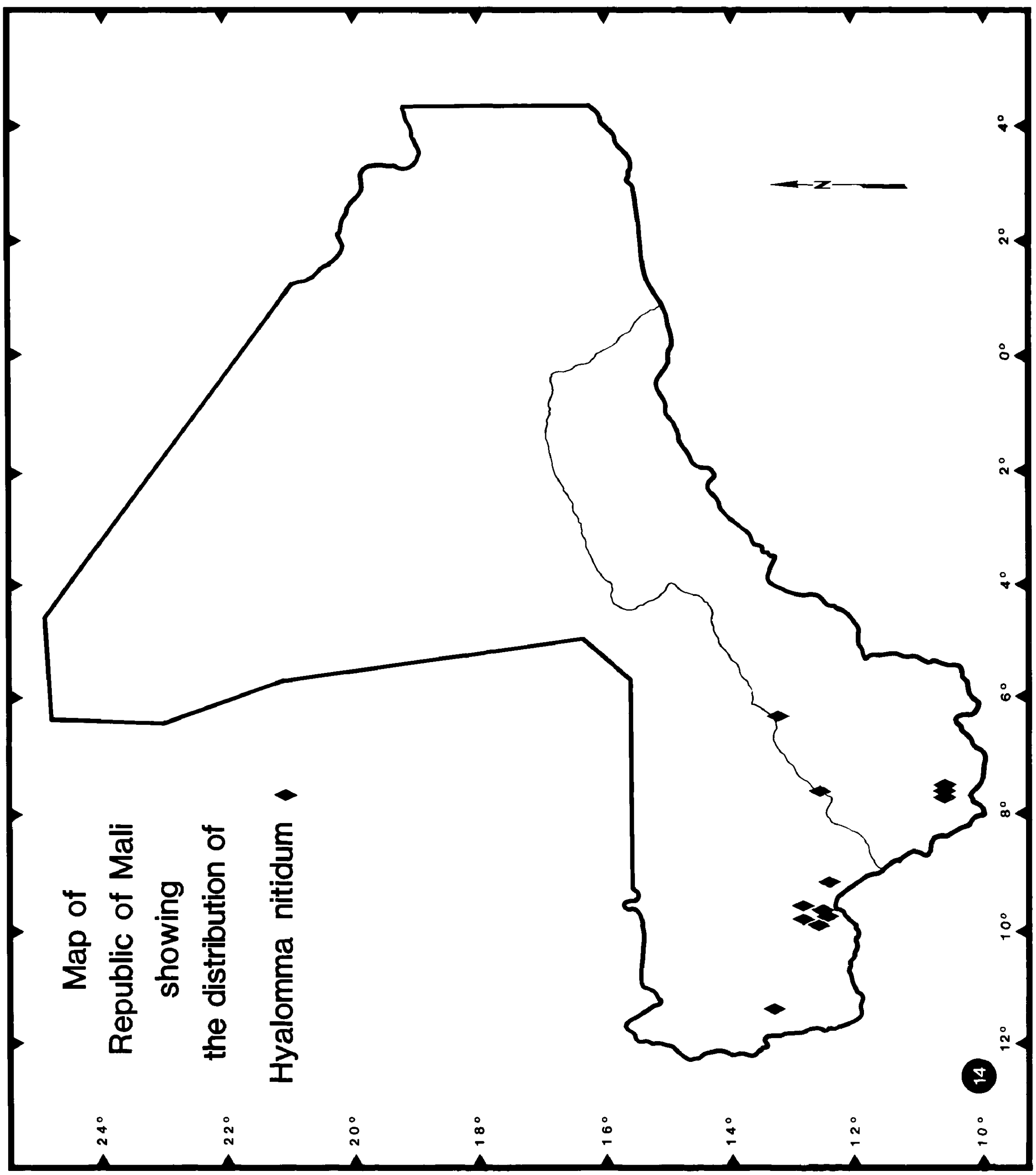
Map of
Republic of Mali
showing
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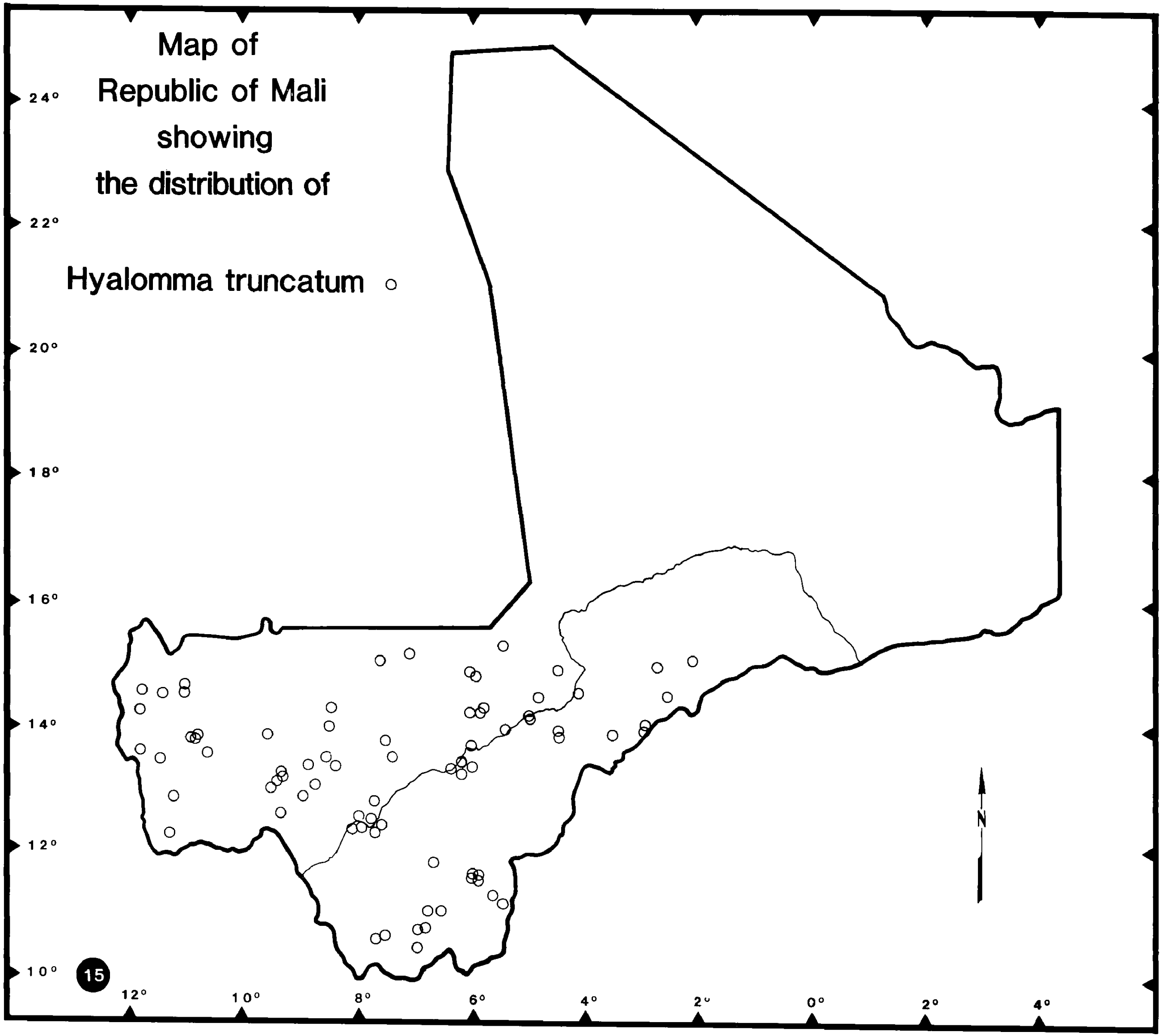
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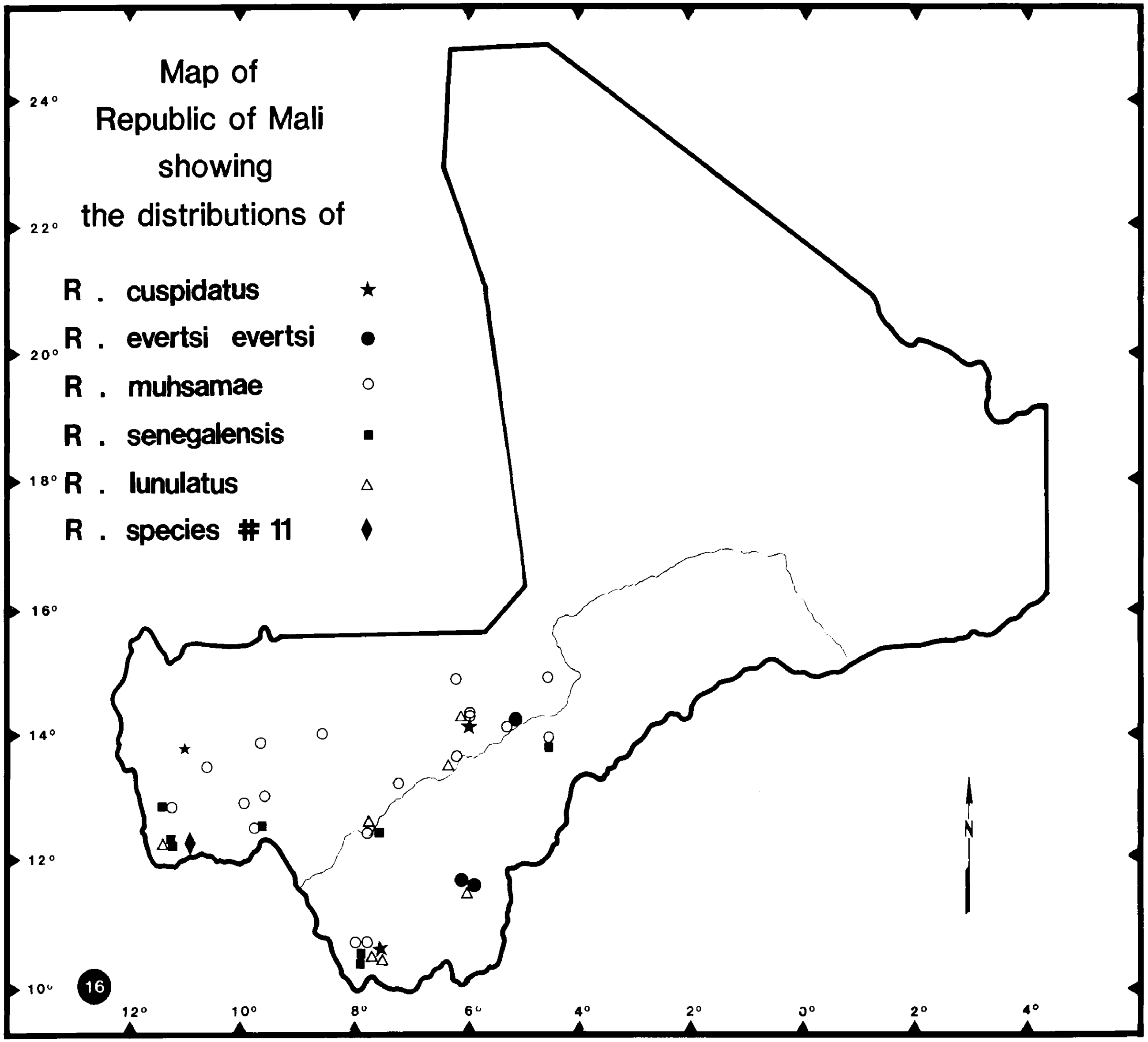
Map of
Republic of Mali
showing
the distributions of
R . cuspidatus
R . evertsi evertsi
R . muhsamae
R . senegalensis
R . lunulatus
R . species # 11
24°
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20°
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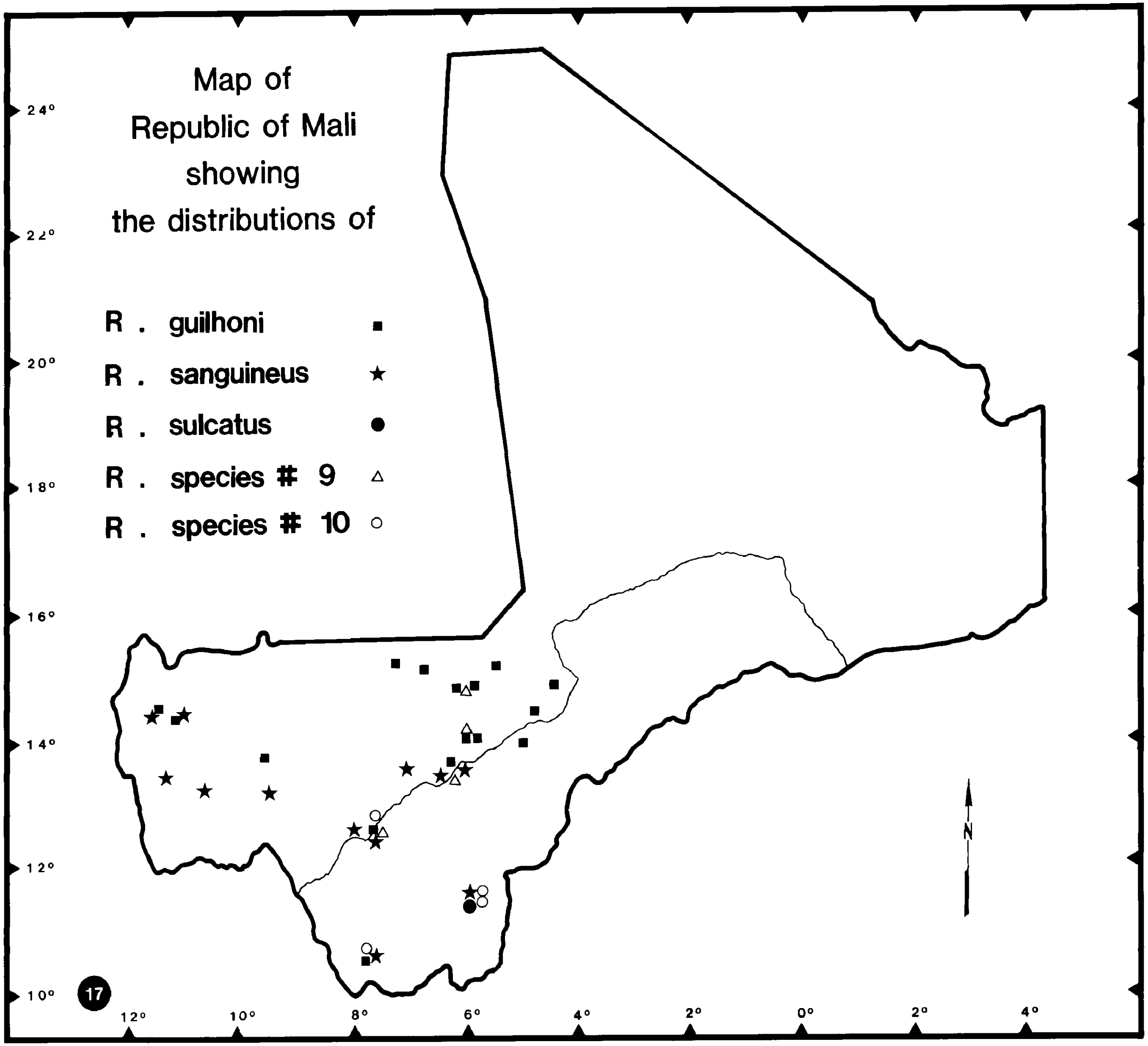
16


Map of
Republic of Mali
showing
the distributions of
R . guilhoni
R . sanguineus
R . sulcatus
R . species # 9
R . species # 10
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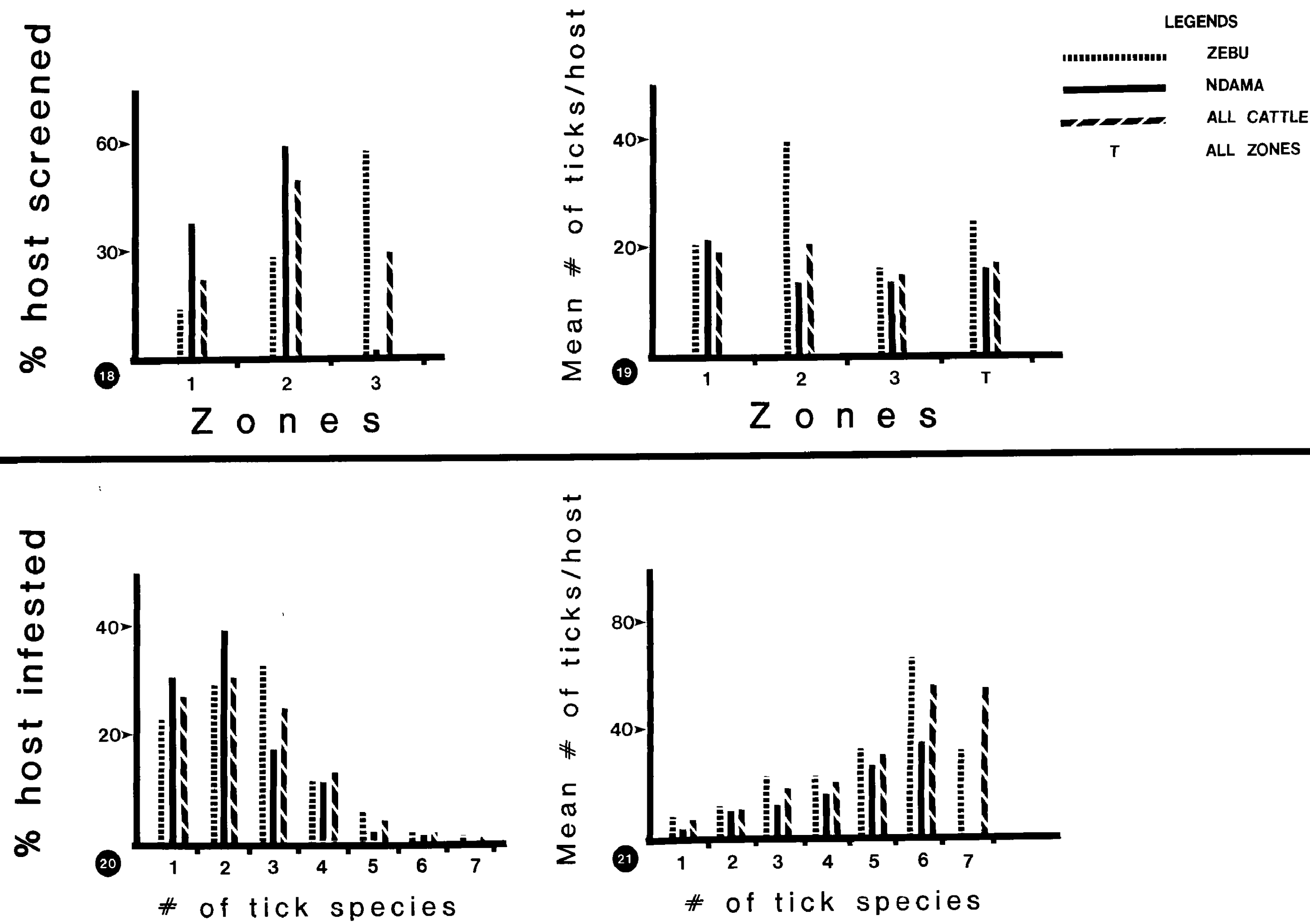
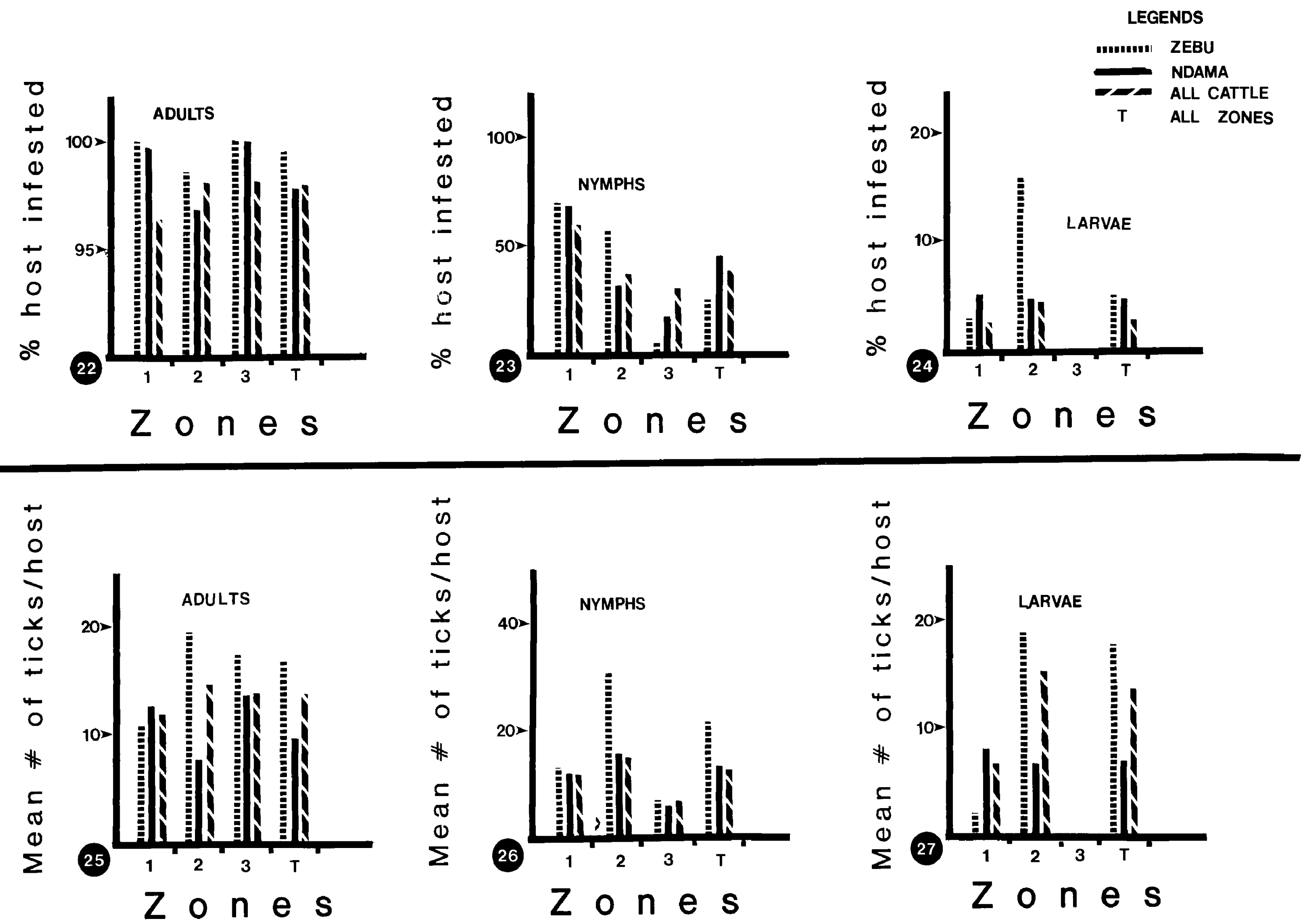
17

Graph 1. Tick infestation of cattle in Mali (overall counts)



Graph 1. Tick infestation of cattle in Mali (overall counts).

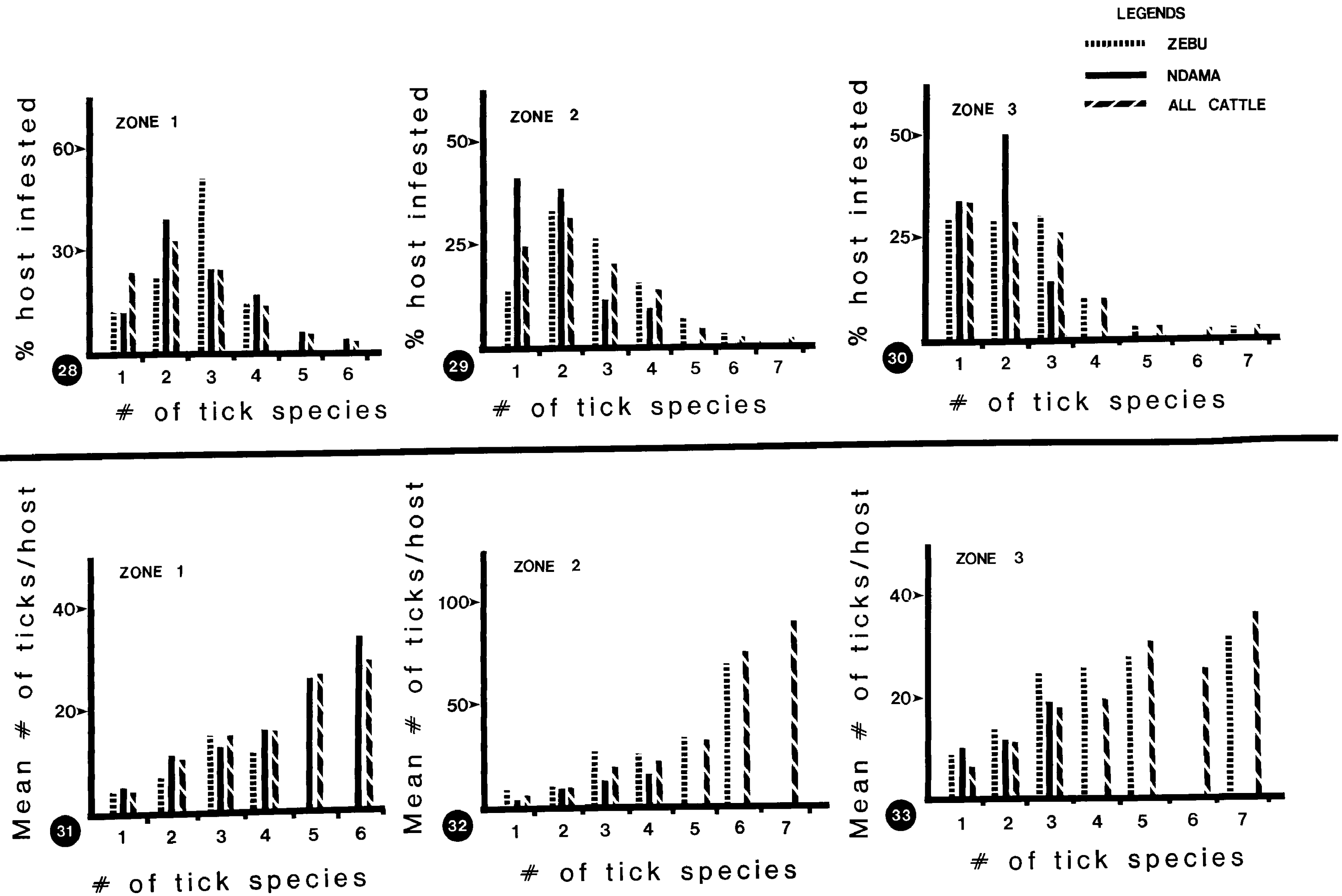
Graph 2. Tick infestation of cattle in Mali (stadial counts)



Graph 2. Tick infestation of cattle in Mali (stadial counts).

Graph 3. Tick infestation of cattle in Mali

(multi-species infestation counts)



Graph 3. Tick infestation of cattle in Mali (multi-species infestation counts).

Schematic drawings 1. Female gonopore tissue

Fig. 34. Diagram of the structure of a of a hypothetical, unmounted female gonopore tissue

Legends

1 = Gonopore

2 = Lateral sclerotic bar

3 = Anterior lip of gonopore

4 = Posterior lip of gonopore

5 = Genital grooves

Fig. 35 Diagram of the structure of a of a hypothetical, mounted female gonopore tissue

Legends

1 = Integument of anterior lip of atrial commissure

2 = Atrial commissure

3 = Circum-commissural sclerite

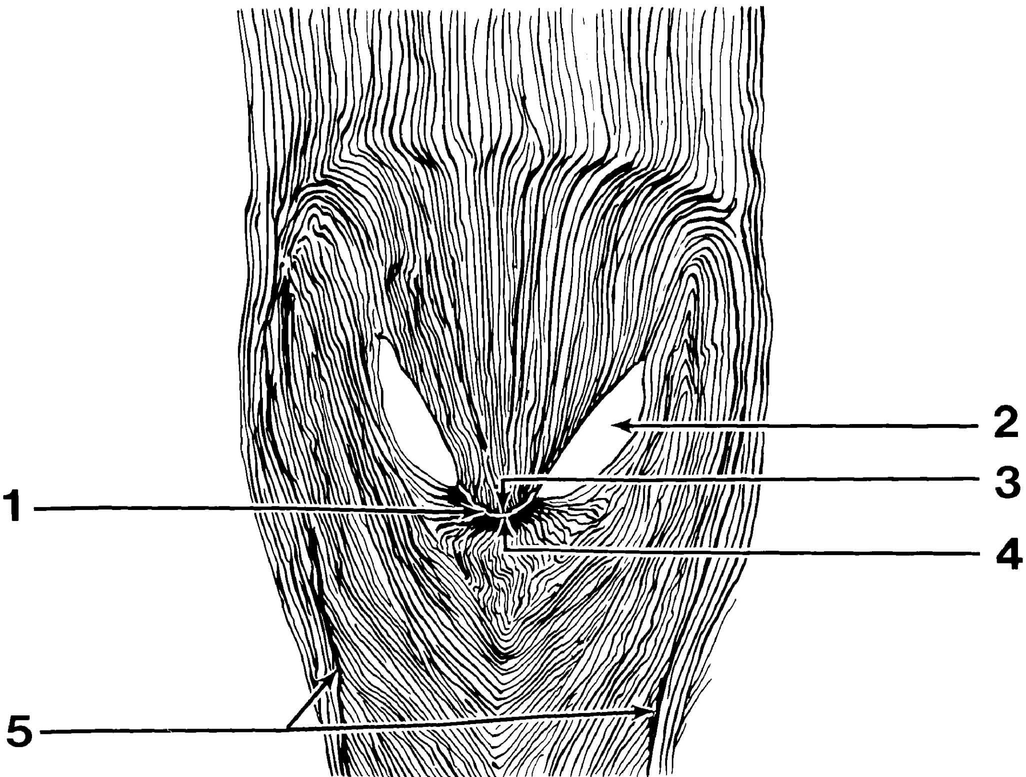
4 = Medial edge of atrial sclerite (sometimes visible externally)

5 = Lateral atrial sclerite

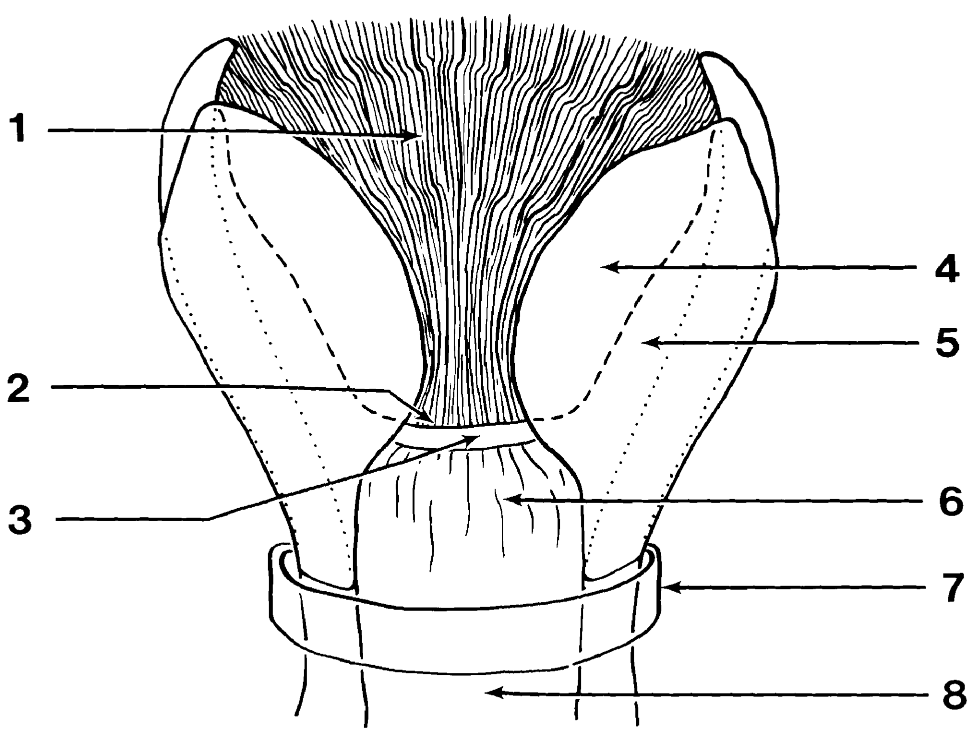
6 = Atrium

7 = Circum-atrial sclerite

8 = Vagina tube



34



35

Schematic drawings 2. Haller's organ and spiracular plate

Fig. 36. Diagram of the external morphology of a hypothetical Haller's organ.

Legends

1 = Post-capsular sensilla

2 = Peri-capsular sensilla

3 = Capsular sensilla

4 = Capsular pore (serrated edge)

5 = Pre-capsular sensilla

6 = Proximal sensillum

Fig. 37 Diagram of the external morphology of a hypothetical spiracular plate

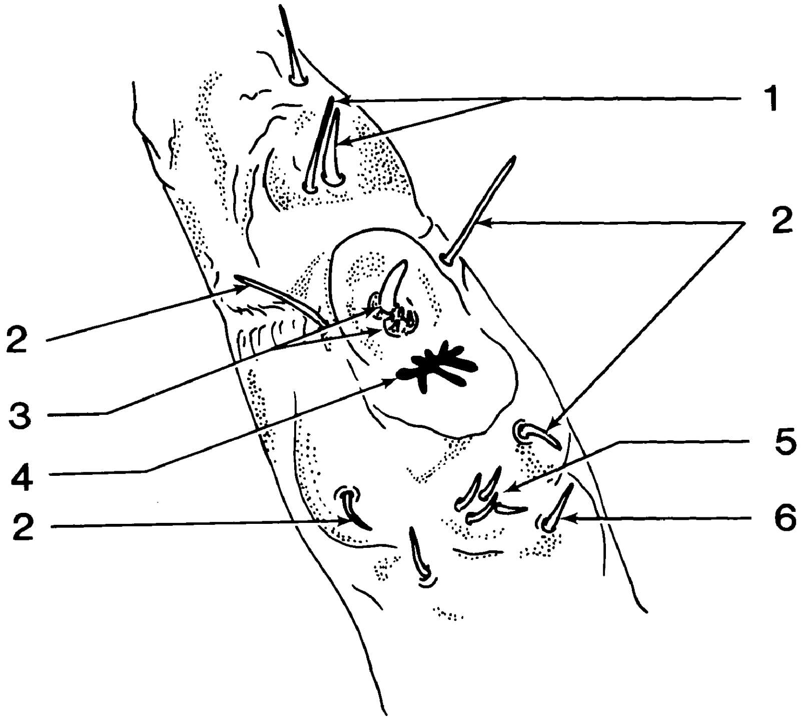
Legends

1 = Goblet cells

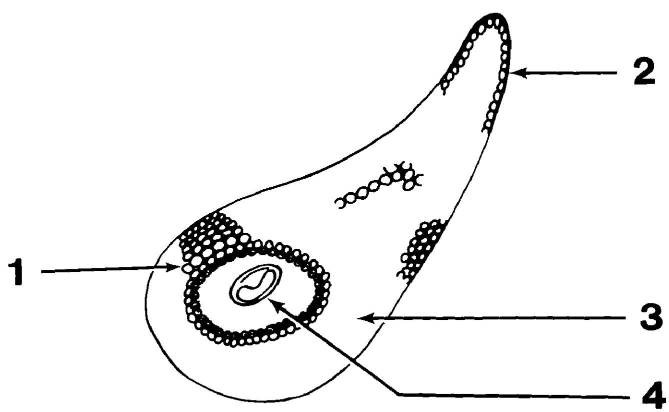
2 = Tail

3 = Body

4 = Macula



36



37