THE OCCURRENCE, GEOGRAPHICAL DISTRIBUTION AND WILD VERTEBRATE HOST RELATIONSHIPS OF TICKS (IXODOIDEA) ON LUZON ISLAND, PHILIPPINES, WITH DESCRIPTIONS OF THREE NEW SPECIES

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PREFACE

It was my privilege, while a member of the United States Air Force Medical Service, to be assigned to Oklahoma State University for the purpose of working toward an advanced degree in entomology. Since the prevention and control of disease vectors in the tropical areas of Southeast Asia where operational Air Force and other United States military personnel are exposed to arthropod-borne diseases is one of the major military entomological problems, a research problem on the little-studied tick fauna of Luzon Island, Republic of the Philippines, was selected. A problem of this type was envisioned when Dr. D. E. Howell, Professor and Head, Department of Entomology, Oklahoma State University, suggested to me in November of 1965 that the Philippines would offer an especially fruitful area for the investigation of certain biological and ecological aspects of various arthropods capable of serving as vectors and reservoirs of human tropical diseases.

I would like to take this opportunity to express my sincere appreciation to Dr. Howell, chairman of my committee, for his continuous counsel and guidance from the inception of this study to its completion, as well as for his valuable assistance on the manuscript preparation.

I am also indebted to the other members of my committee, Dr. R. D. Eikenbary, Associate Professor of Entomology; Dr. S. A. Ewing, Professor and Head, Veterinary Parasitology and Public Health; and Dr. J. H. Young, Professor of Entomology, for their review of the manuscript and helpful suggestions.

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Epidemiological Laboratory, Manila, who made this study possible, is acknowledged.

Apart from the scientific assistance acknowledged above, I would like to pay special tribute to Mrs. Margaret Morrison for her typing excellence and helpful advice in the preparation of the final draft of this manuscript.

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CHAPTER I

INTRODUCTION

The increasing knowledge of ectoparasites, especially ticks, of wild vertebrates as factors in the transmission of tropical human diseases emphasizes the need for additional information on the species present, their geographical distribution and host associations in many areas of the world. The detection, identification and demonstration of ecological or environmental factors involved in the etiology or epidemiology of these infectious diseases are of primary interest in connection with the actual or potential health hazards they represent in terms of effectiveness of operational military forces in geographical areas of Southeast Asia where information concerning the distribution, endemicity and modes of transmission is lacking or inadequate.

A search for literature pertaining to the tick fauna of the Philippine Islands revealed that, aside from the species known to infest human beings and domestic animals, practically no work had been accomplished to determine the species present on Luzon Island, much less their geographical distribution, wild vertebrate host and disease relationships. Correspondence with several leading authorities on ticks of Southeast Asia, including Anastos, Hoogstraal and Kohls, confirmed the lack of knowledge concerning the tick fauna of Luzon Island which comprises approximately 35 percent of the total land area of the Philippine Islands. The only information available concerning the ticks of wild vertebrates derives from collections made on Mindanao and some of the other southern islands of the archipelago in 1946 and 1947 by Hoogstraal and reported by Kohls (1950). During World War II, Howell (1969) made tick collections on various islands of the archipelago, but these specimens were lost in transit to the United States.

Fevers of undetermined origin are common in the Philippines and it is, therefore, important to determine whether ticks in this area have a role in the transmission of pathogenic agents to human beings. As a first step in preparation for the assessment of the disease relationships of the tick fauna on Luzon Island, general preliminary studies on the species composition, host associations and geographic distribution were considered necessary. This, I have endeavored to do, by examining wild vertebrate populations for ticks, based on random sampling techniques, in 16 of 28 provincial areas on Luzon Island, Republic of the Philippines (Fig. 1), during the period between April 1965 and May 1969.

The presence of hostile mountain tribesmen and political unrest among certain elements of the rural Filipino populations during the period of this study, coupled with transportation difficulties between Manila and outlying provinces, prevented systematic and extensive collecting in many geographic areas.

Information concerning the geography, topography, climate, natural vegetation types and animal life of the Philippines, with special reference to Luzon Island, is presented below.

Geography

The Philippine Islands lie between 4^{o} 23' and 21^{o} 25' north latitude and between 116^{o} and 127^{o} east longitude. To the north lies Taiwan (Formosa), on the east the Pacific Ocean, on the south Borneo and the Celebes Sea and on the west the China Sea. The Philippine Archipelago is composed of 7,100 islands and islets of varied sizes with a total land area of 115,600 square miles, roughly equivalent to the state of Arizona or almost twice the size of New England. The islands are situated within the tropics and the lowlands and medium elevations offer a great diversity of typical tropical habitats for both plants and animals. They are exposed to the shifting trade winds and typhoons with the corresponding peculiar distribution of rainfall.

Luzon, the largest island of the Philippines, stretches in overall length for more than 530 miles southeastward from Cape Bojeador in the northwest to the northern shores of San Bernardino Strait between Luzon and the Visayan island of Samar, over a latitudinal distance of approximately six degrees. The island's width varies from a mere eight miles across the Tayabas Isthmus in the south to over 135 miles along the 17th parallel between Palanan Point and the Ilocos Sur coast. Wernstedt and Spencer (1967) state that the island embraces a land area of 40,420 square miles, representing nearly 35 percent of the total land surface of the Philippine Archipelago.

Climate

Heavy rains occur throughout the islands during the monsoons. The air stream direction, together with the topographical features of the islands and their different sizes, influence the difference in rainfall which is decidedly variant at other times during the year. Based primarily upon the patterns of rainfall, four types of climate are recognized by the Weather Bureau of the Philippines as follows:

(1) Two distinct seasons, dry from November to April and wet during the rest of the year.

(2) No dry season, with extensive rainfall from November to January.

(3) Seasons not well pronounced; relatively dry from November to April; wet during the rest of the year.

(4) Rainfall more or less evenly distributed throughout the year.

Topography

The entire Philippine Archipelago is about 65% mountainous and has over 3000 miles of coastline. It has almost every variety of topographical feature. Luzon Island contains the most extensive valleys and largest mountainous areas. The Cagayan Valley in the northern part of the island includes the Provinces of Cagayan, Isabela and Nueva Vizcaya. This valley, hemmed in on the east by the Sierra Madre mountain range, on the west by the Cordillera Central and on the south by the Caraballo mountains, consists of approximately 10,000 square miles. The Central Luzon plain is separated from the Cagayan valley by the Caraballo mountains. The Zambales mountains lie on the western side and on the eastern extension of the Sierra Madre mountain range. The Sierra Madre mountain range extends as far as Southeastern Luzon and here the mountain peaks are of volcanic origin. Mayon volcano, the most famous of Philippine volcanoes, lies in the southern part of the island. There are several plateaus and valleys of considerable size, the Bicol valley being the most extensive.

Natural Vegetation Types

The natural vegetation of the Philippines, based on the classification of Whitford (1911), Brown (1919) and Dickerson (1928), include the following forest types.

(1) Mangrove Type. This type of vegetation is typical of a coastal succession on many of the islands, including Luzon. A typical mangrove forest is found in well sheltered bays, primarily in the vicinity of the openings of rivers.

(2) Beach Type. This type of forest is known as "Strand type" of natural vegetation in other parts of the world. It is fast disappearing on Luzon Island because of coastal settlements.

(3) Dipterocarp Type. This is the principal type of forest found in lowlands and hills and on lower slopes of high mountains. Dipterocarp forest constitutes approximately 75 percent of the whole forest area of Luzon Island and is a typical mixed rain forest in which dipterocarp trees are dominant. Typically, the ground covering in these forests consists of young trees, rattans and various herbaceous spermatophytes.

(4) Molave Type. This type vegetation is found on low limestone hills where the habitat is dry and not adapted to the requirements of a primary dipterocarp forest. The dominant species is the hardwood tree known as molave.

(5) Pine Type. This is the natural type of vegetation in the higher elevations of the mountainous regions of Northcentral Luzon. Most of the pine forest consists of a mosaic of small patches of essentially even-aged Benguet pine. This mosaic pattern of the Benquet pine forest is essentially identical with the pattern of the Ponderosa

pine forest of the Rocky Mountains of the United States. However, the Ponderosa pine forest is a climax vegetation type, whereas the Benguet pine forest is a pyrogenic vegetation type succeeding to broad-leaved forest in the absence of fire.

(6) Mid-Mountain Type. This occurs typically on the higher slopes of mountains above the range of a typical dipterocarp type. There is really no distinct boundary between the mid-mountain and the dipterocarp types, one merging imperceptibly into the other.

(7) Mossy Type. This type of vegetation is a very characteristic community on most highlands of Luzon above the highly specialized pine type from approximately 3000 feet to the top of mountains. The trees, which are usually dwarfed, are characterized by a thick covering of epiphytes. On the branches these are mostly mosses and liverworts, while on the trunks they are primarily ferns. Generally, there is a rather dense ground cover of ferns and herbaceous spermatophytes where the mossy type of vegetation occurs.

Animal Life

Vertebrate forms of animal life found living in tropical rain forests of the Philippines, as in other parts of the world, include the Amphibia, Reptilia, Aves and Mammalia. According to Rabor (1957) species from 75 families of birds are recorded from the Philippines. Including both resident and migratory forms, 860 species representing 252 genera have been reported. Rabor further states that 59 genera of mammals representing 25 families are known to live in Philippine rain forests at one time or another. The various species of bats and rats comprise the greatest numbers of individuals in the mammalian population and are consequently found in the most varied types of habitat within these forests. Wild boar and deer are the most common larger mammals. Tick collections in the course of this study were, therefore, obtained primarily from birds, bats, rats, deer and wild boar.

CHAPTER II

REVIEW OF THE LITERATURE

History of Ticks

For centuries ticks have been known as bloodsucking pests causing great discomfort to man and animals. Pagenatecher (1861) cited extracts from classical literature relating to the earliest mention of ticks. One of these was Aristotle (384-322 B. C.), who, in his famous Historia Animalium, stated that "ticks are generated from couch grass . . . the ass has no lice or ticks, oxen have both." M. Portius Cato (234-149 B. C.) referred to ticks as a troublesome pest of sheep, and regarding treatments stated, "There will be no sores and the wool will be more plentiful and in better condition and the ricini will not be troublesome." Advice is also given by Columella (60 B. C.) concerning the purchase of cattle "to pass the hand under the belly so that ticks, which principally attack cows, may be removed." Later Pliny (23-77 A. D.) wrote the following in his Historia Naturalis regarding the habits of ticks: "There is an animal occurring at the same season living on blood with its head always fixed and swelling; being one of the animals which has no exit for its food, bursts with over-repletion and dies from actual nourishment."

Arthur (1962) points out that the role of ticks in the human economy merits special consideration, for not only are they annoying pests, but in temperate and tropical countries they surpass all other arthropods in the number and variety of diseases which they transmit to man and his domestic animals; and as transmitters of human disease alone they are second only to mosquitoes. Arthur further relates that despite early realization that ticks were ectoparasites of mammals, additional knowledge of consequence did not become available until the latter half of the nineteenth century when a number of descriptions of ticks were published and a systematic approach to their study was initiated by Professor L. G. Neumann of Toulouse.

It was not until the first part of the twentieth century that Professor G. H. F. Nuttall and his collaborators in England fostered the systematic approach to the study of ticks (Arthur, 1962). Arthur points out that, in the study of the Protozoa responsible for red-water fever, Nuttall and co-workers were seriously hampered by a lack of knowledge concerning the morphology, taxonomy, geographical distribution, ecology and biology of ticks which transmitted this disease to cattle. This led Nuttall and co-workers to compile and publish comprehensive monographs on the Argasidae (1908), the genus Haemaphysalis (1915) and the genus Amblyomma (1926). In the United States during this period, Banks (1908) published his revision of the Ixodoidea of the United States. Other active investigators in the United States during this period were Salmon and Stiles (1902). Considerable work was done on the anatomy of ticks by other American workers as exemplified in the papers of Samson (1908, 1909), Robinson (1912, 1926), Robinson and Davidson (1913), Nordenskiold (1920) and others. During the early 1900's, biological studies on ticks were conducted by Hunter and Bishopp (1911) and their colleagues in the United States and by Lounsbury (1905) and his co-workers in Africa.

In more recent years there has been much work accomplished on the taxonomy, biology and ecology of ticks throughout many parts of the world. Some of the notable workers include Cooley and Kohls (1944), Bishopp and Trembley (1945), Anastos (1950), Pomerantzev (1950), Howell (1953), Hoogstraal (1956) and Arthur (1960).

Distribution of Ticks in the Philippines

Kohls (1950) reports that prior to 1946 few species of ticks were known from the Philippines. Of the 13 species that had been reported, Kohls (1950) states that five had to be eliminated because of synonomy or error in identification. This left only eight species which could be credited, with certainty, to the Islands, namely: *Amblyomma cyprium aeratipes* Schulze, *A. helvolum* Koch, *Aponomma ecinctum* Neumann, *A. fimbriatum* (Koch), *Boophilus microplus* (Canestrini), *Haemaphysalis centropi* Kohls, *Indocentor compactus tricuspis* Schulze--probably a species of the *Dermacentor auratus* Supino (Complex)--and *Rhipicephalus sanguineus* (Latreille). Of these species, only three--*Aponomma ecinctum*, *Boophilus microplus* and *Rhipicephalus sanguineus*--were reported from Luzon Island. *Boophilus microplus* was reported from Manila as early as 1904 by Banks and according to de Jesus (1934) cattle served as the primary host. *Rhipicephalus sanguineus* was noted in 1897 by Neumann (1899) who recorded specimens from Bohol. De Jesus (1939) also found this species to be very prevalent on dogs throughout the Philippines. Kohls (1950) reports that numerous adult specimens of *R. sanguineus* taken from dogs in Manila are present in the U. S. Public Health Service Rocky Mountain Laboratory collection. The only record of *A. ecinctum* in the Philippines is that of Neumann (1911) who reported it from Luzon on reptiles.

Single records of *Amblyomma americanum* (L.) and *A. dissimile* Koch, as reported by Robinson (1926) and Neumann (1899), respectively, and the presence of *Dermacentor variabilis* (Say) by Banks (1904) are regarded as highly questionable according to Kohls (1950). All of these are New World species and a review of more recent literature does not reveal confirmation of their reported occurrence in the Philippines.

During the period 1946-1947 Hoogstraal (1951), as a member of the Philippine Zoological Expedition of the Chicago Natural History Museum, collected 13 additional species from the Philippines, but none of these species were collected on Luzon Island (Kohls, 1950). In 1964 two female ticks of the genus *Rhipicephalus* were collected from a man in the Zambales Mountains, Pampanga, Luzon Island. These ticks were later identified as being *Rhipicephalus haemaphysaloides haemaphysaloides* Supino (Pippin, 1965).

Tick-Borne Diseases

During the period 1889 to 1893, Smith and Kilbourne (1893) made biomedical and epidemiological history by discovering that *Babesia bigemina*, the etiological agent of bovine Texas fever, was transmitted by a tick, *Boophilus annulatus* (Say). Texas fever first became an economic problem of the livestock industry in the late 1800's when ranchers ventured into previously undisturbed natural habitats of North America. Hoogstraal (1967a) points out that Asian tick-borne diseases were similarly professionally recognized only during the last three decades when human beings either began entering newly developing regions or occupied areas where they acquired tick-borne infections that previously had circulated within the local fauna.

Soon after the discovery of tick-borne Texas cattle fever in the United States, further studies demonstrated that ticks were capable of transmitting many diseases caused by different organisms (Pratt and Littig, 1962). During the period 1902-1906, Ricketts (1906) incriminated the wood tick, Dermacentor andersoni Stiles, in the transmission of Rocky Mountain spotted fever. Further work also implicated the American dog tick, Dermacentor variabilis (Say), and the lone star tick, Amblyomma americanum, in the transmission of this disease (Herms and James, 1965).

At the present time, ticks are known to transmit several important pathogens to man and domestic animals, and their role involves more than mere transmission from vertebrate to vertebrate. As pointed out by James and Harwood (1970), in many instances the pathogens acquired by female ticks may be transferred to their progeny. Transstadial transmission of pathogens is also common. The five groups of diseases transmitted to man and animals are: (1) rickettsial, such as spotted fever, (2) bacterial, such as tularemia, (3) spirochetal, such as relapsing fever, (4) viral, such as Colorado tick fever and (5) protozoal diseases, such as piroplasmosis (James and Harwood, 1970).

Ticks have been shown to be both vectors and reservoirs of various pathogens; furthermore, they can remain infectious for long periods of time (Philip and Burdorfer, 1961). Rao (1967) reports that the list of viruses recovered from ticks in different parts of the world has increased enormously in recent years. In the Catalogue of Arthropod-Borne Viruses of the World compiled by Taylor (1967), more than 30 viruses have been isolated from ticks. It is also well known that ticks afflict man and other mammals by their irritating bites and by tick paralysis associated with their toxic secretions (Pratt and Lettig, 1962).

Some of the tick-borne diseases of man known to be endemic in the tropical regions of Asia include various hemorrhagic diseases, tick-borne encephalitis and typhus, but the endemicity of human tick-borne diseases in the Philippines remains to be studied (Hoogstraal, 1966).

Morel (1967), in his review of tick-borne diseases of man in Africa south of the Sahara, lists boutonneuse fever, Q fever and relapsing fever as important tick-borne diseases. He states, however, that in comparison with Eurasian and American ticks, the African species do not appear to play an important role in the epidemiology of human viral infections.

Literature pertaining to tick-borne diseases in various tropical regions of the world include the works of several notable workers such as Brumpt (1901, 1949), North Africa; Du Toit (1942), South Africa; Hoogstraal (1956), Sudan; Anastos (1950), Indonesia; Fairchild, Kohls and Tipton (1966), Panama.

Host Associations of Ticks

Fuller (1956) discusses the many and varied ecological problems encountered and the various degrees of complexity which characterize the ecologic relationships among tick species and their vertebrate hosts. He points out that during at least one stage in their life cycle all ticks are parasitic on terrestrial vertebrates; and since some of these parasitic forms attack human beings, they may act as direct causative agents of disease or may transmit pathogenic microorganisms; furthermore, certain species not known to attack man may play roles in the biological survival mechanisms of important pathogens by transmitting them among suitable wild hosts and by acting as reservoirs of infection.

Both habitat and potential hosts available in numbers sufficient to insure successful transfer from one host animal to another during the course of larval, nymphal and adult developmental process seem basically important to the success of a tick population according to Hirst (1927); Eskey (1930); Green, Evans and Larson (1943); Joyce and Eddy (1943); Mohr and Lord (1960); Herms and James (1965); Philips (1966). The studies of Milne (1949), Worth (1951), and Philips (1966) revealed that larger hosts usually have a higher incidence of infestations probably due to body size and behavior. However, Mohr and Stumpf (1964) point out that within a given population differences in size of home range have not been demonstrated to be significant.

Hoogstraal (1967b) points out that tick distribution and host specificity are intimately related, tick distribution being influenced by several factors. According to Hoogstraal (1967b) these include host preference and degree of host specificity of each developmental stage of the tick species; geographical isolation and ecological tolerance range of the preferred hosts of each developmental stage within islands and archipelagos, mountain masses and continental limits; mobility, behavior and life cycle of the preferred hosts of each developmental stage; ecological tolerance of each developmental stage; ability, chiefly of adult ticks, but also of immature stages, to adapt to birds and mammals that are domesticated in large numbers and are frequently transported long distances by man.

The following statements are made by Hoogstraal (1967b) regarding host specificity of ticks: "Since each of the world's some 800 known tick species has evolved in close association with a specific vertebrate host family, the continuing tick-host family relationship has a more or less limited range of specificity." "Thus each stage, larva, nymph and adult, in each zoogeographic-ecological area of the world, has in nature either a strictly specific or somewhat less limited degree of host preference within a specific vertebrate family or group of families occupying certain ecological niches or zones." "This fact may tend to be obscured when the area inhabited by the tick is invaded by domestic animals, or man, that are more or less acceptable as hosts to ticks requiring a blood meal."

Ecology of Ticks in Relation to the Epidemiology of Human Disease

Hanson (1962), Naumov (1963), and Odum (1963) point out that the complexities of all the factors concerning abiotic and biotic influences upon ticks in nature is somewhat difficult to understand due to the variety of external environmental factors affecting them. Furthermore, according to these authors, the problem becomes even more complicated since many of these factors are changing all the time, but never simultaneously. Because of these changing factors, these authors are of the opinion that only some of the problems of the ecology of ticks can be studied separately. According to these workers, the epidemiology is still in need of complex investigations which would make it possible to give an epidemiological, scientifically justified prognosis based on the system of pathogenic agent - maintenance host - tick (vector) - man.

In connection with the epidemiology of infections transmitted by ticks, their involvement in a certain ecosystem is of importance since this role also enhances their epidemiological significance (Rosicky, 1967). In most cases the infections transmitted by ticks are characterized by the phenomenon of the so-called natural focality, and one of its main features is the dependence of the causative agent and of the vector on natural biotic communities which have undergone long-lasting development (Pavlovsky, 1966). As examples of this association of ticks with certain clearly defined ecosystems, Pavlovsky lists tick-borne encephalitis, Colorado tick fever, tick-borne rickettsioses and tick-borne relapsing fever.

CHAPTER III

METHODS AND MATERIALS

Faunal surveys are usually conducted in two phases, a general preliminary survey followed by a detailed ecogeographic survey. The methodology employed in the conduct of this study was designed to obtain from preliminary surveys an indication of the species composition and general distribution of ticks on Luzon Island. Collections from wild vertebrates in natural biotypes were made in as many geographic areas of the Island as possible. Limitations on time, lack of personnel, transportation difficulties, and the presence of hostile Filipino populations in various areas made it unfeasible to make island-wide studies of a systematic nature.

Although the primary objective of this study was to examine wild vertebrates for the presence of ticks, domestic animals were examined also.

A three-quarter ton, four-wheel-drive truck was used for transporting personnel and equipment to the more accessible study areas of the Island. In order to reach some of the more remote and inaccessible areas, a helicopter was used.

The following procedures and materials were utilized in this study.

Rodent Trapping Procedures

These animals were captured in Japanese wire-cage traps provided with an entrance chamber through the top of the cage. Number 0 steel jaw traps and Young's model 1-SA box traps were also used in the beginning of the study, but these proved to be considerably less effective than the Japanese cage traps and they were discontinued. After initially experimenting with several bait formulae, fresh apples proved to be the preferred bait and were used exclusively throughout the period of the study. Between 200 and 225 traps were "set" at each collecting site per night. Traps were initially baited at the base camp site and hand-carried to trapping sites during late afternoon. The trap lines were "run" during early morning hours, and traps containing rodents were returned to the camp site where the specimens were processed for storage prior to examination for ticks and other ectoparasites in the laboratory. These traps were re-baited and returned to the collecting site in the afternoon of the same day.

Handling Rodents for Examination

The following procedures were used in handling rodents for examination. Traps containing captured live specimens were placed in 20-gallon air tight metal cans lined with plastic bags and euthanitized with ether. The dead animals were removed from the traps, placed in appropriately labeled plastic bags, and stored in styrofoam containers containing dry ice for transporting to the laboratory in Manila. After traps containing dead rodents were removed from the killing containers, the plastic liners were inspected and ticks that had become detached from the host during euthanasia were recovered. Upon arrival at the laboratory, the plastic bags containing the dead rodents were removed from the styrofoam shipping containers and stored in a walk-in freezer at temperatures below 32° F. until ready for processing.

In study areas located within one day's travel time from Manila, rodents were brought back to the laboratory and held alive until ticks dropped from them. Certain living ticks from these specimens were maintained in the laboratory for molting and rearing to supplement the paucity of better quality specimens required for detailed taxonomic study.

Removal of Ticks from Rodents

After the host specimens were removed from the freezer, thawed, and warmed to room temperature, they were removed from the plastic bags, held over large white enamel pans and combed vigorously with a fine-toothed comb. Close inspection was made of the host-specimen storage bags to remove ticks that had become detached from the animal carcasses while in storage. After combing, the animals were placed in one-half gallon jars containing one quart of water in which a tablespoon of detergent (Calgonite) had been dissolved. Six drops of isopropyl alcohol were added to the detergent solution to reduce foaming. The jars were sealed and shaken vigorously at 10 minute intervals over a period of two hours. The animals were then removed from the jar, care being taken to wash all ectoparasites out of the fur. After allowing the jars to set for three hours the detergent solution was siphoned off, leaving the residue containing ticks and other ectoparasites in the bottom of the jars. This residue was then transferred to a filter paper lined funnel and allowed to stand for 10 minutes. Ticks and other ectoparasites were then removed from the filter paper and stored in vials containing 70% ethanol, to which a small amount of glycerine had been added.

Examination of Deer and Wild Boar

It was necessary to obtain a scientific collector's permit from the Philippine Department of Wildlife Conservation to study these wild game animals. Professional hunters were hired from time to time to assist in killing these animals with .22 caliber rifles for examination. During the legal hunting season arrangements were also made, whenever possible, to examine carcasses freshly killed by local hunters throughout the Provinces. Box traps were also utilized to capture live deer for examination. Both deer and wild boar were visually examined at the site of kill or capture, and if ticks or other ectoparasites were present, they were removed and preserved in 70% ethanol containing a small amount of glycerine.

Collecting Procedures for Bats and Birds

Japanese nylon mist nets, measuring 40 feet x 8 feet with a mesh size of 1.5 inches, were used for capturing these vertebrate hosts. The nets were positioned at entrances of bat caves and in known flyways of birds. Occasionally birds were shot with 20 gauge shotguns. Procedures used for removal of ticks from bats and birds were the same as those described for rodents.

Species Determinations

After all ticks were removed from the hosts, tentative identifications were made in the USAF Epidemiological Laboratory. These determinations were based on either original descriptions or on redescriptions of Ixodoidea species known to occur in the Oriental zoogeographical region. The keys prepared by Anastos (1950) and Kohls (1950) were used extensively. Confirmation of tentative determinations were made by either Dr. Harry Hoogstraal of the U. S. Naval Medical Reserach Laboratory, Cairo, Egypt, or Dr. Glen M. Kohls of the U. S. Public Health Rocky Mountain Laboratory, Hamilton, Montana. Descriptions of newly discovered species were made in collaboration with Dr. Hoogstraal and Dr. Kohls in accordance with the international rules of zoological nomenclature.

CHAPTER IV

RESULTS AND DISCUSSION

Survey Data

As a starting point it was decided to begin the study, from a disease-hazard standpoint, in Pampanga Province, the location of Clark Air Base, where large numbers of United States Air Force and other military personnel are exposed to potential tick-borne diseases. Although large game animals are not present in this area, wild rodents are plentiful. This initial survey in Pampanga Province was followed by a survey of Zambales Province, the location of Subic Bay Naval Station and Cavite Province, the location of Sangley Point Naval Air Station, where large numbers of United States Naval personnel are stationed. The next order of survey priority was based as much as possible on areas within Provinces utilized as recreational sites by United States Military personnel, such as Mountain Province where John Hay Air Base is located.

The major portion of the survey data was collected between October 1966 and March 1968, supplemented with data obtained as early as April 1965 and as late as May 1969. A considerable amount of the survey data obtained prior to October 1966 consisted of collections from domestic animals.

Surveys were conducted in 16 of the 28 Provinces of Luzon Island from the northernmost Province of Cagayan to the Province of Quezon which extends down into the southern part of the island to the Sibuyan Sea (Figure 1).

An attempt was made to sample the wild vertebrate populations in all major natural vegetation types represented in each of the provincial areas surveyed, but the following type habitats provided the primary sources for host material: Aves--lowland dipterocarp forest and mangrove; Mammalia--low-mountain dipterocarp forest and mid-mountain forest types (Artiodactyla); low-mountain dipterocarp forest (Carnivora); caves located in hill and low-mountain dipterocarp forest (Chiroptera); lowland, hill and low-mountain dipterocarp forests (Rodentia); Reptila--mangrove.

During this study 3,718 wild vertebrates, representing 69 species, were examined for ticks. Of this number, 653 individual hosts, representing 29 species, were infested with 4,079 ticks, representing 9 genera and 18 species.

Species Composition of Ticks

Ticks found on wild vertebrate hosts in one or more of the 16 Provinces of Luzon Island in which random samplings were made consisted of the following species: *Amblyomma helvolum* Koch, *Amblyomma javanense* (Supino), *Aponomma fimbriatum* (Koch), *Aponomma ecinctum* Neumann, *Argas pusillus* Kohls, *Boophilus microplus* (Canestrini), *Dermacentor auratus* Complex Supino, *Haemaphysalis doenitzi* Warburton and Nuttall, *Haemaphysalis gigas* Hoogstraal, *Haemaphysalis luzonensis* sp. n., *Haemaphysalis ornithophila* Hoogstraal and Kohls, *Haemaphysalis papuana* Thorell, *Haemaphysalis psalistos* sp. n., *Haemaphysalis rusae* Kohls, *Haemaphysalis susphilippensis* sp. n., *Ixodes granulatus* Supino, Ornithodoros batuensis Hirst and Rhipicephalus haemaphysaloides pilans Schulze. Species taken from domestic animals were Boophilus microplus (Canestrini) and Rhipicephalus sanguineus (Latreille).

Of the above listed species H. luzonensis, H. psalistos and H. susphilippensis are new species, as indicated, and the descriptions of these species are presented in a later section of this chapter. In addition to these new species, H. doenitzi, H. gigas, and H. ornithophila are reported for the first time in the Philippine Islands. In addition to the above six species, the following species collected during the course of this study are reported from Luzon Island for the first time: Amblyomma helvolum, A. javanense, Aponomma fimbriatum, Argas pusillus, Haemaphysalis rusae, Ixodes granulatus, Ornithodoros batuensis and Rhipicephalus haemaphysaloides pilans.

At the present time an extensive revision of D. auratus-like material is being made by Hoogstraal and Kohls (1968) and until this revision is completed it is impossible to assign a satisfactory species name to Luzon material. As presently used by specialists, the name D. auratus appears to be a "catchall" for a singularly difficult complex of races, species, or subspecies that are widely distributed parasites of mammals in India and Southeast Asia, Indonesia and the Philippines (Sharif 1928; Anastos 1950; Kohls 1950, 1957).

Tick-Wild Vertebrate Host Associations

The various wild vertebrate hosts found infested with ticks in the 16 provinces surveyed during the course of this study are listed below.

Artiodactyla. Eight species of ticks were taken from 37 wild boar, Sus celebensis philippinus Nehring (Table I). One new

TABLE I

SPECIES OF TICKS TAKEN FROM WILD BOAR,
LUZON ISLAND, PHILIPPINES
1965-1969

Host Species	Tick Species
Sus celebensis philippinus	*Amblyomma javanense*
	Dermacentor auratus-group
	Haemaphysalis luzonensis
	Haemaphysalis papuana
	Haemaphysalis psalistos
	Haemaphysalis susphilippensis
	Haemaphysalis rusae
	Rhipicephalus haemaphysaloides pilans

Haemaphysalid species, Haemaphysalis (Kaiseriana) susphilippensis, is described from 14 collections of adults from this host.

Nine species of ticks were found on 61 Luzon deer, Cervus (Rusa) philippinus Smith (Table II). Two additional new Haemaphysalid species, Haemaphysalis (Kaiseriana) luzonensis and Haemaphysalis (Kaiseriana) psalistos, are described from collections of adults, nymphs and larvae from this host.

Aves. A total of 874 birds, representing 37 species, were examined for ticks and six species of ticks were found on the following nine species: Acrocephalus arundinaceus (L.), Coturnix chinensis L., Lophura sp., Loctustella lanceolata (Temminck), Miralea javanica philippensis (Forster), Pitta erythrogaster (Muller), Pitta sordida Bonaparte, Turdus obscurus Gmelin and Zoothera dauma aurea Sharpe (Table III).

Carnivora. Seventeen civet cats, Viverra tangalunga Gray and 12 feral domestic cats, Felis domestica Brisson were examined. Three species of ticks were taken from the Philippine civet cat and one species was found on feral domestic cats (Table IV).

Chiroptera. As of 1952 there were 39 species of bats reported from the Philippine Islands, with the majority of these species being reported from the southern islands of Mindanao, Negros and Palawan (Sanborn, 1952). According to Sanborn only three chiropterid species were collected on Luzon Island by the 1946-1947 Philippine Zoological Expedition of the Chicago Natural History Museum.

During the present study 977 bats, representing 17 species, were captured and examined for ticks. Ticks were found parasitizing the following five species: Hipposideros bicolor antricola Peters,

TABLE II

SPECIES OF TICKS TAKEN FROM DEER, LUZON ISLAND, PHILIPPINES, 1965-1969

Host Species	Tick Species
Cervus (Rusa) philippinus	Amblyomma helvolum
	Amblyomma javanense
	Boophilus microplus
	Dermacentor auratus complex
	Haemaphysalis gigas
	Haemaphysalis luzonensis
	Haemaphysalis psalistos
	Haemaphysalis susphilippensis
	Haemaphysalis rusae

TABLE III

SPECIES OF TICKS TAKEN FROM BIRDS, LUZON ISLAND, PHILIPPINES, 1965-1969

Host Species	Tick Species
Great Reed Warbler (*Acrocephalus arundinaceus*)	*Haemaphysalis doenitzi*
Painted Quail (*Coturnix chinensis lineata*)	*Argas pusillus* *Dermacentor auratus* complex *Haemaphysalis doenitzi*
Streaked Grasshopper Warbler (*Locustella lanceolata*)	*Haemaphysalis doenitzi*
Kalij Pheasant (*Lophura* sp.)	*Haemaphysalis ornithophila*
Bush Lark (*Mirafra javanica philippensis*)	*Haemaphysalis doenitzi*
Red-breasted Pitta (*Pitta erythrogaster*)	*Amblyomma helvolum* *Haemaphysalis doenitzi* *Ixodes granulatus*
Black-headed Pitta (*Pitta sordida*)	*Dermacentor auratus* complex
Grey-headed Thrush (*Turdus obscurus*)	*Haemaphysalis doenitzi*
Golden Ground Thrush (*Zoothera dauma aurea*)	*Haemaphysalis doenitzi*

TABLE IV

SPECIES OF TICKS TAKEN FROM CARNIVORA, LUZON ISLAND, PHILIPPINES, 1965-1969

Host	Tick Species
Civet Cat (*Viverra tangalunga*)	*Dermacentor auratus* complex *Haemaphysalis susphilippensis* *Haemaphysalis psalistos*
Feral Domestic Cat (*Felis domestica*)	*Haemaphysalis luzonensis*

H. diadema griseus Meyen, Rousettus amplexicandatus Geoffroy, Ptenochirus jagori Peters, Pteropus vampyrus lanensis Mearns and Taphozous philippenensis Waterhouse. The species of ticks taken from these bats are listed in Table V.

Reptilia. Examinations of 126 monitor lizards (Varanus spp.) and 23 pythons, Python reticulatus Schneider were made. Three species of ticks were found on monitor lizards and two species were taken from P. reticulatus (Table VI).

Rodentia. The Philippine Zoological Expedition, 1946-1947 (Sanborn, 1952), collected 14 species of rats in Luzon, including both domestic and forest species. During the present study 1,591 rats, representing eight forest and one semi-domestic species, were captured and examined for ticks. Ticks were taken from all nine of the following species: Apodemus sp., Chrotomys whiteheadi Thomas, Rattus benguetensis Hollister, R. (Apomys) datae Meyer, R. everetti Gunther, R. exulans querceti Hollister, R. latidens Sanborn, R. rattus mindanensis Mearns and R. norvegicus Erxleben. All of these species are wild with the exception of R. norvegicus norvegicus, which is considered to be semi-domestic in the Philippines. The species of ticks found on these rodents are listed in Table VII.

Ticks Collected from Domestic Animals

Collecting ticks from domestic animals was not included as an integral part of this study, since numerous reports of ticks infesting these animals have been published, including those by Neumann (1899), Banks (1904), de Jesus (1934), Kohls (1950) and others. When it was convenient, however, domestic animals were examined for ticks throughout

TABLE V

SPECIES OF TICKS TAKEN FROM BATS, LUZON ISLAND, PHILIPPINES, 1965-1969

Host Species	Tick Species
Hipposideros diadema griseus *Hipposideros bicolor antricola* *Ptenochirus jagori* *Taphozous philippinensis*	*Ornithodoros batuensis*
Pteropus vampyrus lanensis	*Argas pusillus*

TABLE VI

SPECIES OF TICKS TAKEN FROM REPTILES, LUZON ISLAND,
PHILIPPINES, 1965-1969

Host Species	Tick Species
Monitor Lizard (*Varanus* sp.)	*Amblyomma helvolum* *Aponomma fimbriatum* *Aponomma ecinctum*
Python reticulatus	*Amblyomma javenense* *Aponomma fimbriatum*

TABLE VII

SPECIES OF TICKS TAKEN FROM RODENTS, LUZON ISLAND, PHILIPPINES, 1965-1969

Tick Species	Host Species
Amblyomma helvolum	Chrotomys whiteheadi Rattus everetti Rattus rattus mindanensis
Amblyomma javanense	Rattus rattus mindanensis
Dermacentor auratus complex	Rattus (Apomys) datae Rattus everetti Rattus exulans querceti Rattus latidens Rattus rattus mindanensis
Haemaphysalis luzonensis	Rattus everetti Rattus exulans querceti
Haemaphysalis papuana	Apodemus sp. Rattus rattus mindanensis Rattus everetti
Ixodes granulatus	Chrotomys whiteheadi Rattus benguetensis Rattus everetti Rattus exulans querceti Rattus rattus mindanensis
Rhipicephalus haemaphysaloides pilans	Rattus rattus mindanensis Rattus norvegicus norvegicus

the period of this study. Examinations were made of 167 cattle, 122 carabao (water buffalo) and 83 dogs. The species of ticks collected from these animals are listed in Table VIII.

Number of Ticks Collected by Species

The total number and rank of each tick species collected from wild vertebrates are tabulated in Table IX.

Amblyomma helvolum and Haemaphysalis luzonensis comprised 40 percent of the total collections from all of the wild vertebrates examined. A. helvolum was the most prevalent species collected and was found predominantly on species of forest-dwelling rodents. This species numerically outranked all of the other species collected, representing slightly over 20 percent of the total collections. Of the eight haemaphysalids collected, H. luzonensis was the most prevalent and was found predominantly on deer and wild boar. This species ranked number two in total abundance or slightly under 20 percent of the total tick collections.

Geographic Distribution

The distribution of each of the 18 species of ticks collected from wild vertebrates in one or more of the 16 provincial regions of Luzon Island is shown in Figures 2-19. Amblyomma helvolum was by far the most widely distributed species and was found parasitizing rodents in all of the 16 provinces included in this study. While there was wide distribution for Dermacentor auratus-complex and Ixodes granulatus on wild rodents, it was less extensive than expected based on the observations of Marchette (1966) in Malaya where he found Dermacentor auratus

TABLE VIII

SPECIES OF TICKS COLLECTED FROM DOMESTIC ANIMALS,
LUZON ISLAND, PHILIPPINES, 1965-1969

Domestic Host	Tick Species
Cattle	*B. microplus*
Carabao	*B. microplus* *R. sanguineus*
Dog	*R. sanguineus*

TABLE IX

THE NUMBER OF TICKS BY SPECIES TAKEN FROM EACH SUBDIVISION OF VERTEBRATES AND THE RANK OF THE TICK SPECIES WHEN THE TOTAL NUMBER OF INDIVIDUALS WAS CONSIDERED

Host	Tick Species	Number	Rank
Mammalia			
Artiodactyla			
Luzon Deer	A. helvolum	14	1
	A. javanense	209	3
	B. microplus	62	15
	D. auratus-complex	51	7
	H. gigas	18	18
	H. luzonensis	601	2
	H. psalistos	327	4
	H. susphilippensis	16	5
	H. rusae	43	14
Wild Boar	A. javanense	116	3
	D. auratus-complex	42	7
	H. luzonensis	131	2
	H. rusae	31	14
	H. papuana	71	9
	H. psalistos	123	4
	H. susphilippensis	297	5
	R. haemaphysaloides	22	13
Carnivora			
Civet Cat	D. auratus-complex	12	7
	H. psalistos	17	4
	H. susphilippensis	9	5
Wild Cat	H. luzonensis	21	2
Chiroptera	A. pusillus	67	10
	O. batuensis	269	6
Rodentia			
Muridae	A. helvolum	758	1
	A. javanense	129	3
	D. auratus-group	32	7
	H. luzonensis	41	2
	H. papuana	37	9
	I. granulatus	86	8
	R. haemaphysaloides pilans	54	13

TABLE IX (Continued)

Host	Tick Species	Number	Rank
Aves			
Galliformes	A. pusillus	27	10
	D. auratus - group	12	7
	H. doenitzi	21	12
	H. ornithophila	23	16
Passeriformes	A. helvolum	19	1
	D. auratus-group	5	7
	H. doenitzi	57	12
	I. granulatus	26	8
Reptilia			
Squamata			
Boidae	A. fimbriatum	52	11
	A. javanense	34	3
Varanidae	A. helvolum	44	1
	A. ecinctum	19	17
	A. fimbriatum	34	11

and Ixodes granulatus to be the most prevalent and widely distributed species on rodent hosts.

The major taxonomic groups of wild vertebrate hosts from which ticks were collected in each of the 16 provinces included in this study are listed in Table X.

Sixteen of 18 tick species collected from wild vertebrates were found in two or more of the provinces surveyed. Two species, Haemaphysalis gigas and H. ornithophila, were found in only one province, Nueva Ecija and Laguna, respectively. It is interesting to note that Boophilus microplus, normally found only on domestic cattle and carabao in the Philippines, was found on Luzon deer in the provinces of Nueva Vizcaya and Quezon.

Collection and Depository Data for New Species

(1) Haemaphysalis (Kaiseriana) luzonensis (Luzon Mountain Glossy Haemaphysalid). Holotype: Male, from Luzon deer, Cervus (Rusa) philippinus Smith, Mt. Dumug, ± 3,000 feet altitude, Labi, Bongabong, Nueva Ecija, Luzon, Philippine Islands, 8 October 1966, D. W. Parrish, J. K. Palmer and J. L. Libay (HH6960). Deposited in the Rocky Mountain Laboratory, Hamilton, Montana (RML48,586). Allotype: Female, same data and depository as for holotype. Paratypes: Total 226 females, 111 males, 148 nymphs and 6 larvae. All from Luzon Island collected by D. W. Parrish, J. K. Palmer and J. L. Libay. Paratype collections are deposited in the Rocky Mountain Laboratory; Philippine National Museum, Manila; British Museum (Natural History), London; Field Museum of Natural History, Chicago; Bernice P. Bishop Museum, Honolulu; Naval Medical Research Unit No. 3, Cairo; USAF Epidemiological Laboratory, Manila.

TABLE X

MAMMALIAN, AVIAN AND REPTILIAN HOSTS FROM WHICH TICKS WERE COLLECTED IN 16 PROVINCES OF LUZON ISLAND, PHILIPPINES

Province	Host
Bataan	Aves Rodentia
Batangas	Aves Rodentia
Benguet	Rodentia
Cagayan	Aves Rodentia
Cavite	Aves Rodentia
Laguna	Aves Reptilia Rodentia
La Union	Rodentia
Mountain	Aves Carnivora Reptilia Rodentia
Nueva Ecija	Artiodactyla (deer and wild boar) Aves Carnivora Chiroptera Reptilia Rodentia
Nueva Vizcaya	Artiodactyla (deer and wild boar) Aves Carnivora Chiroptera Rodentia
Pampanga	Aves Rodentia

TABLE X (Continued)

Province	Host
Pangasinan	Reptilia Rodentia
Quezon	Artiodactyla (deer and wild boar) Aves Chiroptera Reptilia Rodentia
Rizal	Aves Rodentia
Tarlac	Rodentia Reptilia
Zambales	Aves Carnivora Reptilia Rodentia

(2) Haemaphysalis (Kaiseriana) psalistos (Luzon Clipped-Spur Haemaphysalid). Holotype: Male, from Luzon deer, Cervus (Rusa) philippinus Smith, Mt. Kamatis, ± 3,000 feet altitude, San Luis, Quezon, Luzon, Philippine Islands, 1 February 1967, D. W. Parrish, J. K. Palmer and J. L. Libay (HH7310). Deposited in the Rocky Mountain Laboratory (RML47,611). Allotype: Female, data and depository as for holotype. Paratypes: Total 26 females, 20 males and two nymphs. All from Luzon Island from Cervus (Rusa) philippinus Smith. Twelve females, 10 males and two nymphs from same host individual as holotype and allotype (HH7310). Fourteen males and 10 females, Mt. Silangan (1½ miles west of Mt. Dumug), 1,800 feet altitude, Bongabong, Nueva Ecija, 30 January 1967, D. W. Parrish, J. K. Palmer and J. L. Libay (HH7307). Lots consisting of two females and one male each from collection HH7310 are deposited in the British Museum (Natural History), Bernice P. Bishop Museum and the Field Museum of Natural History. The remainder of collection HH7310 and HH7307 are in the Naval Medical Research No. 3 collection, Cairo, Egypt.

(3) Haemaphysalis (Kaiseriana) susphilippensis (Philippine Boar Haemaphysalid). Holotype: Male, from Philippine Boar, Sus celebensis philippensis Nehring, Mt. Salabusob, Bongabong, Neuva Ecija, Luzon, Philippine Islands, 16 August 1967, D. W. Parrish, J. K. Palmer and J. L. Libay (HH7548). Deposited in the Rocky Mountain Laboratory (RML48,980). Allotype: Female, same data and depository as for holotype. Paratypes: Total 43 males, 25 females, all from Luzon, Philippine Islands, from Sus celebensis philippensis, Bongabong, Nueva Ecija, between 1,800 and 3,000 feet elevation, 1967, James K.

Palmer and J. L. Libay: Three males and one female, Mt. Payapaya, 27 February (HH7318); six males, Mt. Nabu, 23 April (HH7484); one male and one female, Mt. Alan, 24 April (HH7494); two males and one female, Mt. Salabusob, 15 August (HH7547); three males, four females, Mt. Salabusob, 16 August (HH7548); three males and one female, Mt. Minalad, 2 June (HH7526); one male, Mt. Minalad, 6 June (HH7527). From Cervus (Rusa) philippinus: Five males and two females, Sapang Bato, 19 November (other data as above) (HH7927).

Paratypes are deposited in collections of the Rocky Mountain Laboratory, Field Museum of Natural History, British Museum (Natural History), Bernice P. Bishop Museum and Naval Medical Research Unit No. 3.

Descriptions of New Species

(1) Haemaphysalis (Kaiseriana) luzonensis.

(a) Male (Plate I, Figs. 1-2; Plate II, Figs. 5-12). Length from palpal apices to posterior scutal margin averages 2.5 mm (2.1 to 2.6 mm), breadth 1.5 to 1.9 mm. Color yellowish to reddish yellow. Capitulum (Plate II, Figs. 5-7). Basis capituli dorsally approximately 1.8 times as broad as long (including cornua), margins straight; cornua triangular, pointed, length equal to basal breadth, at least one-half as long as base of basis capituli; ventrally with three pairs of short posterior setae and one pair of short posthypostomal setae. Palpi moderately salient posteriorly; combined breadth approximately 1.25 times that of basis capituli; each palpus approximately 1.25 times as long as broad. Segment one a narrow pedicle with one dorsal and two ventral setae. Segment two approximately 1.35 times as broad as long;

posterior margins dorsally and ventrally curving anteriorly from internal margin to external surface (slightly crenulate dorsally); external profile two-thirds as long as internal margin, acutely converging to anterior margin; dorsointernal margin approximately straight, ventrointernal margin convex; setae number four dorsally, three ventrally; dorsointernal setae number three; ventrointernal setae number five (sometimes six). Segment three (except for dorsal spur) slightly longer than two and broader posteriorly than two anteriorly (thus externally forming a small break in palpal profile at juncture of these segments); dorsal spur median, elevated, broadly triangular, overlapping anterior one third or one fourth of segment two; external profile confluent with bluntly rounded apex; dorsointernal margin convex; apex broadly rounded; ventral spur a broadly triangular, bluntly pointed blade seldom extending beyond midlength of segment 2 (it is important to measure this length only directly from above when palpal segment 3 is in a flat plane; if this segment is tilted ventrally, the ventral spur length in relation to segment 2 appears to be greater than it actually is); setae number 5 dorsally, 5 ventrally, and 3 on internal margin ventrally. Hypostome (Plate II, Fig. 7) short, stout, not so long as palpi, 2 times as long as broad; apex truncate or broadly rounded; corona dense, approximately one-fourth as long as denticle files; dental formula 6/6 or 5/5 (6/6 in holotype; in 136 paratypes in which this formula was checked, it is 5/5 in 83 and 6/6 in 53 specimens); denticles in files of approximately 9.

Scutum (Plate I, Fig. 1) unusually smooth and glossy; broadly oval, 1.3 to 1.5 times as long as broad; margins broadly rounded; outline broadest at level of coxa IV; small apex of spiracular plate visible from dorsal view. Lateral grooves shallow, obscure, extend to or slightly beyond scutal midlength (usually shallower and more obscure or obsolete in area of scutal midlength); may enclose first festoon. Cervical grooves as short, deep, apical pits. Punctations obscure or obsolete; shallow, small, few. Festoons number 11.

Venter and genital area as illustrated (Plate I, Fig. 2; Plate II, Fig. 8). Spiracular plates (Plate II, Fig. 9) subquadrate, junctures, rounded; dorsal projection at an angle to plate, short, triangular, apex pointed.

Legs (Plate I, Figs. 1, 2; Plate II, Figs. 10-12). Coxae (Plate II, Fig. 10) each with a triangular spur; spur I spinelike, bluntly pointed, length and basal breadth approximately equal, extending to but not beyond anterior margin of coxa II; spurs of II to IV subequal, broadly triangular, approximately one-half as long as spur of I. Trochanter I with dorsal plate pointed (Plate I, Fig. 1); ventral spur (Plate II, Fig. 10) triangular, approximately one-third as long as spur of coxa I; other trochanters with elevated ridges but lack definite spurs (II may have a very small, indistinct spur). Femur IV with 9 (7-10) ventro-internal setae, each approximately one-half as long as diameter of femur at its site of insertion (Plate II, Fig. 11). Tarsi (Plate II, Fig. 12) moderately long; dorsal surfaces flat proximally, gradually taper distally; ventral surfaces each with a small subapical hook and II to IV with a moderate subbasal angle. Claws moderate. Pulvilli reach to or almost to apical curvature of claws.

(b) Female (Plate I, Figs. 3, 4; Plate II, Figs. 12-20). The female differs from the male in secondary sexual characteristics but is similar to it in chief diagnostic details. Length (unengorged) approximately 2.8 mm, breadth 1.8 mm.

Capitulum (Plate II, Figs. 13-15). Basis capituli dorsally 2.3 times as broad as long (including cornua); margins straight; cornua slightly less than one-half as long as base of basis capituli, broadly triangular, pointed; porose areas subcircular, small, widely spaced. Palpi as in male except for slightly greater breadth and length of segment 2. Hypostome (Plate II, Fig. 15) as in male except that dental formula is 5/5 in all specimens listed; denticles in files of 9 to 12.

Scutum (Plate I, Fig. 3) smooth, glossy, 1.10 to 1.25 times as broad as long; margins gradually rounded, posterior margin broadly rounded. Cervical grooves more or less subapical, linear, extend to anterior one fourth or to midlength of scutum. Punctations obscure, few, small, shallow.

Genital operculum (Plate II, Fig. 16) simple, elongate, outline gradually converging to truncate posterior margin. Spiracular plates (Plate II, Fig. 17) subcircular; dorsal projection small, pointed apically.

Legs (Plate I, Figs. 2, 3; Plate II, Figs. 18-20) approximately as in male except that (Plate II, Fig. 18) coxal spurs are somewhat shorter and ventral spurs are absent on all trochanters. Femur IV (Plate II, Fig. 19) with 11 ventrointernal setae. Tarsi (Plate II, Fig. 20) as illustrated.

(c) Nymph (Plate III, Figs. 21, 22; Plate IV, Figs 25-30). Length unengorged approximately 1.6 mm, breadth 1.0 mm. Capitulum (Plate IV, Figs. 25-27). Basis capituli dorsally 2 times as broad as long (including cornua); margins straight; cornua broadly triangular, approximately 0.8 times as long as base of basis capituli; ventrally as illustrated, with a pair of posteroexternal setae and a pair of posthypostomal setae. Palpi quite similar to those of female. Segment 1 lacking setae. Segment 2 like that of female except that dorso-posterior margin is not crenulate and posteroexternal juncture dorsally and ventrally is very slightly produced into a small, angular point; dorsointernal seta single; ventrointernal setae number 2; setae number 3 dorsally and 2 ventrally. Segment 3 similar to that of female except that apex is slightly more narrowly rounded and ventral spur is slightly shorter; setae number 3 dorsally and 5 ventrally. Hypostome (Plate IV, Fig. 27) 2.1 times as long as broad, outline similar to that of female; corona moderate, one-fifth as long as outer denticle files, hooklets small, in approximately 5 rows; dental formula 3/3 (rarely 2/2); denticles in rows of 6 (innermost) and 8 (outer).

Scutum (Plate III, Fig. 21) 1.35 times as broad as long, outline gradually converging from rounded midlength to broadly rounded posterior margin; cervical grooves narrow, parallel, extend to scutal midlength; punctations rare.

Dorsum (Plate III, Fig. 21) and venter (Plate III, Fig. 22) as illustrated. Spiracular plates (Plate IV, Fig. 28) subcircular; dorsal extension small, bluntly triangular.

Legs (Plate III, Figs 21, 22; Plate IV, Figs 29, 30). Coxae (Plate IV, Fig. 29) with spurs as in male though proportionately those of II to IV may be very slightly larger than in male. Trochanters (Plate IV, Fig. 29) lack ventral spurs. Tarsi (Plate IV, Fig. 30) narrowly elongate; dorsal surfaces flat proximally, gradually taper distally. Claws moderate. Pulvilli large, reach to or almost to apical curvature of claws.

(d) Larva (Plate III, Figs. 23, 24; Plate IV, Figs. 31-35). Length unengorged approximately 0.75 mm, breadth 0.57 mm. Capitulum (Plate IV, Figs. 31-33). Basis capituli dorsally 2.7 times as broad as long (including cornua); cornua triangular, one-third as long as base of basis capituli; ventrally as illustrated, with a pair of small posthypostomal setae. Palpi as in nymph except that segment 3 posteriorly is no broader than 2 anteriorly and its broadly bladelike ventral spur overlaps only anterior one fourth of segment 2. Hypostome (Plate IV, Fig. 33) with 2/2 dental formula. Scutum (Plate III, Fig. 23) approximately 1.3 times as broad as long, outline as in nymph except that subposterior margins are slightly indented. Cervical grooves as in nymph. Punctations number 12. Dorsum (Plate III, Fig. 23) and venter (Plate III, Fig. 24) as illustrated. Legs (Plate III, Figs. 23, 24; Plate IV, Figs. 34, 35). Coxa I (Plate IV, Fig. 35) with spur proportionately slightly shorter than that of nymph; II and III each with a slightly elevated ridge in place of a spur. Tarsi, claws, and pulvilli (Plate IV, Fig. 35) as illustrated.

(e) Diagnosis (Adults). A medium-size haemaphysalid (subgenus _Kaiseriana_) (total length: male, 2.5 mm; female, 2.8 mm). Basis capituli dorsally 1.8 (male) to 2.3 (female) times as wide as long; cornua broadly triangular, at least one-half (male) or almost one-half (female) as long as base of basis capituli; porose areas (female) subcircular, small, widely spaced. Palpi moderately salient posteriorly, each approximately 1.5 (male) or 1.4 (female) times as broad as long. Segment 2 with posterior margins dorsally and ventrally curving (slightly crenulate dorsally); dorsointernal setae number 3; ventrointernal setae number 5 (rarely 6). Segment 3 with dorsal spur broadly triangular, overlapping anterior one third or one fourth of segment 2; ventral spur a broadly triangular, bluntly pointed blade seldom extending beyond midlength of segment 2. Hypostome with dense corona approximately one-fourth as long as denticle files; dental formula 6/6 or 5/5 in files of 9 (male) or 5/5 in files of 9 to 12 (female). Scutum (male), 1.3 to 1.5 times as long as broad, margins broadly rounded; unusually smooth and glossy; lateral grooves shallow, obscure, extend to or slightly beyond scutal midlength, may enclose first festoon; punctations obscure or obsolete. Scutum (female) 1.10 to 1.25 times as broad as long, posterior margin broadly rounded; cervical grooves linear; punctations as in male. Genital operculum (female) simple. Spiracular plates subquadrate, dorsal projection triangular, pointed apically (male); subcircular (female). Coxae I with spur spinelike, bluntly pointed, length and basal breadth approximately equal; spurs of II to IV approximately one-half as long as that of I, subequal, broadly triangular (spurs of female may be slightly shorter than those of male). Trochanters with short, triangular ventral spur present on I, present or absent on II (male); absent in female. Femur IV with ventrointernal setae numbering 9 (7-10) (male) or 11 (female). Tarsi moderately long, gradually tapered.

(2) Haemaphysalis (Kaiseriana) psalistos.

(a) Male (Plate V, Figs. 1-2; Plate VI, Figs. 5-12). Length from palpal apices to posterior scutal margin approximately 2.5 mm (2.3 to 2.8 mm); width 1.6 mm (1.5 to 1.8 mm). Color yellowish or reddish yellow.

Capitulum (Plate VI, Figs. 5-7). Basis capituli approximately 1.6 times as wide as long (including cornua), external margins essentially parallel; posterior margin between cornua straight; cornua large, triangular, sharply pointed, approximately one-half as long as base of basis capituli. Basis capituli ventrally as illustrated, with a pair of small posthypostomal setae. Palpi (Plate VI, Figs. 5-6) widely salient (cornigera female type); each palpus with L-W ratio approximately 1:1. Segment one as a pedicle; setae single dorsally and ventrally. Segment two twice as wide as long; dorsoposterior margin crenulate, sharply angled anteriorly from insertion to external surface; ventroposterior margin proximally crenulate (forming a small, more or less pointed median spur), distally extended into a large, pointed, posteriorly directed, external spur; external profile somewhat crenulate, acutely converging anteriorly; dorsointernal margin expanded anteriorly; ventrointernal margin almost straight; dorsointernal setae number 3; ventrointernal setae number 5; setae number 5 dorsally, 3 ventrally. Segment 3 widely subtriangular, 2 times as wide as long; length approximately equal to that of segment 2; dorsoposterior margin crenulate (median spur obsolete), internal margin and external profile converge to rounded apex; ventral outline more acutely pointed externally; ventral spur large, wide basally, sharply pointed apically, overlapping approximately anterior one half of segment 2; setae number 5 dorsally, 6 ventrally, 3 posteriorly from ventrointernal margin, several smaller setae from internal surface subapically. Segment 4 in pit at midlength of 3. Hypostome (Plate VI, Fig. 7) as long as palpi, approximately 2.2 times as long as wide, external profile straight, apex truncate; corona approximately one-seventh as long as denticle files, hooklets in 6 to 9 files of approximately 4; dental formula 5/5; denticles in files of 6 or 7 (internal) to 11 or 12 (external).

Scutum (Plate V, Fig. 1) approximately 1.3 times as long as wide; margins gradually rounded, bulging from level of anterior one fourth to constriction of dorsal projection of spiracular plates; anterior emargination wide, shallow. Lateral grooves obsolete. Cervical grooves as short, wide subapical pits. Punctations shallow, moderately numerous, small and medium size, few medioanteriorly, those in scapular areas slightly larger than elsewhere. Festoons number 11.

Venter (Plate V, Fig. 2; Plate VI, Figs. 8, 9) with several irregular rows of widely spaced setiferous punctations. Genital area as illustrated (Plate VI, Fig. 8). Spiracular plates (Plate VI, Fig. 9) subcircular; dorsal extension elongately triangular, pointed.

Legs (Plate V, Figs. 1, 2; Plate VI, Figs. 10-12) robust. Coxa I (Plate VI, Fig. 10) with a long, narrow, pointed spur 2 times as long as wide; II with a short, widely triangular spur extending only slightly beyond coxal margin; III with a broadly rounded elevation just breaking coxal margin; IV with a male - cornigera type combination of stationary and moveable spur; stationary spur similar to that of II; moveable spur long, laceolate. Trochanter I with dorsal shield pointed (Plate V, Fig. 1); trochanters ventrally lack spurs (Plate VI, Fig. 10). Femur IV with 8 ventrointernal setae (Plate VI, Fig. 11). Tarsi (Plate VI, Fig. 12) stout, moderately long; dorsal surfaces flat proximally, thence abruptly curving, narrow distally; ventral surfaces each with a strong apical hook and II to IV each with a strong subproximal spurlike angle. Claws large. Pulvilli large, reach to or almost to apical curvature of claws.

(b) Female (Plate V, Figs 3, 4; Plate VI, Figs. 13-20). Length (unengorged or very slightly engorged) from palpal apices to posterior body margin 2.5 mm (2.3 to 3.0 mm); width 1.8 mm. Capitulum (Plate VI, Figs. 13-15). Basis capituli approximately 2.1 times as wide as long (including cornua); cornua triangular, pointed, approximately one-third as long as base of basis capituli; porose areas circular, small, widely spaced; ventrally as illustrated. Palpi (Plate VI, Figs. 13, 14) widely salient (cornigera female type); each palpus approximately 1.3 times as long as wide. Segment 1 as pedicle; setae single dorsally and ventrally. Segment 2 similar to that of male except that juncture of dorsoposterior margin and external surface is more pointed and mildly crenulate; ventroposterior margin forms only a short, widely triangular external spur; external profile concave; other features and setae as in male except that dorsointernal seta is single (rarely double). Segment 3 subtriangular; length equal to that of 2; L-W ratio approximately 1:1; dorsoposterior margin forming a large, triangular median spur overlapping anterior one third of segment 2; external profile and internal margin converge to gradually rounded apex; ventral spur slightly larger than that of male; setal counts as in male. Hypostome (Plate VI, Fig. 15) 2.4 times as long as wide, profile and apex as in male; corona as in male but shorter; dental formula 4/4; denticles in files of approximately 12 to 14.

Scutum (Plate V, Fig. 3) with L-W ratio 1:1.2; outline widest approximately at midlength; gradually rounded posteriorly; anteriorly gradually converging. Cervical grooves shallow, parallel, reach scutal midlength. Punctations similar to those of male.

Integument of dorsum and venter as illustrated (Plate V, Figs. 3, 4). Genital operculum simple (Plate VI, Fig. 16). Spiracular plates subcircular; dorsal extension pointed (almost obsolete) (Plate VI, Fig. 17).

Legs (Plate V, Figs. 3, 4; Plate VI, Figs 18-20) robust. Coxa I (Plate VI, Fig. 18) with spur similar to but very slightly shorter than that of male; II to IV each with a broadly triangular or rounded elevated ridge that breaks posterior margin of coxae (II, III) or extends slightly beyond it (IV). Trochanter I with dorsal shield as in male (Plate V, Fig. 3); trochanters ventrally lack spurs (Plate VI, Fig. 18). Femur IV with 6 ventrointernal setae (Plate VI, Fig. 19). Tarsi (Plate VI, Fig. 20) narrow, elongate; dorsal surfaces of II to IV flat proximally, gradually taper apically; ventral surfaces almost straight, each with a very small apical or slightly subapical hook. Claws and pulvilli as in male.

(c) Nymph (Plate VII, Figs 21-28). Available specimens are slightly engorged.

Capitulum (Plate VII, Figs. 23-25). Basis capituli 2.3 times as wide as long; margins straight; cornua triangular, pointed, one-half as long as base of basis capituli; ventrally as illustrated. Palpi (Plate VII, Figs. 23, 24) with outline of female type but segment 2 ventroposteriorly with a very large subexternal, posteriorly directed spur; each palpus dorsally 1.5 times as long as wide; segment 2 1.2 times as long as 3; external profile not notched at juncture of segments; apex narrowly rounded; segment 3 lacking dorsal spur, ventral spur extending slightly beyond anterior margin of 2; setae as follows: dorsointernal and ventrointernal each single, segment 2 with 3 dorsals and 3 ventrals, segment 3 with 3 dorsals, 4 ventrals, and 1 on ventrointernal margin posteriorly; segment 1 as a pedicle lacking setae.

Hypostome (Plate VII, Fig. 25) narrowly elongate; dental formula 2/2; corona small.

Scutum (Plate VII, Fig. 21) approximately 1.3 times as wide as long; outline broadly rounded, posterior margin with a slight median bulge. Cervical grooves narrow, deep, converging, extending to level of anterior one third of scutal length. Punctations rare.

Integument of dorsum and venter as illustrated (Plate VII, Figs. 21, 22). Spiracular plates subovate (Plate VII, Fig. 26).

Legs (Plate VII, Figs. 21, 22, 27, 28) robust. Coxae (Plate VII, Fig. 27) each with an elongately triangular, pointed spur; that of I similar to those of adults; spurs of II and III about one-half as long, subequal; spur of IV about one-half as long as those of II and III. Trochanter I with dorsal shield (Plate VII, Fig. 21) as in adults; trochanters ventrally (Plate VII, Fig. 27) lack spurs. Tarsi (Plate VII, Fig. 28) narrow, elongate, surfaces gradually taper distally. Claws large. Pulvilli large, reach apical curvature of claws.

(d) Larva. This stage not collected.

(e) Diagnosis (Adults). A moderate-size haemaphysalid (subgenus Kaiseriana; group cornigera) (total length: male, 2.3 to 2.8 mm; female, 2.3 to 3.0 mm). Basis capituli with straight margins; cornua triangular, one-half (male) or one-third (female) as long as base. Palpi widely salient (cornigera type); male palpal segment 2 forming a large, posteriorly directed external spur from ventro-posterior margin, segment 3 with dorsal spur obsolete; female palpal segment 2 forming a short, widely triangular external spur from ventro-posterior margin, segment 3 with large, median dorsoposterior spur; dorsointernal setae number 3 (male) or 1 or 2 (female); ventrointernal setae number 5 (male, female); other palpal features essentially as in H. cornigera subspp. Hypostome narrowly elongate; dental formula (male) 5/5, denticles in files of 6 to 12, (female) 4/4, denticles in files of 12 to 14. Scutum (male) with lateral grooves obsolete; punctations moderately numerous, shallow, mixed small and medium size; (female) with L-W ratio 1:1.2, punctations as in male anteriorly. Operculum (female) simple. Spiracular plates (male) subcircular; dorsal extension elongately triangular, pointed; (female) subcircular, dorsal extension almost obsolete. Coxae (male) I with a long, narrow, pointed spur 2 times as long as wide; II with a short, widely triangular spur extending only slightly beyond coxal margin; III with a broadly rounded elevation just breaking coxal margin; IV with stationary spur similar to that of II, moveable spur long, lanceolate; (female) I with spur similar to but slightly shorter than that of male, II to IV each with a broadly triangular or rounded elevated ridge that breaks posterior margin of coxae (II, III) or extends slightly beyond it (IV). Trochanters lack ventral spurs. Femur IV with 8 (male) or 6 (female) ventrointernal setae. Tarsi (male) short, stout, dorsal surfaces abruptly narrowed, ventrally each with a strong apical hook and II to IV each with a strong subproximal, spurlike angle; (female) narrow, elongate, dorsal surfaces gradually taper, ventral surfaces almost straight, each with a very small apical or slightly subapical hook. Claws large. Pulvilli large, reach to or almost to apical curvature of claws.

(3) Haemaphysalis (Kaiseriana) susphilippensis.

(a) Male (Plate VIII, Figs. 1, 2; Plate IX, Figs. 5-12). Length from palpal apices to posterior scutal margin averages 2.6 mm

(2.3 to 2.8 mm), breadth 1.6 to 1.9 mm. Color reddish yellow.

Capitulum (Plate IX, Figs. 5-7). Basis capituli dorsally approximately 1.6 times as broad as long (including cornua); margins straight, externally indented at midlength; cornua broadly triangular, apex bluntly pointed; length slightly less than one-third that of base of basis capituli; ventrally with outline as illustrated, with three pairs of posterior setae and one pair of short posthypostomal setae. Palpi compact; combined breadth approximately 1.12 times that of basis capituli; each palpus approximately 1.4 times as long as broad. Segment one a narrow pedicle with one dorsal and one ventral seta. Segment two approximately 1.3 times as broad as long; posterior margins dorsally and ventrally forming an acute angle; external profile one-third as long as internal margin, acutely converging to anterior margin; dorsointernal and ventrointernal margins approximately straight (dorsally very slightly bulging anteriorly); setae number five dorsally, four ventrally; dorsointernal setae number two; ventrointernal setae number four. Segment three (not including dorsal spur) 0.9 times as long as 2 and broader posteroexternally (thus forming a small break in palpal profile at juncture of these segments); dorsoposterior margin typically forming a small, wide, spurlike median or submedian angle overlapping anterior margin of segment 2 (as illustrated) (this angle may also be somewhat more triangular or it may be reduced almost to the point of obsolescence); external profile and internal margin gradually converging to more or less bluntly rounded apex; ventral spur triangular, apex narrowly pointed, extending to midlength of segment 2; setae number 5 dorsally, 5 ventrally, 2 on internal margin ventrally, and a subapical group of small setae. Hypostome (Plate IX, Fig. 7) as long as palpi, approximately 2.5 times as long as broad; apex gradually rounded; corona dense, approximately one-fifth as long as denticle files; dental formula 5/5 (6/6 a single specimen from Mindanao), denticles in files of 7 to 9.

Scutum (Plate VIII, Fig. 1) with surface convex, markedly depressed externally and posteriorly, mildly rugose (more so following heavy feeding) with slightly elevated ridges posteromedianly and in area of lateral grooves and anterior festoons; outline typically 1.25 times as long as broad; broadest at level between coxa IV and spiracular plate; margins broadly rounded; scapulae blunt; anterior emargination comparatively narrow, moderately deep; small apex of spiracular plates visible or not visible from dorsal view. Lateral grooves short, do not reach scutal midlength, depth and breadth variable, sometimes obscure, do not clearly enclose any festoons. Cervical grooves as short, deep, subapical pits. Punctations usually discrete, more or less shallow, small and medium size, moderately numerous, tending to fewer anteriorly and on posteromedian and posterolateral ridges. Festoons number 11.

Venter and genital area as illustrated (Plate VIII, Fig. 2; Plate IX, Fig. 8). Spiracular plates (Plate IX, Fig. 9) small, oval; dorsal projection as a narrowly triangular elongation of plate.

Legs (Plate VIII, Figs. 1, 2; Plate IX, Figs. 10-12). Coxae (Plate IX, Fig. 10) each with a broadly triangular, approximately equilateral, spur; spurs I to III subequal, that of IV slightly smaller. Trochanter I with bluntly pointed dorsal spur (Plate VIII, Fig. 1); ventrally (Plate IX, Fig. 10) I and II with a small triangular spur or with these spurs much reduced, III and IV with more or less elevated darkened surfaces posterodistally. Femur IV with 7 ventrointernal setae each slightly more than one-half as long as diameter of femur at its site of insertion (Plate IX, Fig. 11). Tarsi (Plate IX, Fig. 12) short, stout; dorsal surfaces proximally flat or slightly humped, distally gradually or abruptly tapering; ventral surfaces each with a small or moderate-size apical or subapical hook and II to IV with a small to moderate subproximal angle. Claws moderate. Pulvilli reach almost to apical curvature of claws.

(b) Female (Plate VIII, Figs. 3, 4; Plate IX, Figs 13-20). The female differs from the male in secondary sexual characteristics but is similar to it in chief diagnostic details. Length (unengorged) approximately 2.8 mm, breadth 1.9 mm.

Capitulum (Plate IX, Figs. 13-15). Basis capituli dorsally approximately 1.8 times as broad as long (including cornua), margins straight; cornua triangular, approximately one-third as long as base of basis capituli; porose areas oval, small, tilted, distant; basis capituli ventrally as illustrated. Palpi similar to those of male but more narrowly elongate, each approximately 1.6 times as long as broad. Segment 2 with external profile two-thirds as long as inner margin, posteroexternal juncture may form a small, triangular, externally directed projection or this may be absent; anterior bulge of dorsointernal margin pronounced; setae number 3 dorsally, 3 ventrally; dorsointernal setae number 3; ventrointernal setae number 5. Segment 3 dorsally almost equal to 2 in length; dorsoposterior margin forming a small, median, triangular spur overlapping anterior margin of 2; ventral spur elongately triangular, reaching to or almost to midlength of 2 (apex frequently broken in engorged specimens); setae number 5 dorsally, 4 ventrally, and 2 on ventrointernal margin posteriorly.

Other palpal characters essentially as in male. Hypostome (Plate IX, Fig. 15) slightly longer than palpi; approximately 3.4 times as long as broad; apex bluntly rounded; corona dense, approximately one-seventh as long as denticle files; dental formula 5/5 (5.5/5.5 or 6/6 in 3 specimens), denticles in files of 10 or 11.

Scutum (Plate VIII, Fig. 3) with L-B ratio 1:1 (wider in engorged specimens) margins bluntly rounded externally, gradually rounded posteriorly; anterior emargination shallow, broad. Cervical grooves as deep, narrow, elongate, subapical pits followed by shallow, diverging grooves extending to posterior one third of scutal length. Punctations shallow, large and medium size, moderately numerous, fewer in anteromedian field.

Genital operculum (Plate IX, Fig. 16) simple, broadly V-shaped (easily distorted in engorged specimens). Spiracular plates (Plate IX, Fig. 17) broadly oval; dorsal projection obsolete.

Legs (Plate VIII, Figs 3, 4; Plate IX, Figs. 18-20) approximately as in male. Coxae (Plate IX, Fig. 18) with spurs smaller than those of male, on II and III reduced to broadly triangular spurs extending only slightly beyond posterior margin of coxae. Trochanters ventrally (Plate IX, Fig. 18) with small spur present or absent on I, absent on II to IV. Femur IV (Plate IX, Fig. 19) with 7 ventrointernal setae. Tarsi and claws (Plate IX, Fig. 20) as in male except that tarsi are moderately elongate and subproximal angles of ventral surfaces are obscure or obsolete. Pulvilli reach to apical curvature of claws.

(c) Nymph and larva. These stages not collected.

(d) Diagnosis (Adults). A moderate-size haemaphysalid (subgenus Kaiseriana), total length: male, 2.6 (2.3 to 2.8) mm; female, 2.8 mm. Basis capituli dorsally 1.6 (male) or 1.8 (female) times as broad as long; cornua broadly triangular, slightly less than (male) or approximately (female) one-third as long as base of basis capituli; porose areas (female) oval, small, tilted, distant. Palpi compact, combined breadth approximately 1.12 times that of basis capituli, each 1.4 (male) or 1.6 (female) times as long as broad; segment 2 with posterior margins dorsally and ventrally forming an acute angle; dorso-internal setae number 2 (male) or 3 (female); ventrointernal setae number 4 (male) or 5 (female); segment 3 with dorsoposterior margin typically forming a small, wide, spurlike median or submedian angle overlapping anterior margin of segment 2 (angle may be triangular or much reduced), and with ventral spur triangular (male) or elongately triangular (female), extending to or almost to midlength of segment 2. Hypostome 2.5 (male) or 3.4 (female) times as long as broad, dental formulae 5/5 (rarely 6/6), denticles in files of 7 to 9 (male) or 10 or 11 (female). Scutum (male) with surface convex, mildly rugose, depressed externally and posteriorly; outline typically 1.25 times as long as broad; margins broadly rounded; lateral grooves short, variable in depth and breadth; cervical grooves as small subapical pits; punctations usually discrete, more or less shallow, small and medium size, moderately numerous, irregularly distributed. Scutum (female) with L:B ratio 1:1; margins bluntly rounded externally, gradually rounded posteriorly; cervical grooves as deep, elongate pits followed by shallow, diverging grooves extending to posterior one third of scutal length; punctations shallow, large and medium size, moderately numerous. Genital operculum (female) simple, broadly V-shaped. Spiracular plates (male) small, oval, dorsal projection as a narrowly triangular elongation, or (female) broadly oval with no dorsal projection. Coxae each with a broadly triangular, approximately equilateral spur, except II and III of female, on which spurs are shorter and more broadly triangular. Trochanters I and II with a poorly or well developed short, triangular spur. Tarsi (male) short, stout; (female) moderately elongate; ventrally with an apical or subapical hook and II to IV (male) with a small to moderate subproximal angle. Pulvilli reach almost to (male) or to (female) apical curvature of claws.

CHAPTER V

SUMMARY AND CONCLUSIONS

The objectives of the study reported here were to obtain from general preliminary surveys an indication of the species composition, wild vertebrate host associations and geographic distribution of ticks on Luzon Island, Republic of the Philippines. From this study basic biological and ecological information in broad outline form was obtained. This information should be of value in connection with the planning and conduct of detailed ecogeographic surveys to obtain qualitative and quantitative information on the biological and environmental factors having a determining and influencing effect on the distribution of specific species. Information derived from this study should also be of value in the conduct of planned future studies to determine the disease transmission capabilities of selected Philippine tick species.

A total of 4,079 ticks, representing 18 species and nine genera, were collected from wild vertebrates in 16 provinces of Luzon Island where samplings were made between April 1965 and May 1969. These species are listed below in descending order based on the number of tick species taken from each subdivision of vertebrates: *Amblyomma helvolum*, *Haemaphysalis luzonensis*, *Amblyomma javanense*, *Haemaphysalis psalistos*, *Haemaphysalis susphilippensis*, *Ornithodoros batuensis*, *Dermacentor auratus*-complex, *Ixodes granulatus*, *Haemaphysalis papuana*, *Argas pusillus*, *Aponomma fimbriatum*, *Haemaphysalis doenitzi*, Rhipicephalus haemaphysaloides pilans, Haemaphysalis rusae, Boophilus microplus, Haemaphysalis ornithophila, Aponomma ecinctum and Haemaphysalis gigas. These specimens are available either in the U. S. Air Force Fifth Epidemiological Laboratory Museum, Manila, Philippines, or the U. S. Naval Medical Research Unit No. Three Museum, Cairo, Egypt.

Amblyomma helvolum and Haemaphysalis luzonensis comprised 40 percent of the total collections from all of the wild vertebrates examined. Amblyomma helvolum was the most prevalent species collected and was found predominantly on species of forest-dwelling rodents. This species represented slightly over 20 percent of the total collections. Of the eight haemaphysalid species collected, Haemaphysalis luzonensis was the most prevalent and was found predominantly on deer and wild boar. This species ranked number two in total numbers collected or slightly under 20 percent of the total collections. Amblyomma helvolum was by far the most widely distributed species. This species was found parasitizing rodents in all of the 16 provinces included in this study.

Of the 18 tick species collected, three new species were discovered: Haemaphysalis luzonensis, Haemaphysalis psalistos and Haemaphysalis susphilippensis.

Haemaphysalis (Kaiseriana) luzonensis is described from 493 adults, nymphs and larvae taken from Luzon deer, Cervus (Rusa) philippinus Smith and wild boar, Sus celebensis philippensis Nehring, in Nueva Ecija and Quezon Provinces of Luzon Island. This tick species inhabits vertebrates living in Dipterocarp forests at altitudes between 1800 and 3000 feet in the Sierra Madre Mountain Range. Rains in this area occur each month of the year. Males, females, and usually nymphs, were feeding during each of the following six months between October 1966 and

August 1967 when deer and boar were examined on six mountains: October, January, February, April, June and August. During May of 1968 larvae were found feeding on forest-dwelling species of rodents in Nueva Ecija Province and on feral domestic cats in Tarlac Province. The glossy, almost apunctate, Haemaphysalis luzonensis is closely related to H. lagrangei Larrousse of Vietnam and H. neumanni Donitz of Japan and continental northeastern Asia.

Haemaphysalis (Kaiseriana) psalistos is described from 48 males, females and nymphs taken from Luzon deer and wild boar in Nueva Ecija and Quezon Provinces of Luzon at altitudes between 1800 and 3000 feet in the Sierra Madre Mountain Range where Dipterocarp forest gives way to Benguet pine. All collections of feeding males and females were made during December, January and May. A member of the Haemaphysalis (Kaiseriana) cornigera group, which ranges from Ceylon, India, Nepal to Indonesia, Australia, Taiwan and Japan, this new species is readily distinguished by the much reduced stationary spur of the male coxa IV and also by capitular features. The second, apparently movable, lanceolate spur of the male coxa IV, a unique feature of the cornigera group, is well developed.

Haemaphysalis (Kaiseriana) susphilippensis is described from 68 adults taken from Luzon deer and wild boar in Nueva Ecija Province at altitudes between 1800 and 3000 feet in the Sierra Madre Mountain Range during the months of February, April, June, August and November, 1967. This tick species is a member of the Oriental-Papuan forest boar and tapir-parasitizing papuensis group. This species, with a 5/5 dental formula in both sexes, is easily distinguished from related species with a 4/4 dental formula, i.e., Haemaphysalis (Kaiseriana) nadchatrami

Hoogstraal, Trapido and Kohls; Haemaphysalis (Kaiseriana) kinneari Warburton and Haemaphysalis (Kaiseriana) papuana Thorell. The female operculum of these three species is rectangular rather than broadly V-shaped.

In addition to the above new species, Haemaphysalis doenitzi, H. gigas and H. ornithophila are reported for the first time in the Philippine Islands. The following species, in addition to the above six listed species, are reported from Luzon Island for the first time: Amblyomma helvolum, A. javanense, Aponomma fimbriatum, Argas pusillus, Dermacentor auratus-group, Haemaphysalis rusae, Ixodes granulatus, Ornithodoros batuensis and Rhipicephalus haemaphysaloides pilans.

A total of 3,718 wild vertebrates, representing 69 species, were examined for ticks. Of this number, 653 individual hosts representing 29 species, were infested with ticks, i.e., a 17.5 percent overall infestation rate. Species of forest-dwelling rodents were the most commonly parasitized host and one or more of nine species were found infested with ticks in all of the 16 provincial areas included in the study.

In addition to deer, wild boar and rats, the following wild vertebrates were also examined and found infested with ticks: bats (five species), birds (nine species), carnivores (two species) and reptiles (two species).

Representative specimens of wild vertebrate host material are stored as follows:

Birds - Division of Geographic Pathology, U. S. Armed Forces Institute of Pathology, Tokyo, Japan; U. S. Air Force Fifth Epidemiological Laboratory and Philippine National Museum.

Bats - U. S. Fifth Epidemiological Laboratory; Virus Research Laboratory, Silliman University, Dumaguete City, Negros Oriental, Philippines, and Philippine National Museum.

Rodents - U. S. Fifth Epidemiological Laboratory and Philippine National Museum.

Carnivores - Philippine National Museum.

Deer and wild boar - Philippine National Museum.

Reptiles - Philippine National Museum.

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APPENDIX

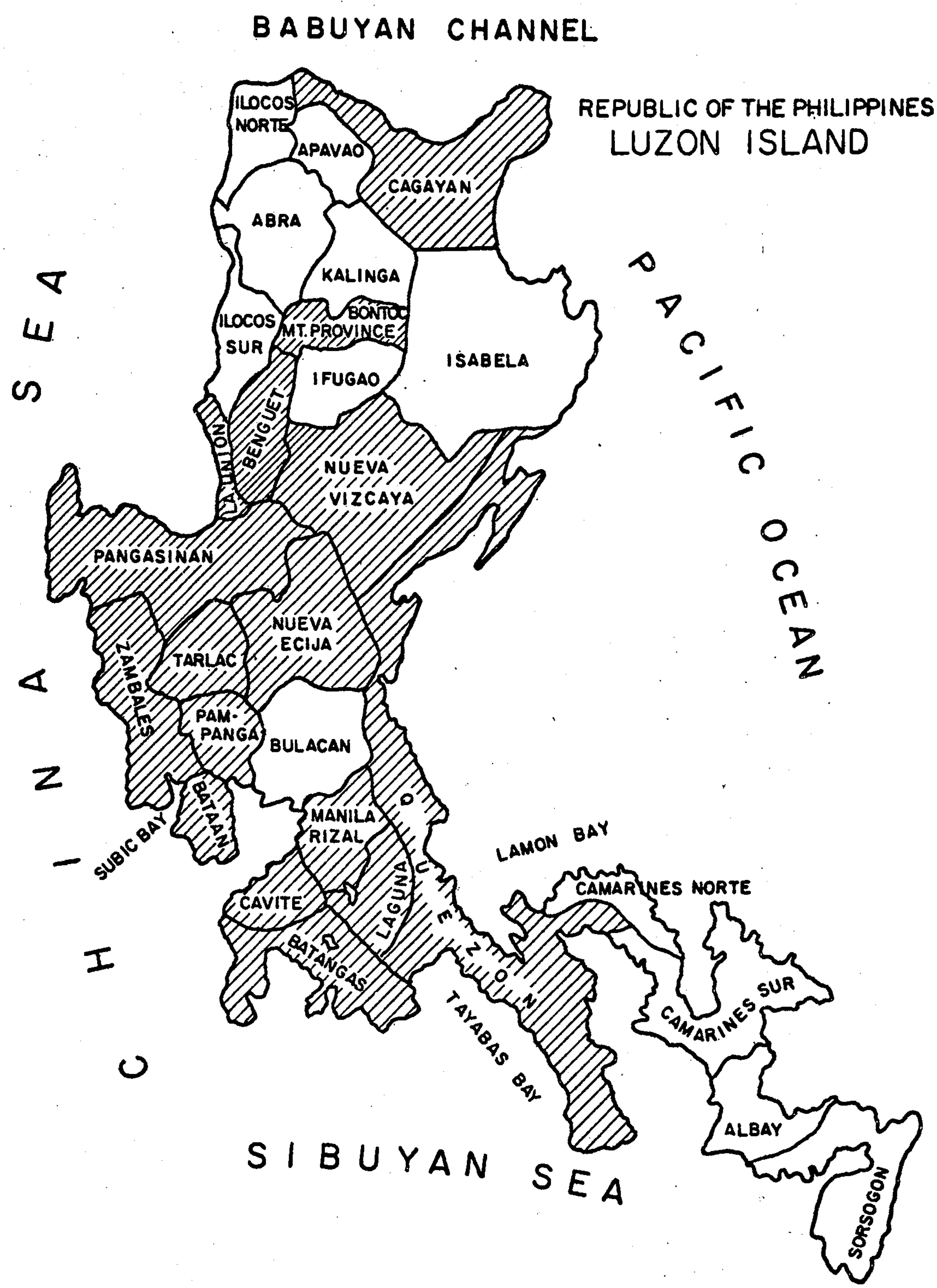


Figure 1. Map of Luzon Island, Philippines, showing the provinces where tick collections were made.

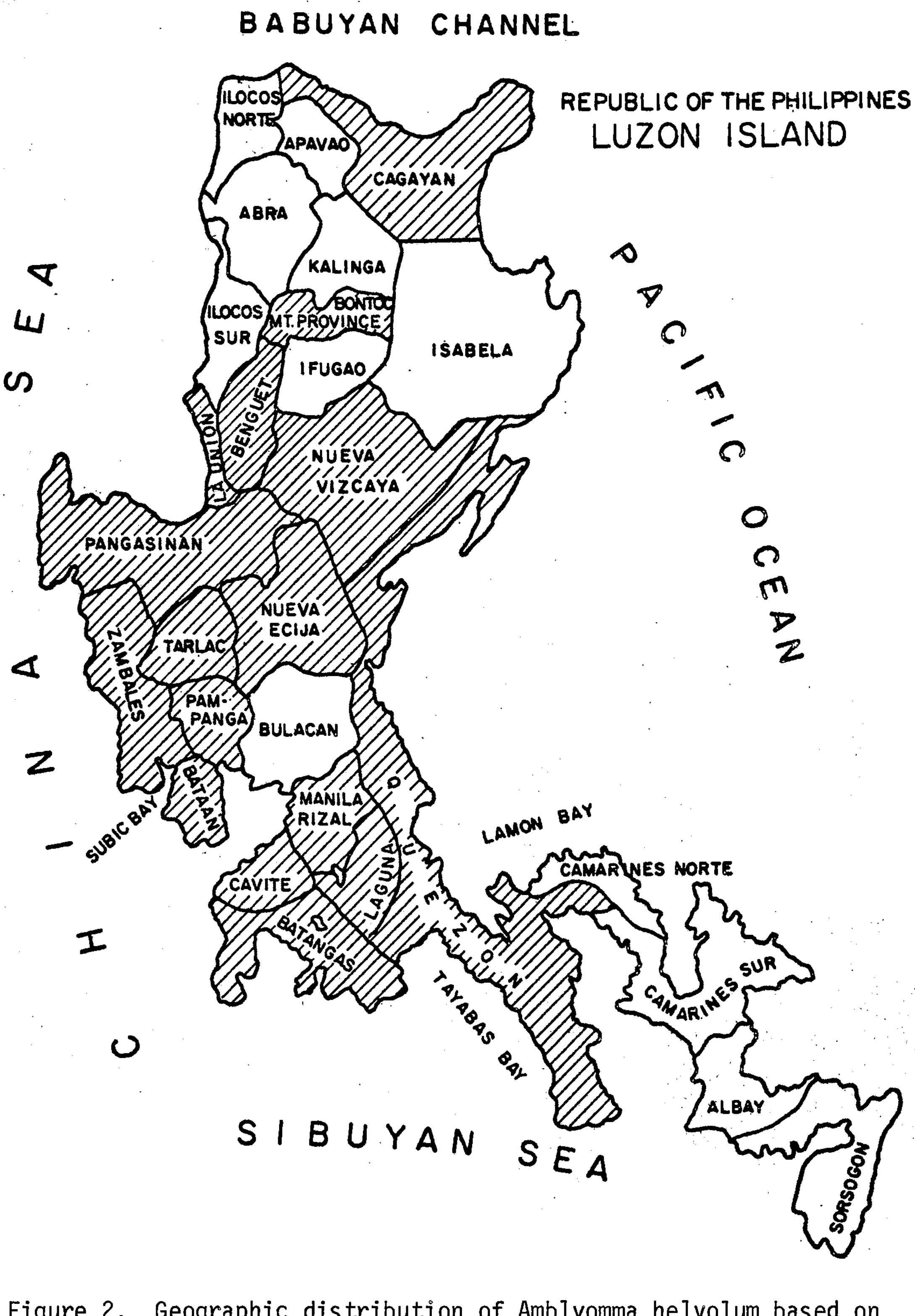


Figure 2. Geographic distribution of Amblyomma helvolum based on collections from wild vertebrate hosts, 1965-1969.

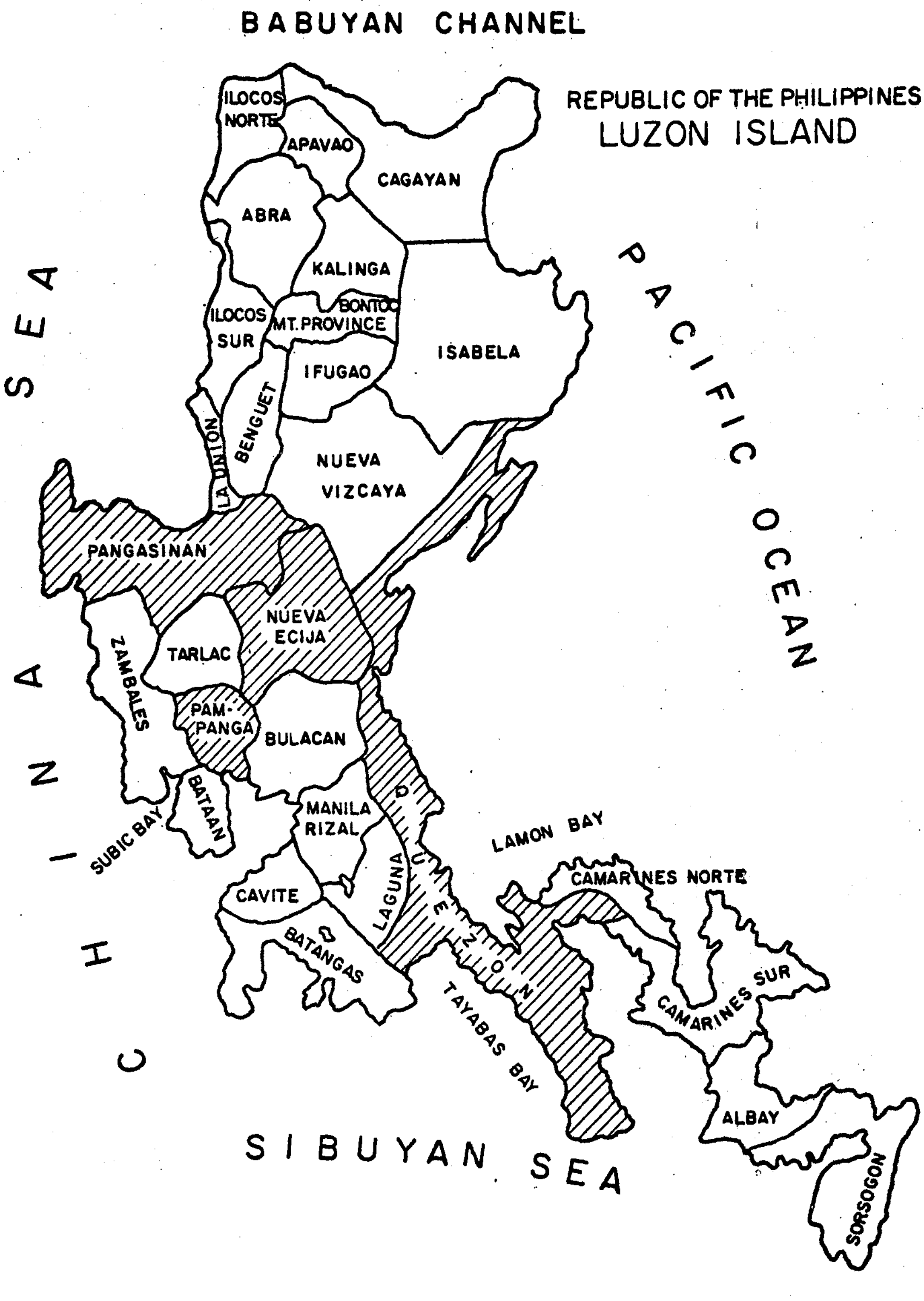


Figure 3. Geographic distribution of Amblyomma javanense based on collections from wild vertebrate hosts, 1965-1969.

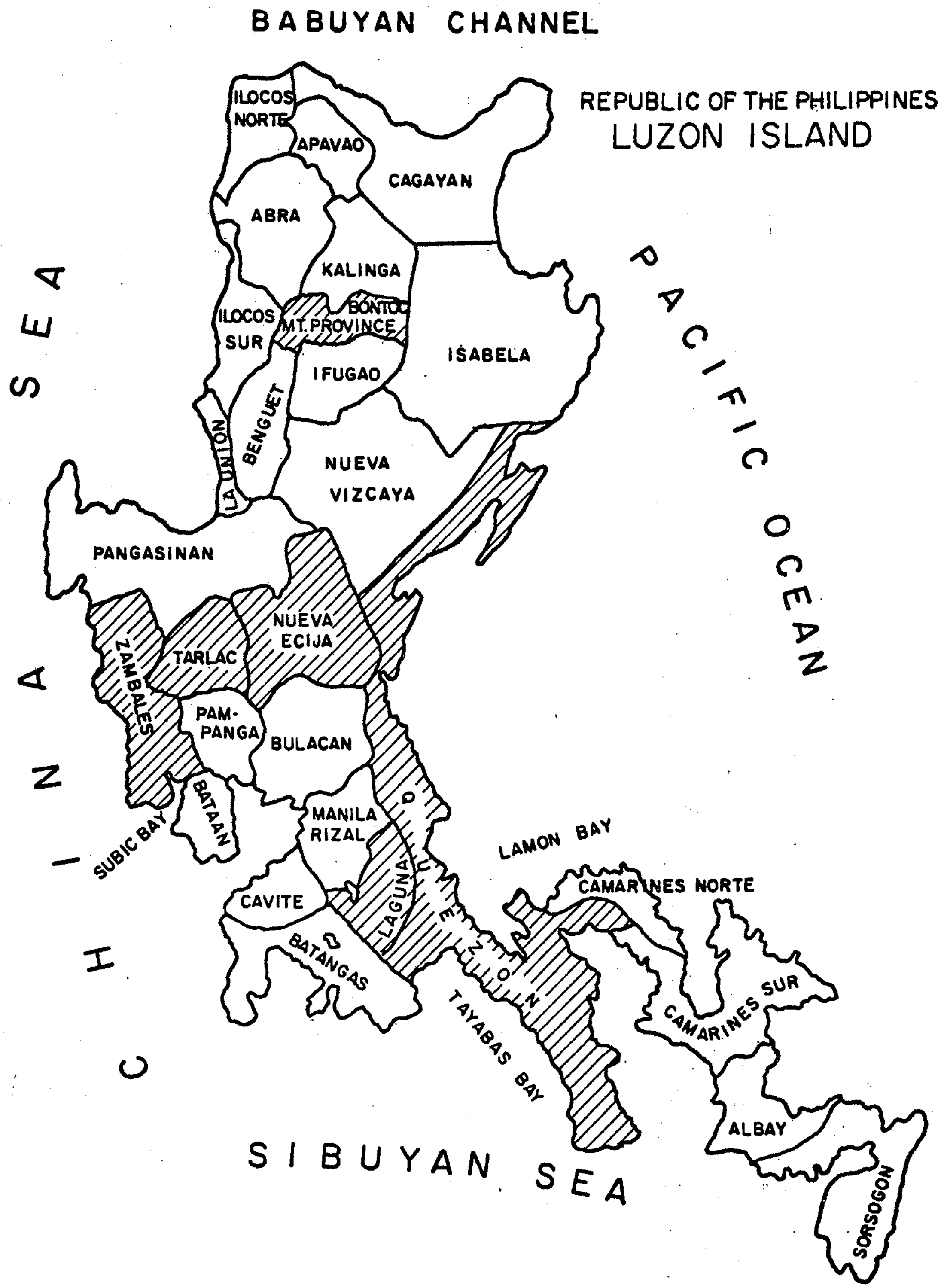


Figure 4. Geographic distribution of Aponomma fimbriatum based on collections from wild vertebrate hosts, 1965-1969.

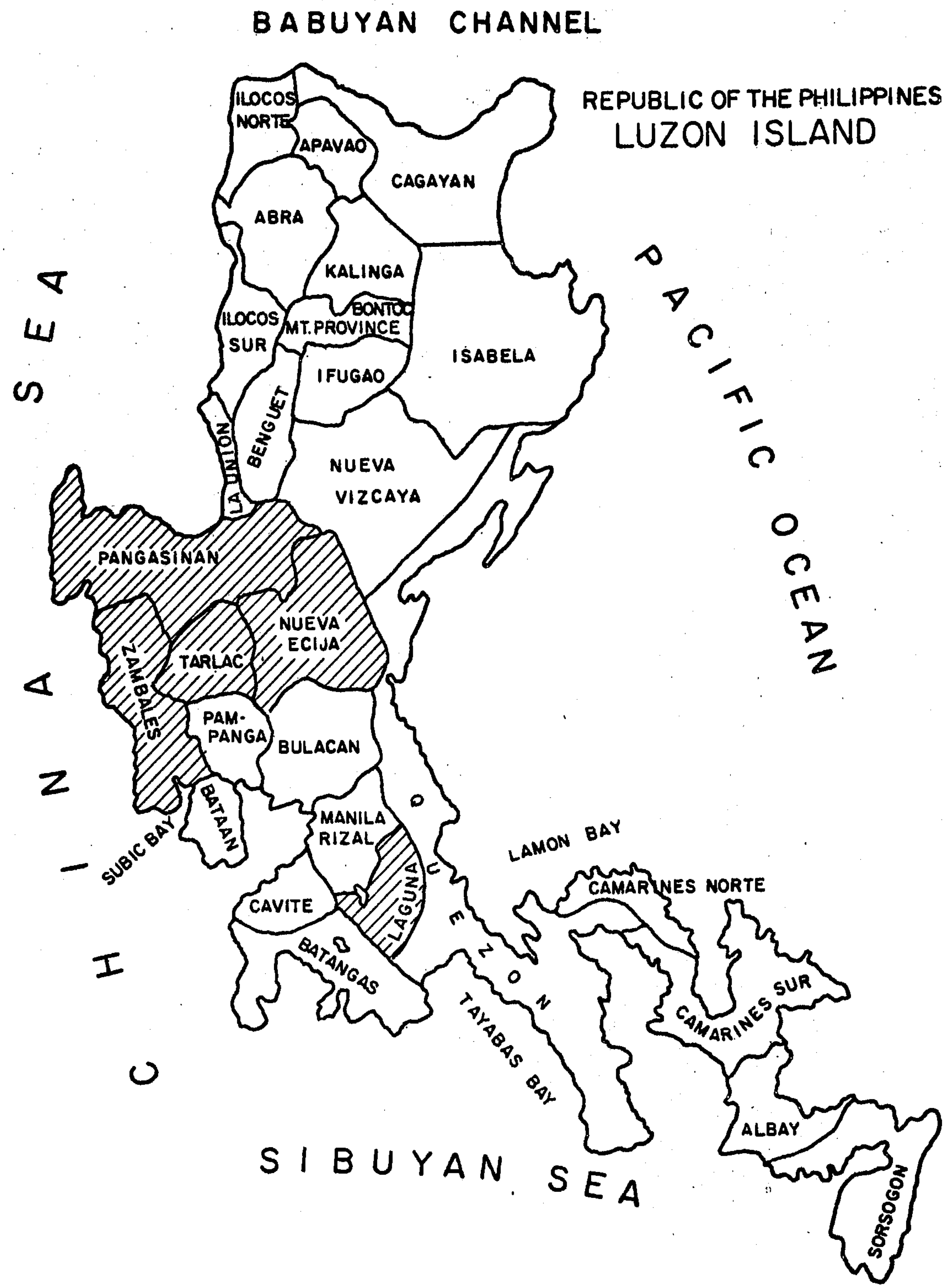


Figure 5. Geographic distribution of Aponomma ecinctum based on collections from wild vertebrate hosts, 1965-1969.

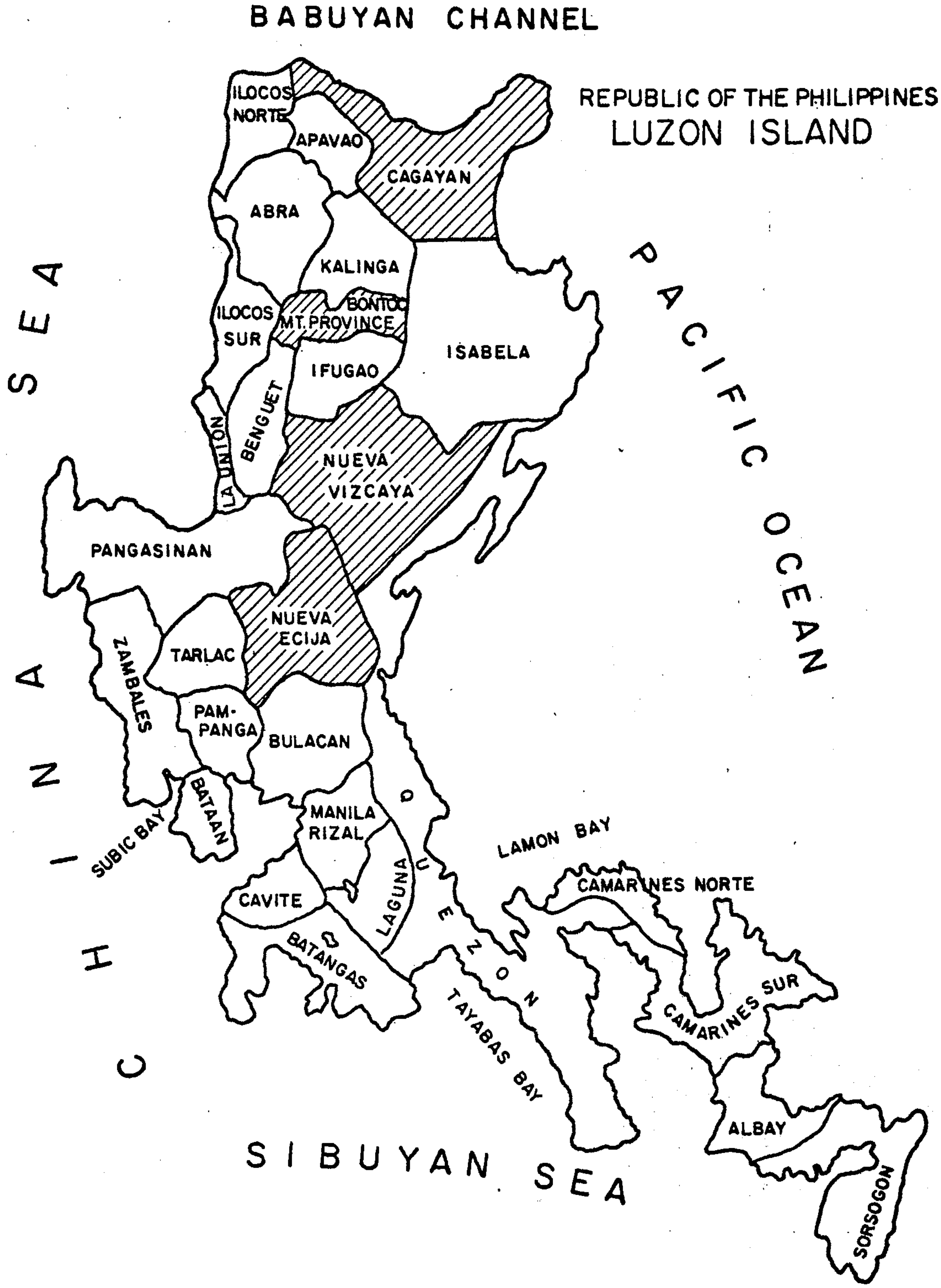


Figure 6. Geographic distribution of Argas pusillus based on collections from wild vertebrate hosts, 1965-1969.

Figure 7. Geographic distribution of Boophilus microplus based on collections from wild vertebrate hosts, 1965-1969.

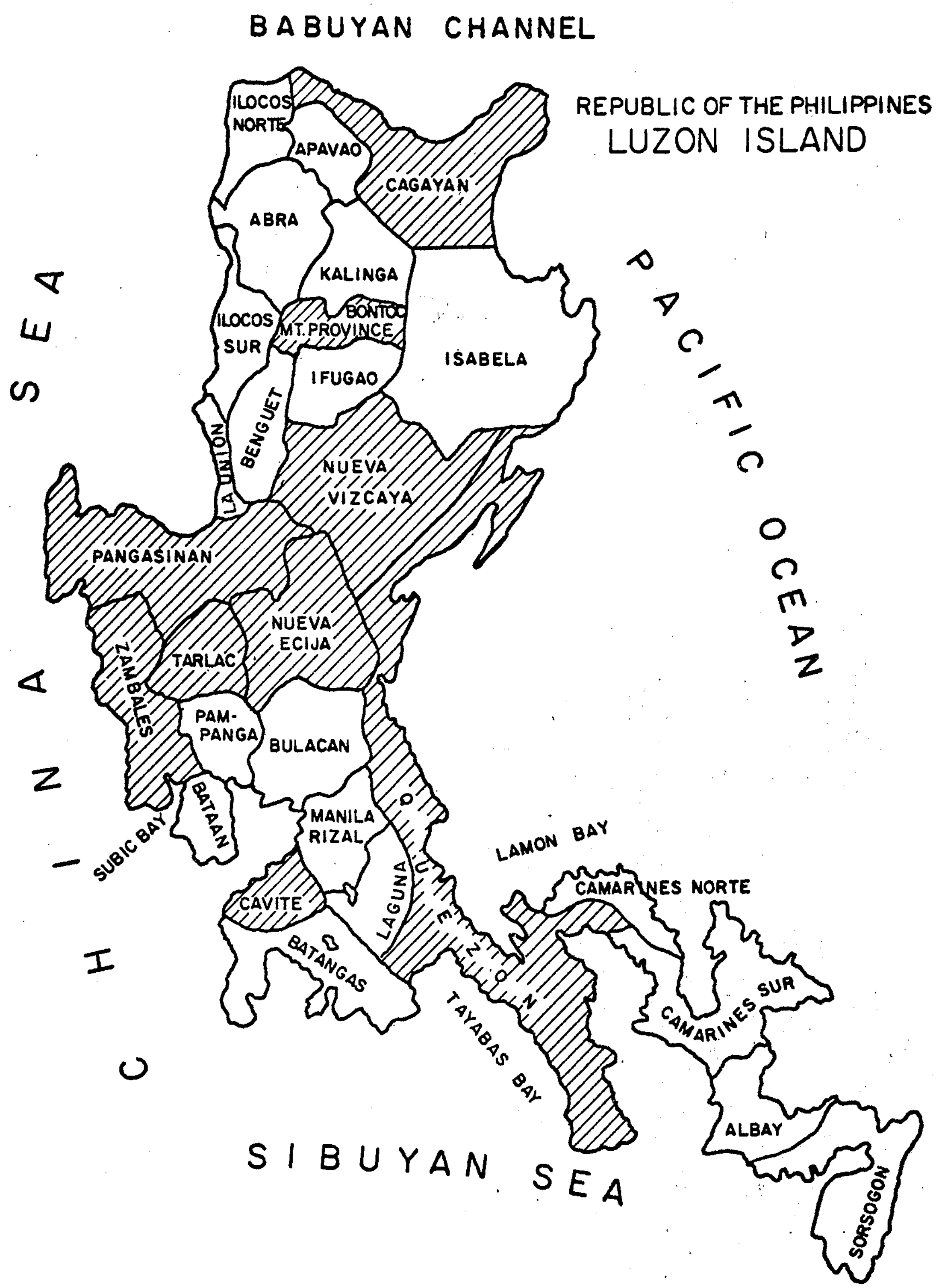


Figure 8. Geographic distribution of Dermacentor auratus complex based on collections from wild vertebrate hosts, 1965-1969.

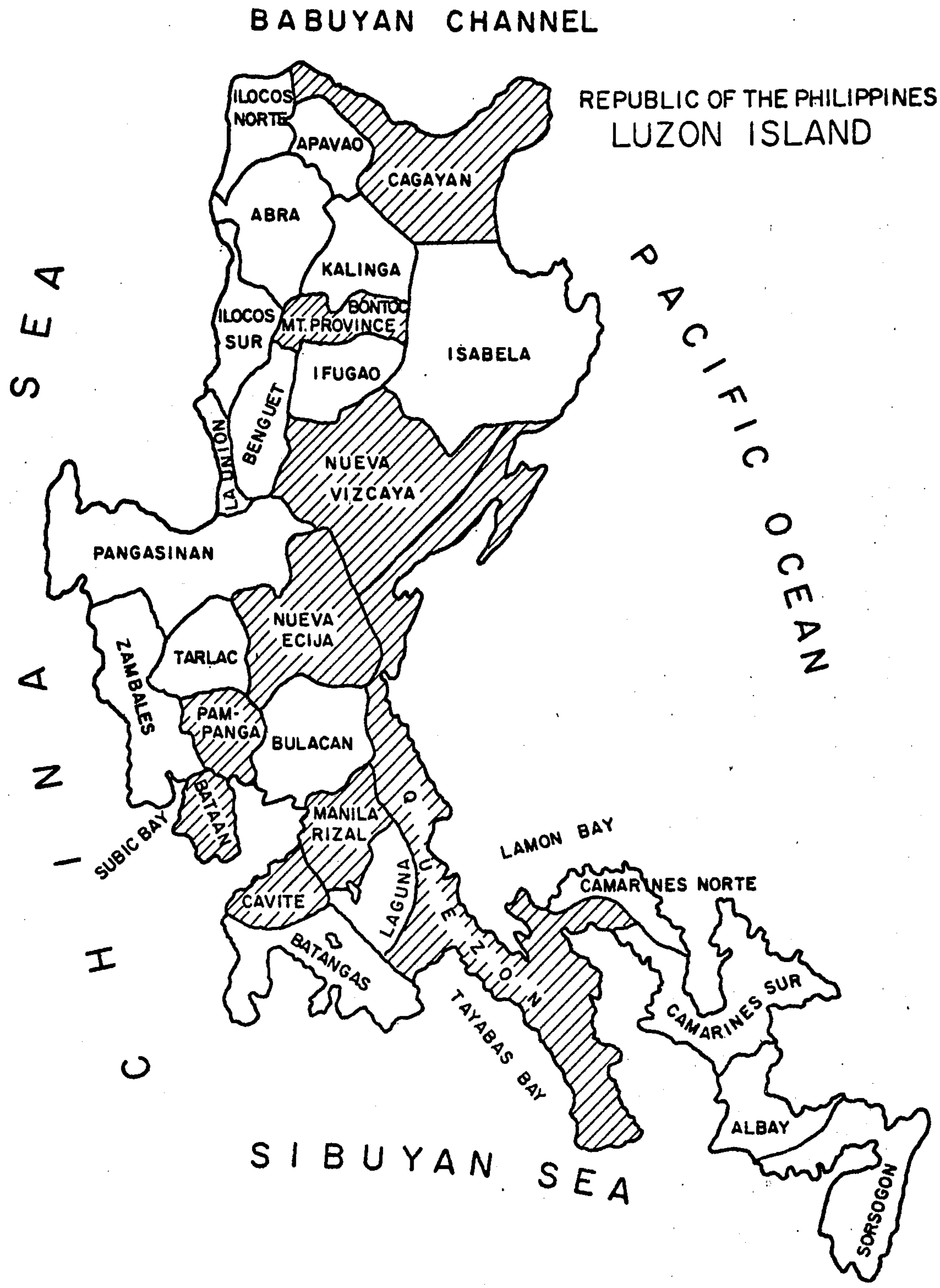


Figure 9. Geographic distribution of Haemaphysalis doenitzi based on collections from wild vertebrate hosts, 1965-1969.

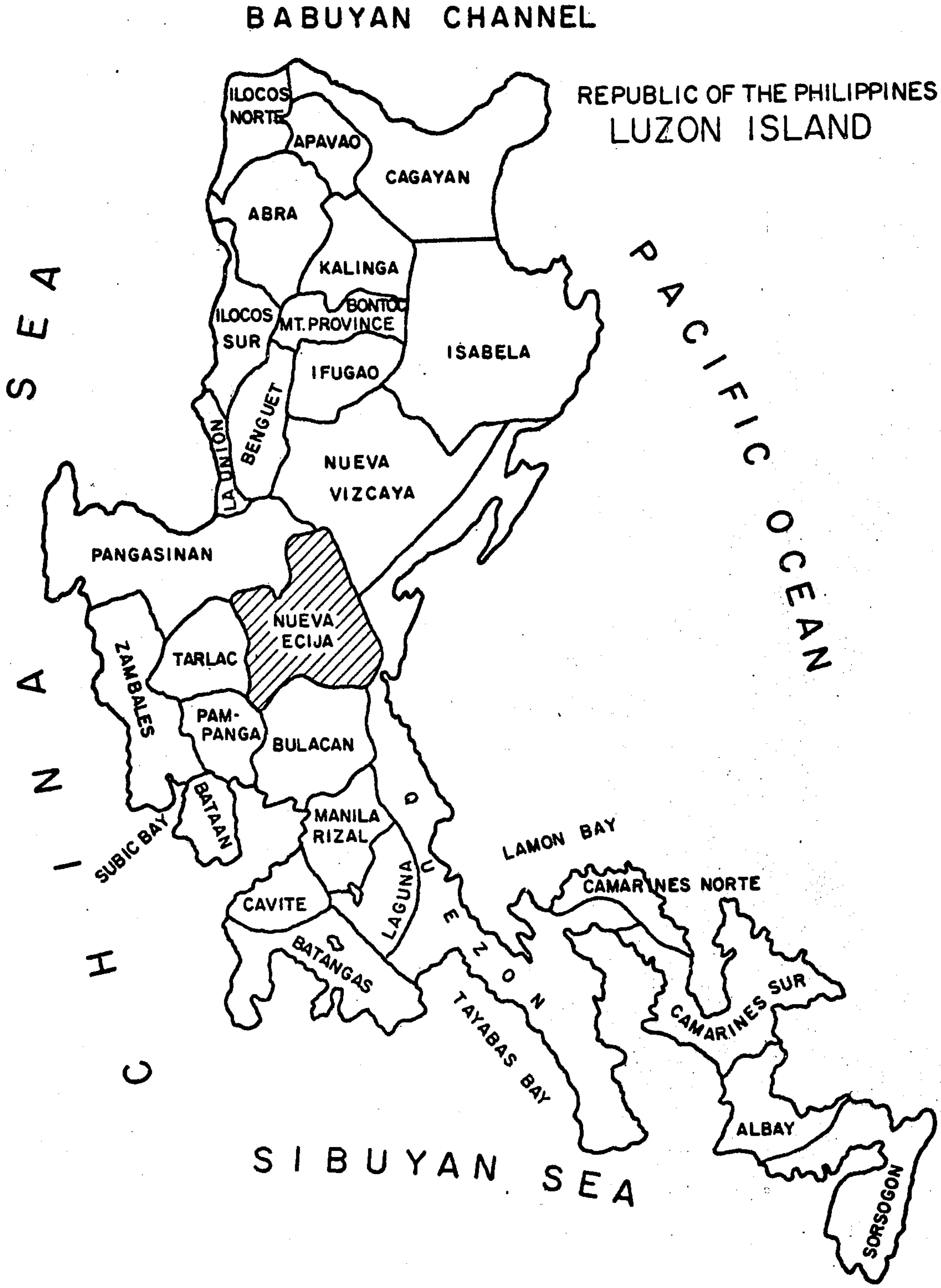


Figure 10. Geographic distribution of Haemaphysalis gigas based on collections from wild vertebrate hosts, 1965-1969.

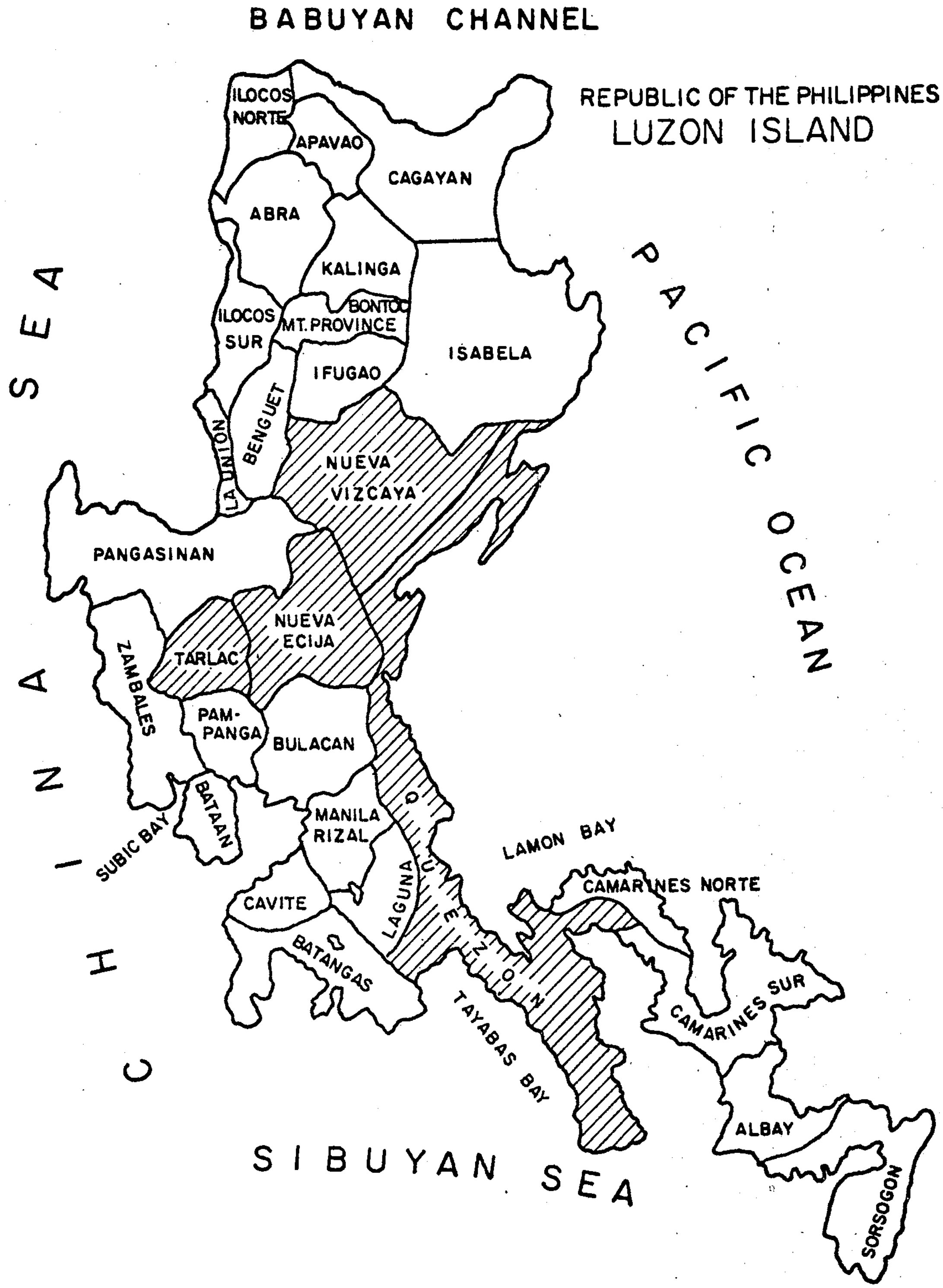


Figure 11. Geographic distribution of Haemaphysalis luzonensis based on collections from wild vertebrate hosts, 1965-1969.

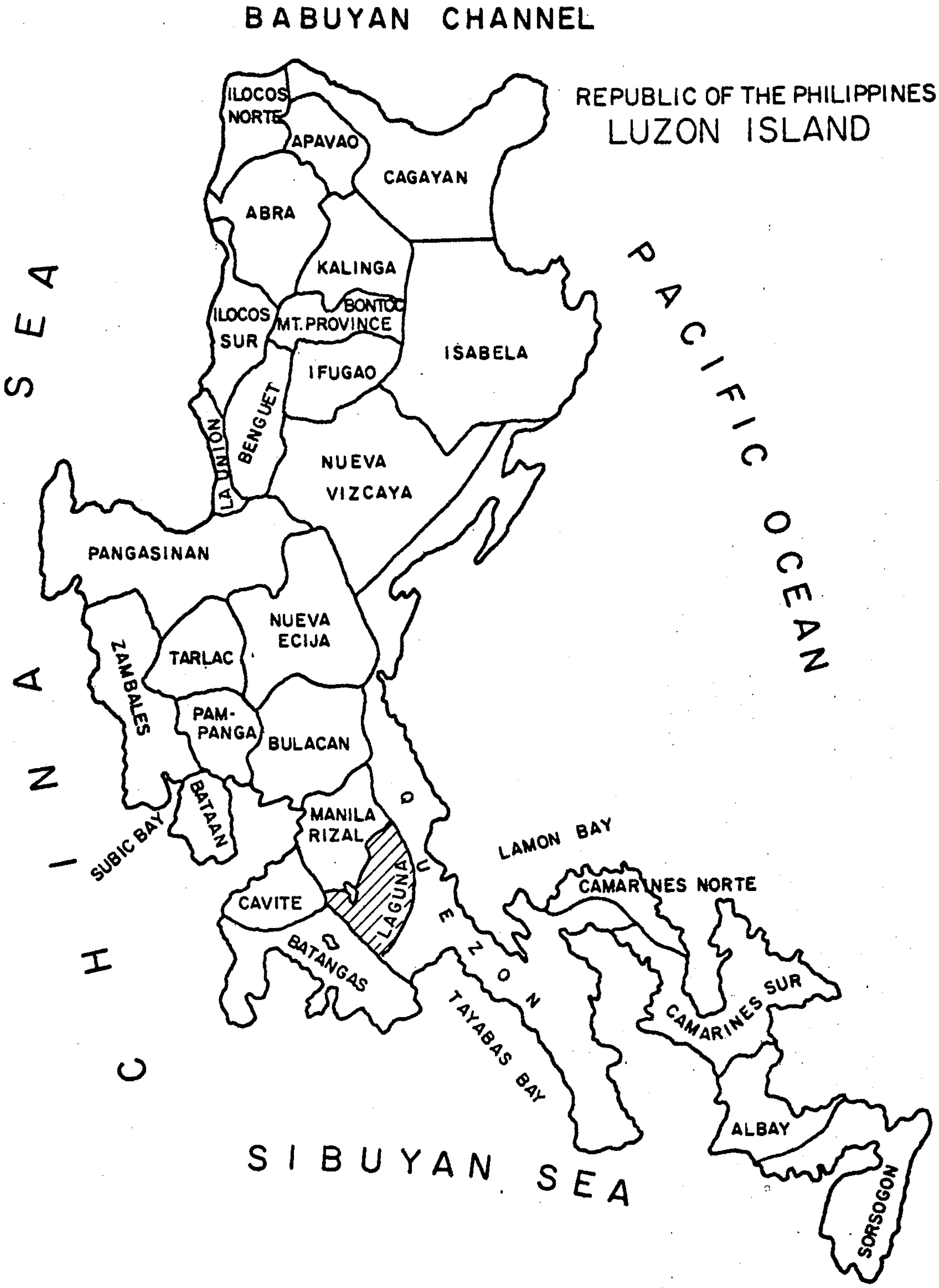


Figure 12. Geographic distribution of Haemaphysalis ornithophila based on collections from wild vertebrate hosts, 1965-1969.

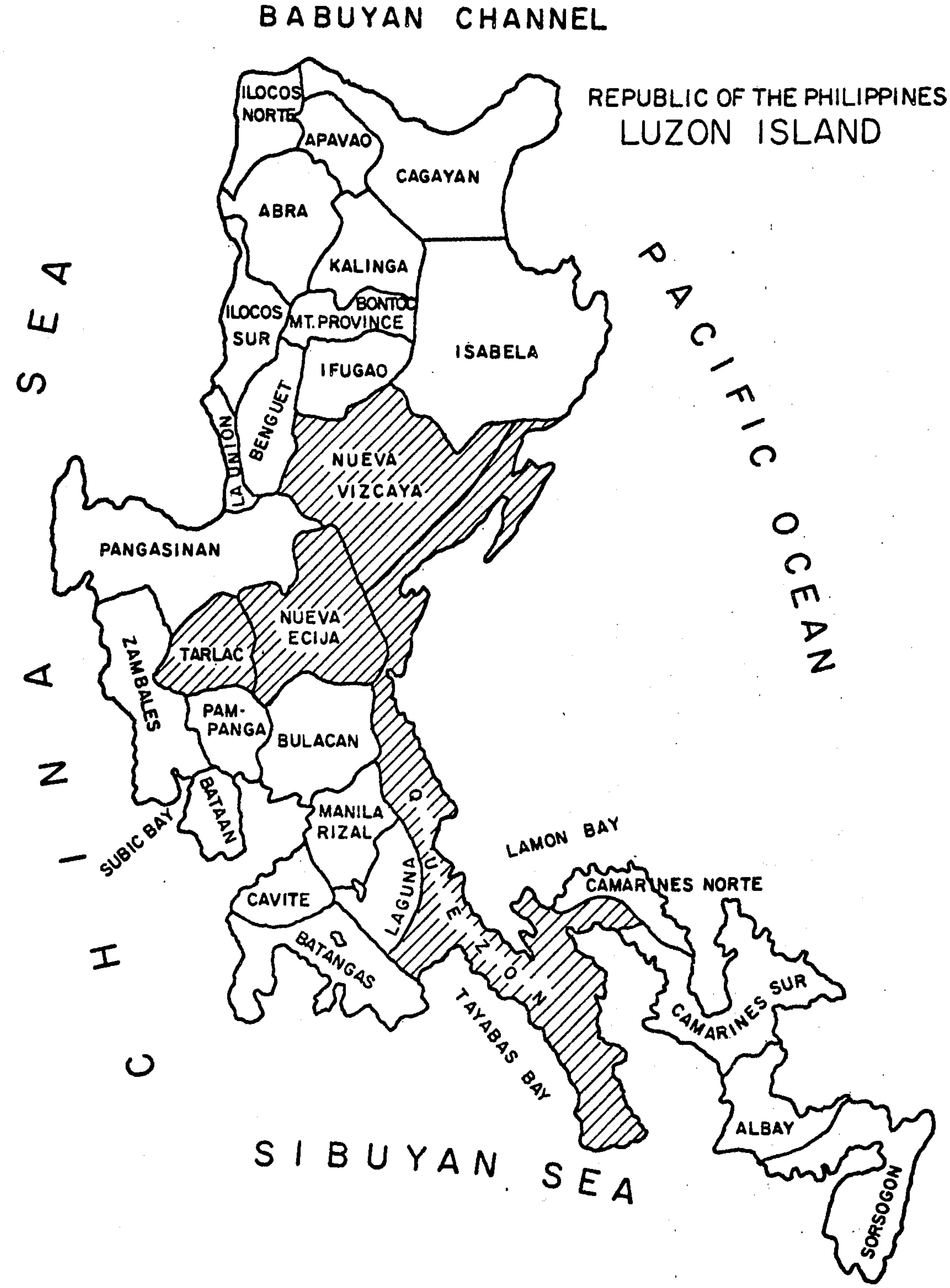


Figure 13. Geographic distribution of *Haemaphysalis papuana* based on collections from wild vertebrate hosts, 1965-1969.

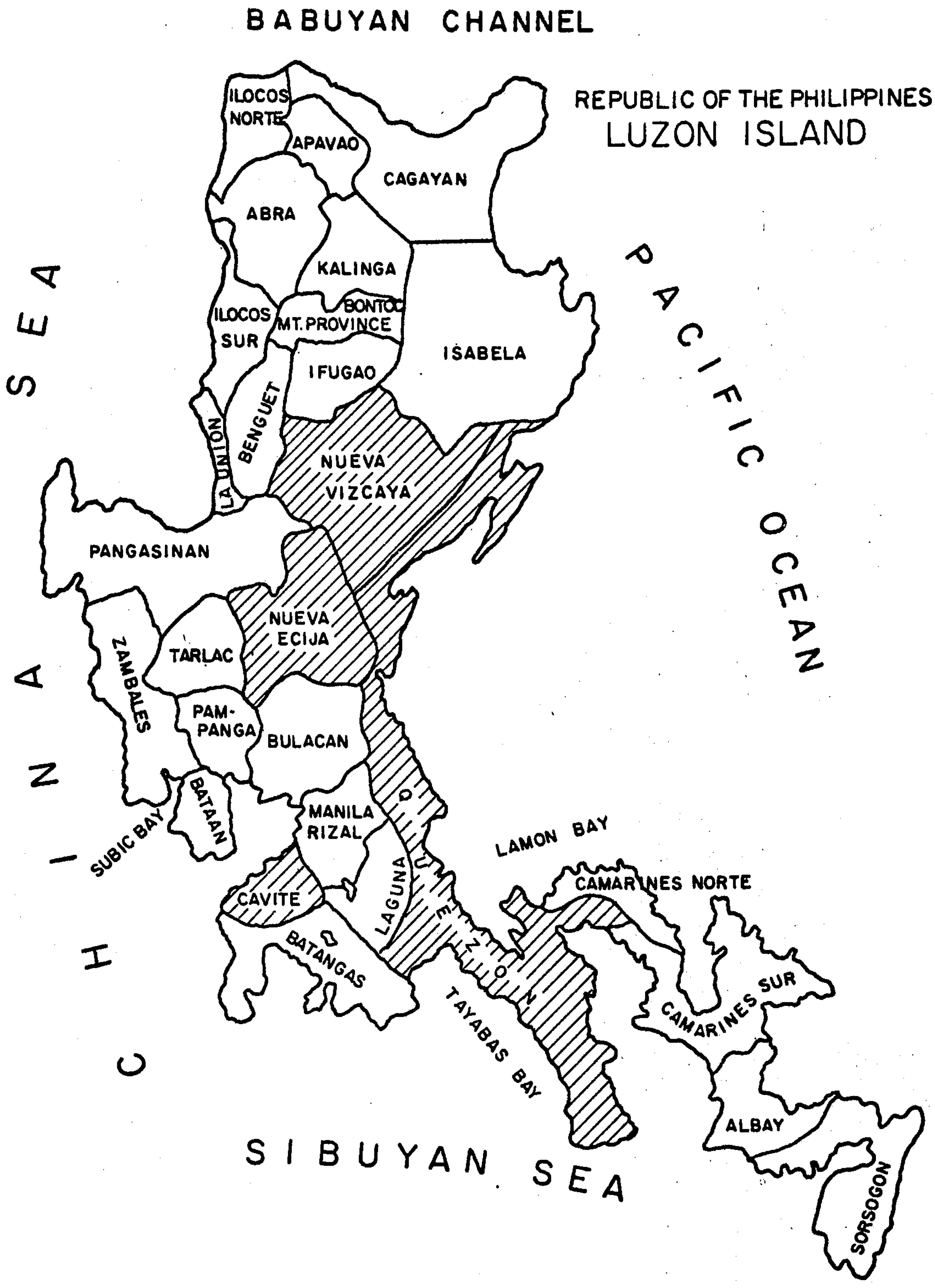


Figure 14. Geographic distribution of <u>Haemaphysalis psalistos</u> based on collections from wild vertebrate hosts, 1965-1969.

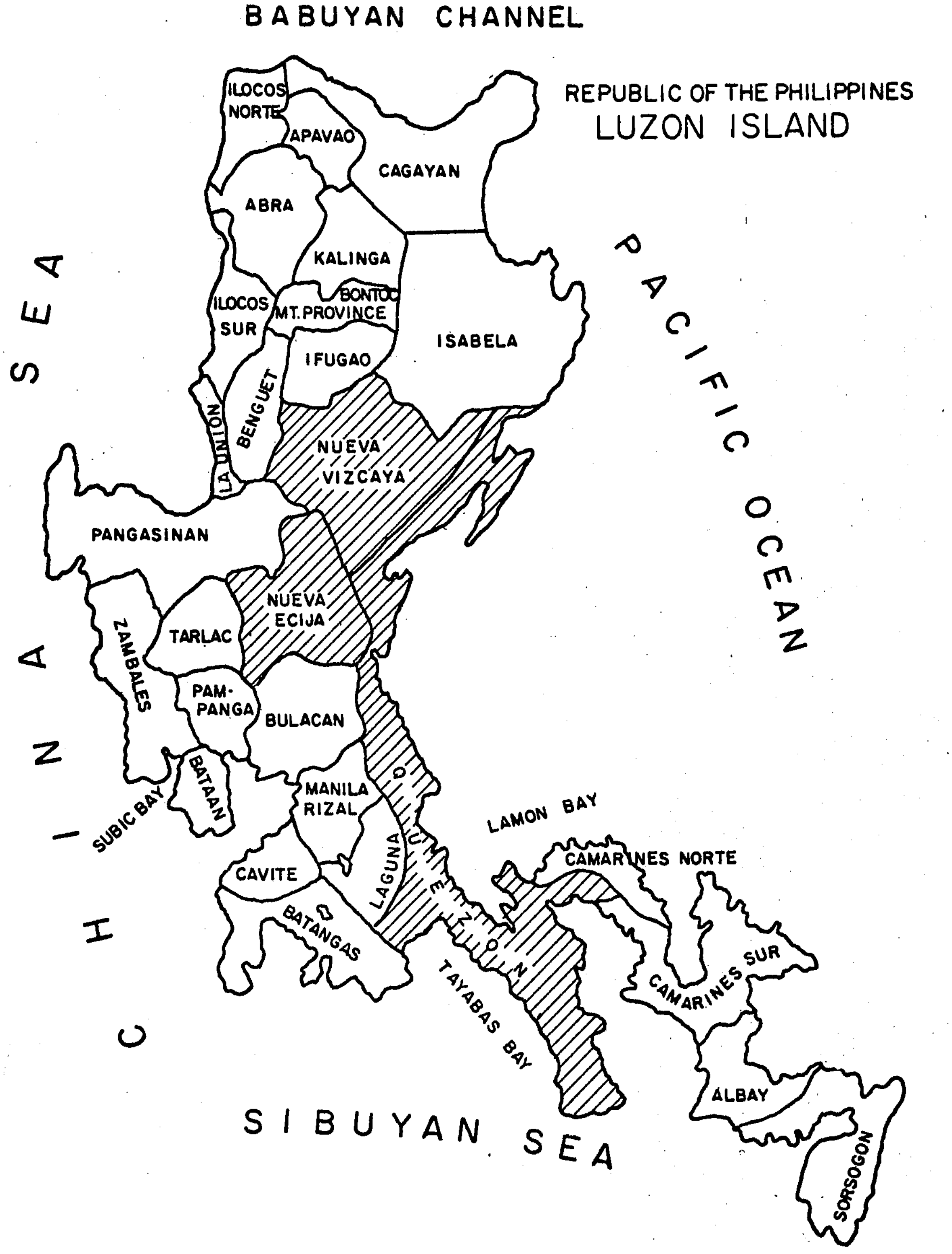


Figure 15. Geographic distribution of Haemaphysalis rusae based on collections from wild vertebrate hosts, 1965-1969.

Figure 16. Geographic distribution of Haemaphysalis susphilippensis based on collections from wild vertebrate hosts, 1965-1969.

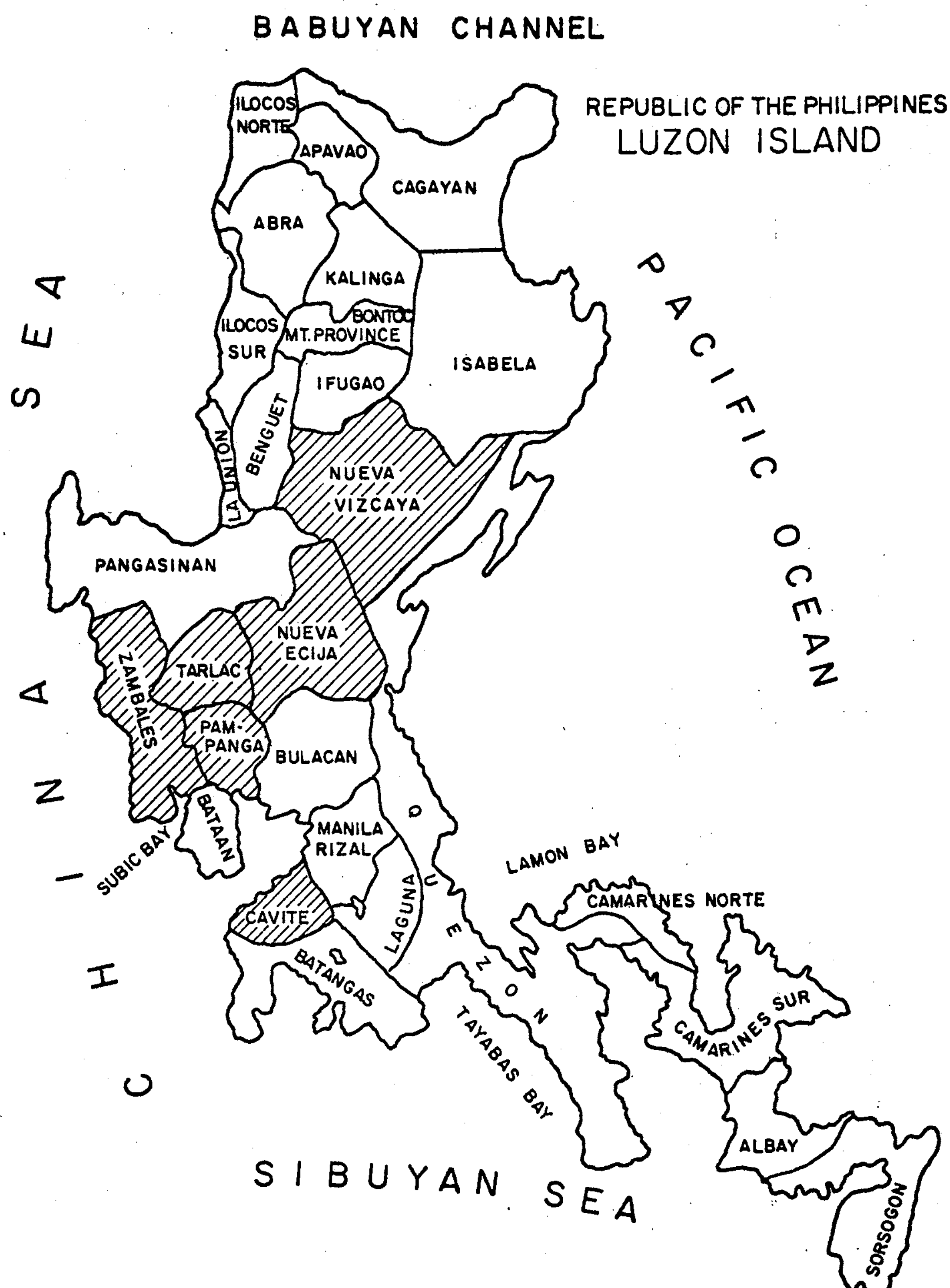


Figure 17. Geographic distribution of Ixodes granulatus based on collections from wild vertebrate hosts, 1965-1969.

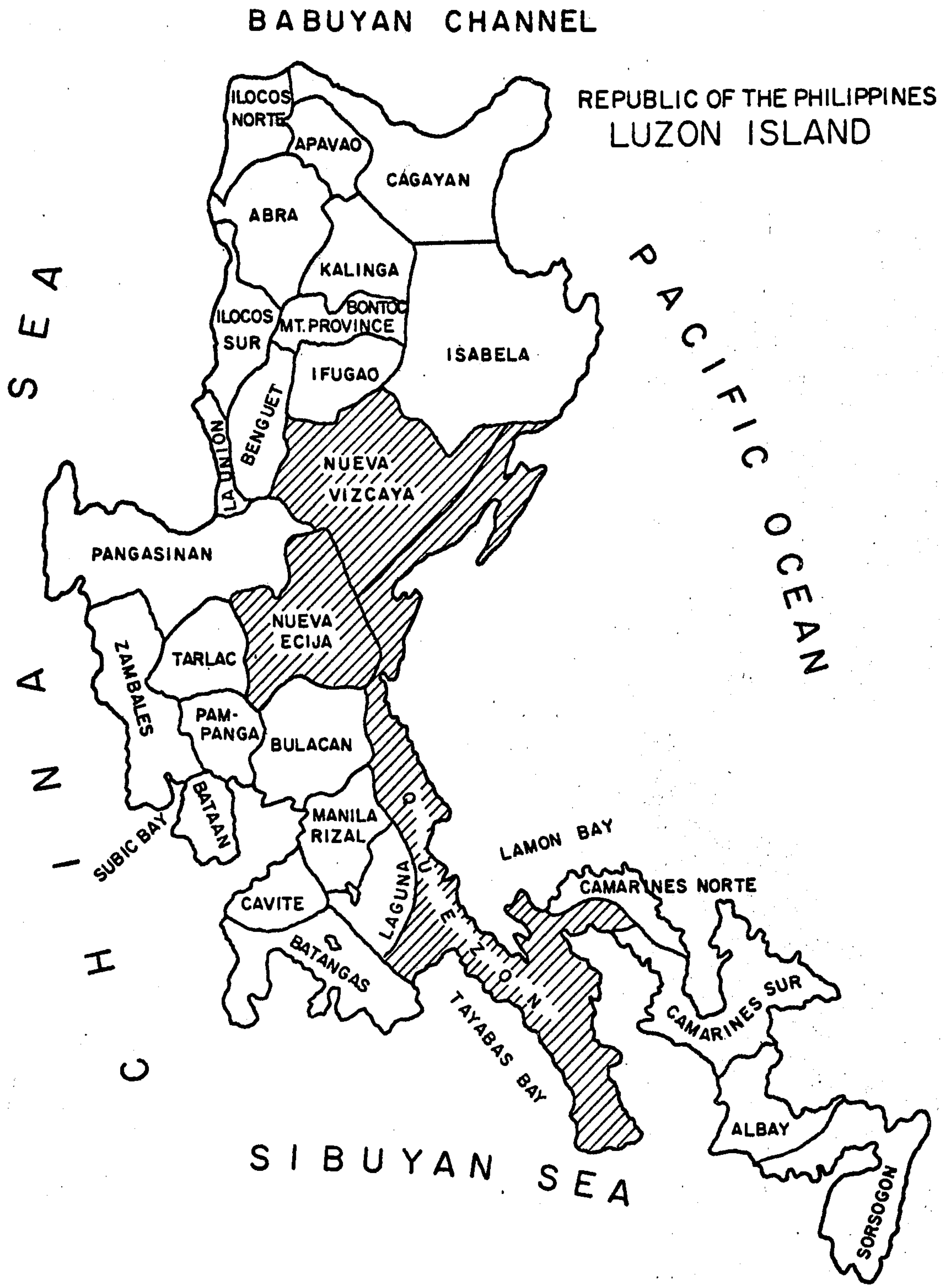


Figure 18. Geographic distribution of _Ornithodoros batuensis_ based on collections from wild vertebrate hosts, 1965-1969.

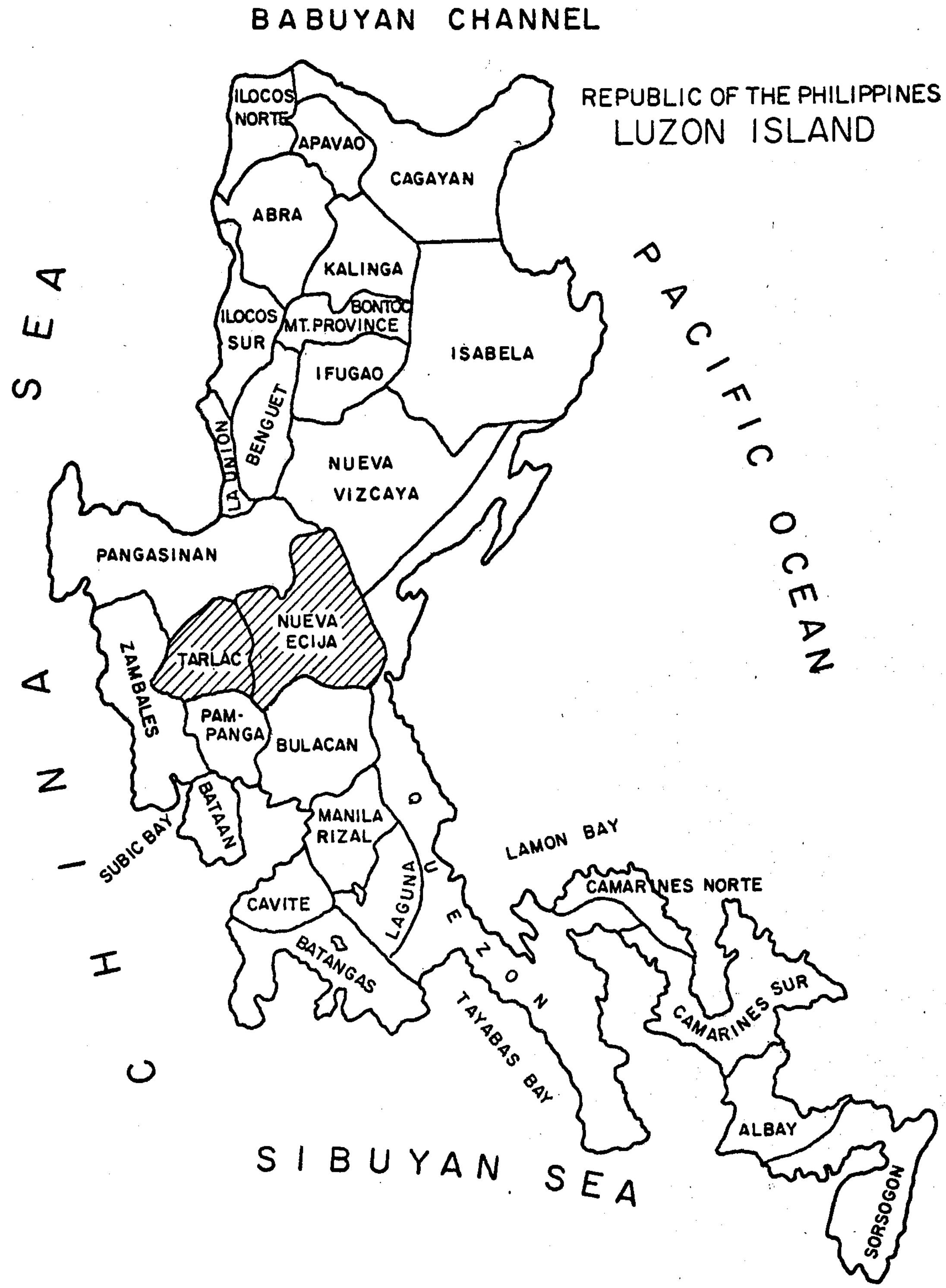


Figure 19. Geographic distribution of Rhipicephalus haemaphysaloides pilans based on collections from wild vertebrate hosts, 1965-1969.

PLATE I

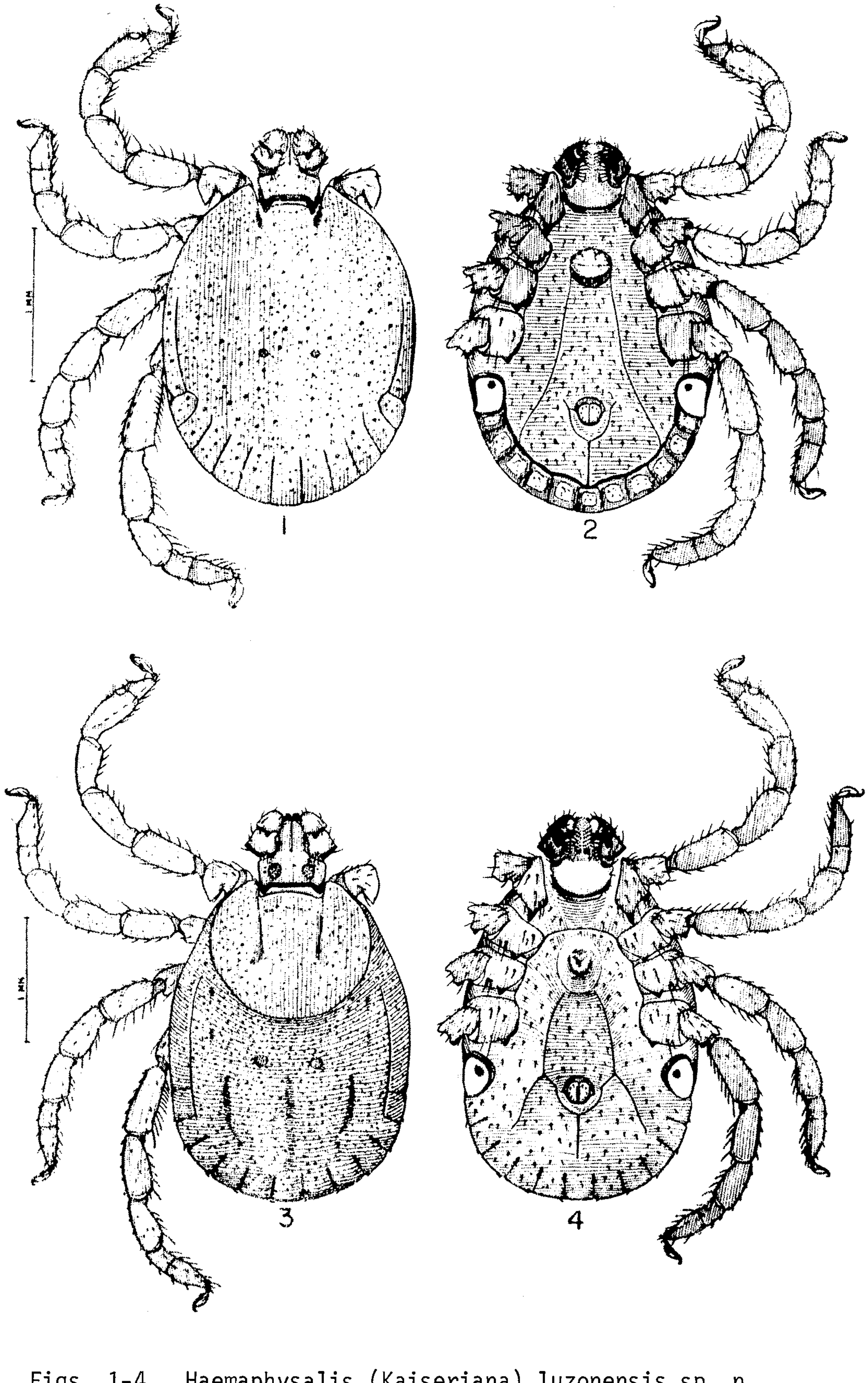
Figs. 1-4. Haemaphysalis (Kaiseriana) luzonensis sp. n.

Fig. 1. Dorsal view of male.

Fig. 2. Ventral view of male.

Fig. 3. Dorsal view of female.

Fig. 4. Ventral view of female.



Figs. 1-4. Haemaphysalis (Kaiseriana) luzonensis sp. n.

PLATE II

Figs. 5-20. Haemaphysalis (K.) luzonensis sp. n.

Fig. 5. Male capitulum, dorsal view.

Fig. 6. Male capitulum, ventral view.

Fig. 7. Male hypostome, ventral view.

Fig. 8. Male genital area.

Fig. 9. Male spiracular plate (A = anterior; D = dorsal).

Fig. 10. Male coxae and trochanters I to IV.

Fig. 11. Male femur IV, internal view.

Fig. 12. Male tarsi I to IV, external view.

Fig. 13. Female capitulum, dorsal view.

Fig. 14. Female capitulum, ventral view.

Fig. 15. Female hypostome, ventral view.

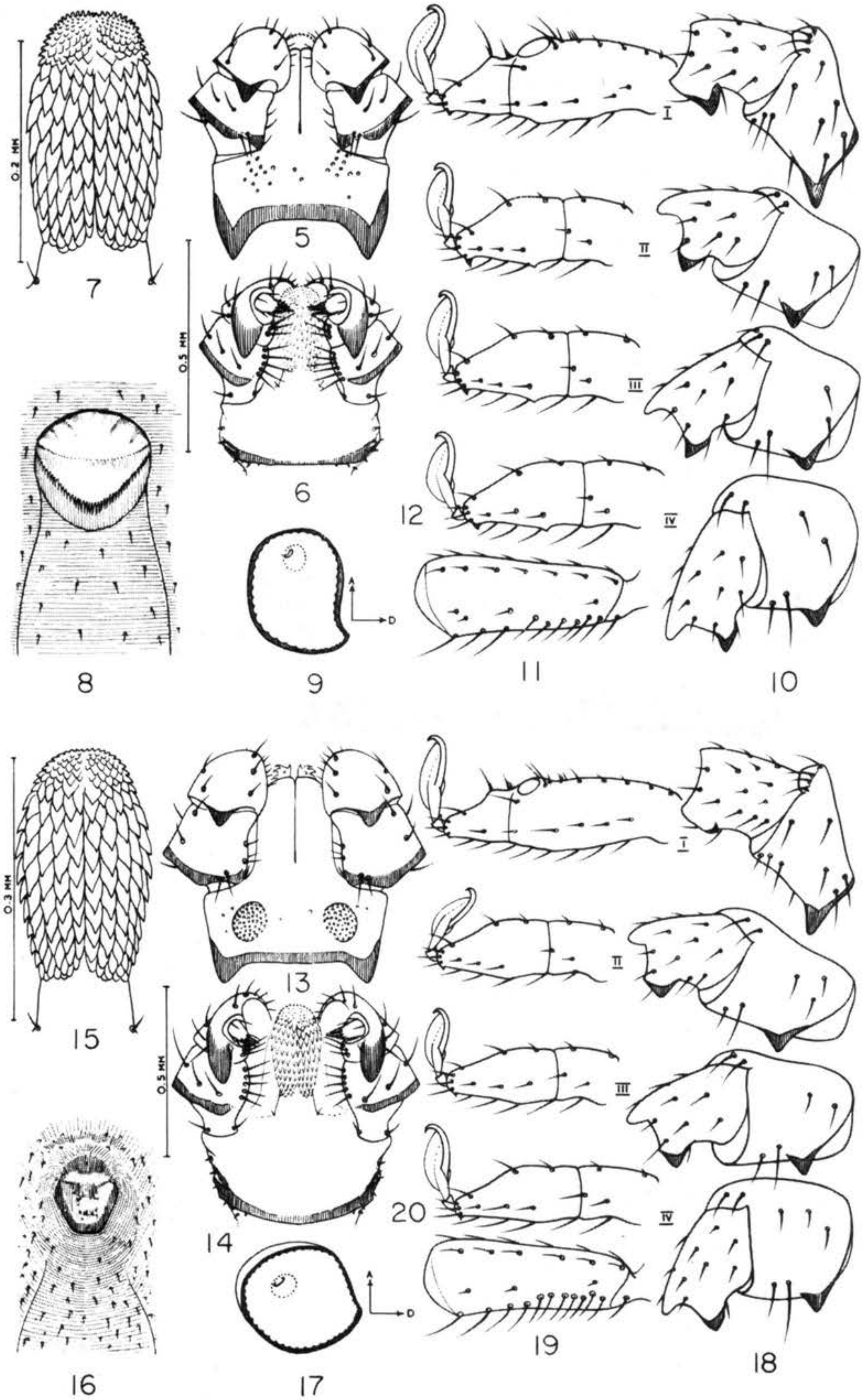
Fig. 16. Female genital area.

Fig. 17. Female spiracular plate.

Fig. 18. Female coxae and trochanters I to IV.

Fig. 19. Female femur IV, internal view.

Fig. 20. Female tarsi I to IV, external view.



Figs. 5-20. Haemaphysalis (K.) luzonensis sp. n.

PLATE III

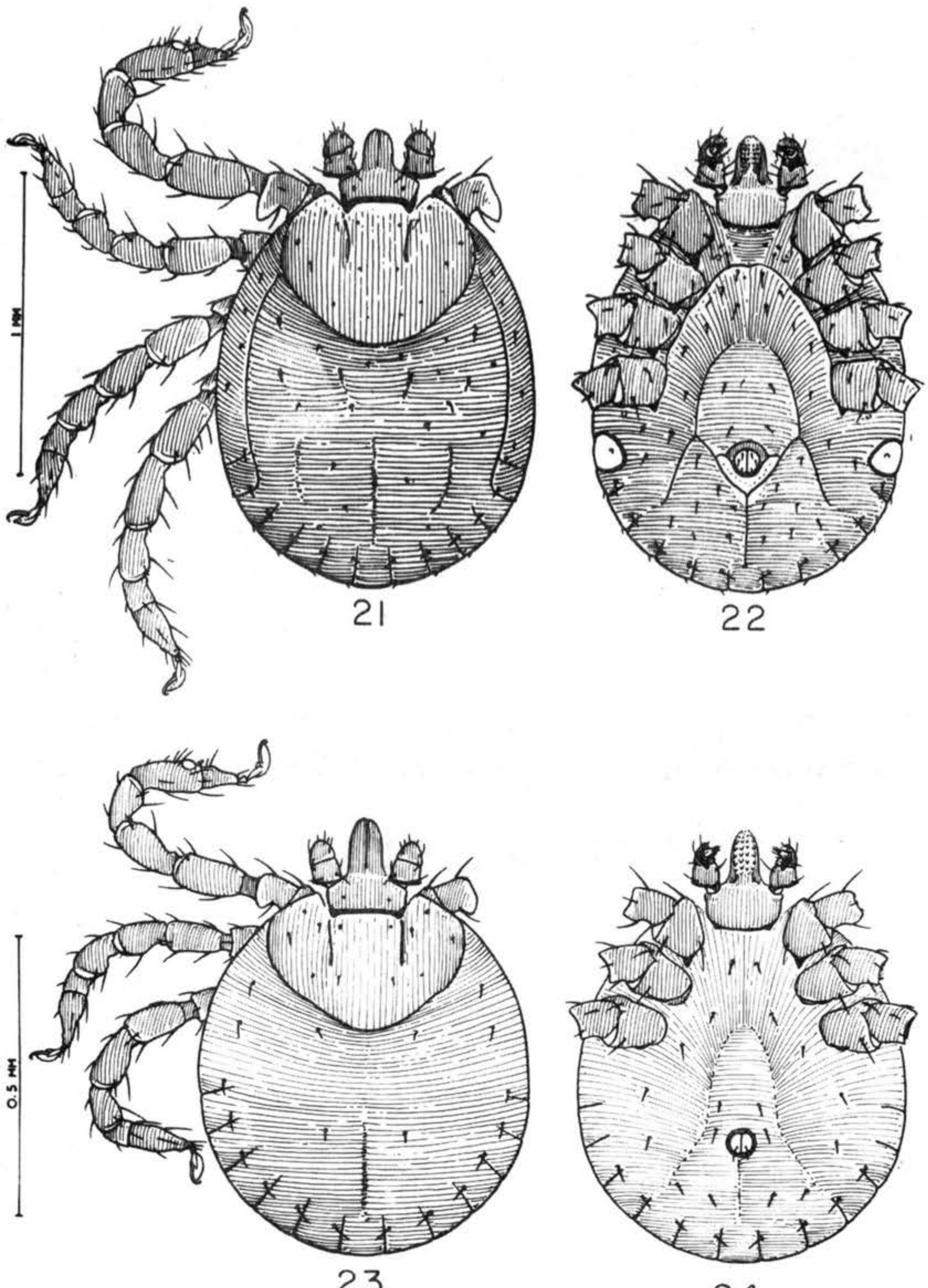
Figs. 21-24. *Haemaphysalis* (*K.*) *luzonensis* sp. n.

Fig. 21. Nymph (slightly engorged), dorsal view.

Fig. 22. Nymph (slightly engorged), ventral view.

Fig. 23. Larva (slightly engorged), dorsal view.

Fig. 24. Larva (slightly engorged), ventral view.



Figs. 21-24. Haemaphysalis (K.) luzonensis sp. n.

PLATE IV

Figs. 25-35. *Haemaphysalis* (*K.*) *luzonensis* sp. n.

Fig. 25. Nymph capitulum, dorsal view.

Fig. 26. Nymph capitulum, ventral view.

Fig. 27. Nymph hypostome, ventral view.

Fig. 28. Nymph spiracular plate (A = anterior; D = dorsal).

Fig. 29. Nymph coxae and trochanters I to IV.

Fig. 30. Nymph tarsi I to IV, external view.

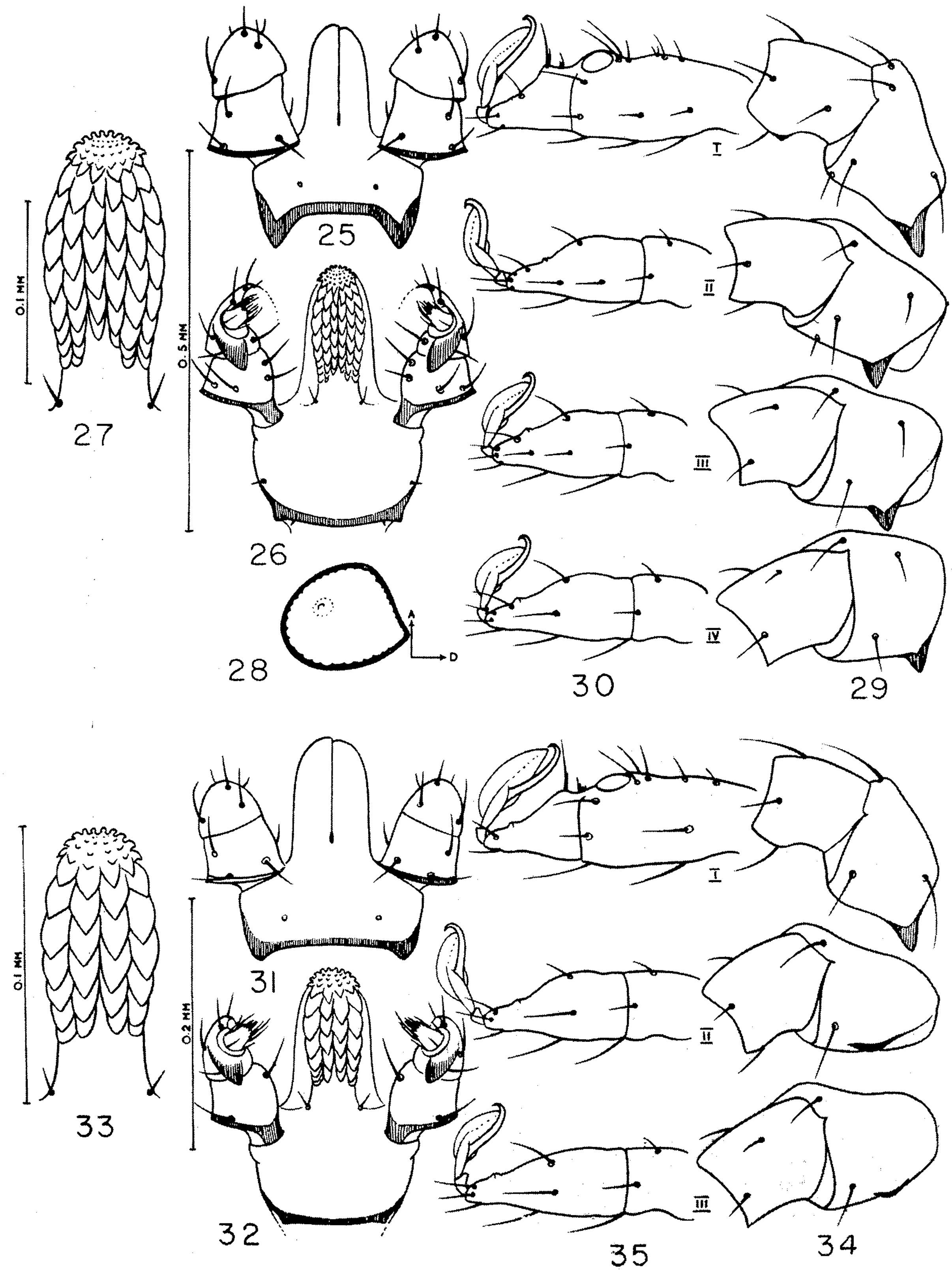
Fig. 31. Larva capitulum, dorsal view.

Fig. 32. Larva capitulum, ventral view.

Fig. 33. Larva hypostome, ventral view.

Fig. 34. Larva coxae and trochanters I to III.

Fig. 35. Larva tarsi I to III, external view.



Figs. 25-35. Haemaphysalis (K.) luzonensis sp. n.

PLATE V

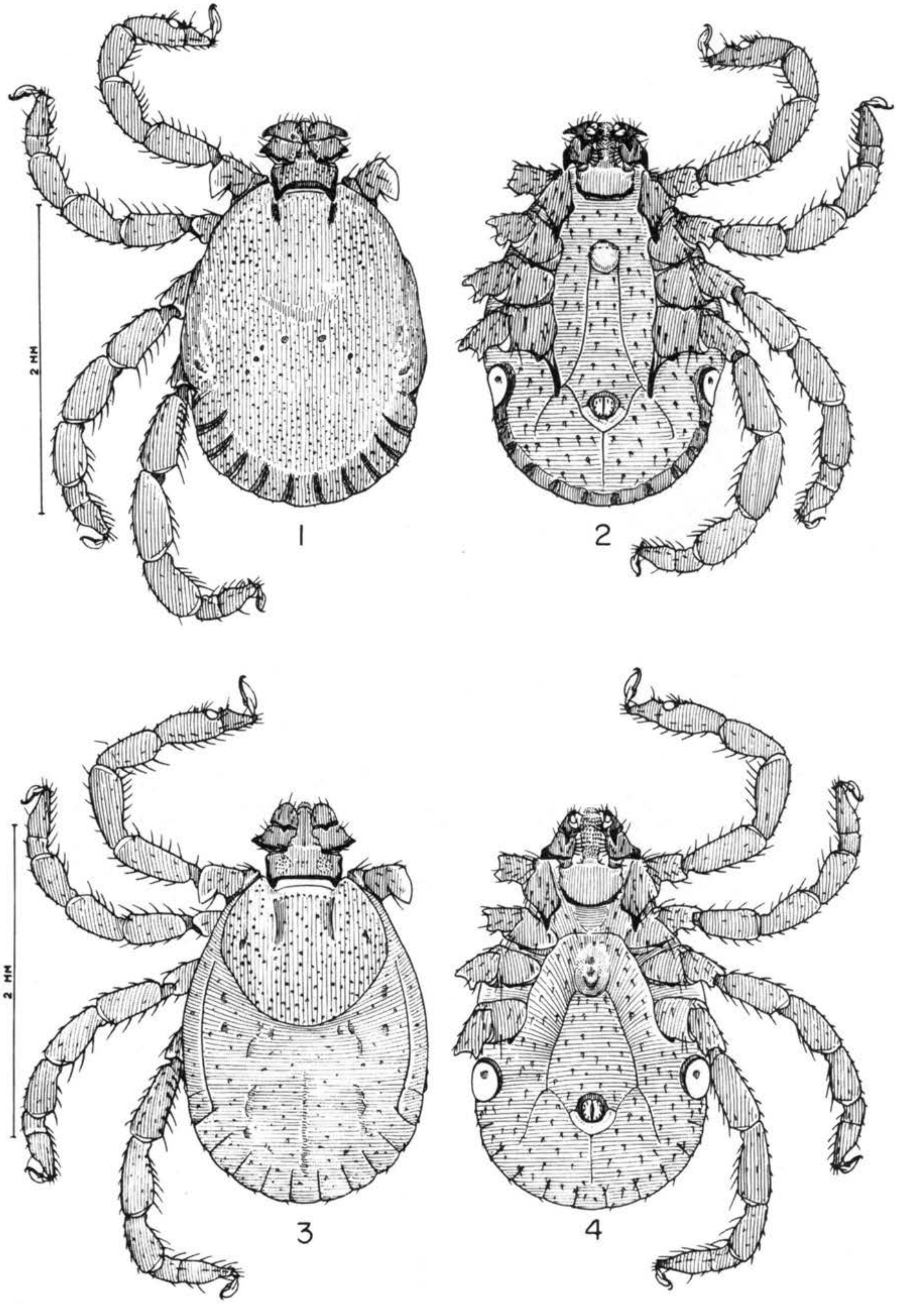
Figs. 1-4. Haemaphysalis (Kaiseriana) psalistos sp. n.

Fig. 1. Male, dorsal view.

Fig. 2. Male, ventral view.

Fig. 3. Female, dorsal view.

Fig. 4. Female, ventral view.



Figs. 1-4. Haemaphysalis (Kaiseriana) psalistos sp. n.

PLATE VI

Figs. 5-20. _Haemaphysalis_ (_K._) _psalistos_ sp. n.

Fig. 5. Male capitulum, dorsal view.

Fig. 6. Male capitulum, ventral view.

Fig. 7. Male hypostome, ventral view.

Fig. 8. Male genital area.

Fig. 9. Male spiracular plate (A = anterior; D = dorsal).

Fig. 10. Male coxae and trochanters I to IV.

Fig. 11. Male femur IV, internal view.

Fig. 12. Male tarsi I to IV, external view.

Fig. 13. Female capitulum, dorsal view.

Fig. 14. Female capitulum, ventral view.

Fig. 15. Female hypostome, ventral view.

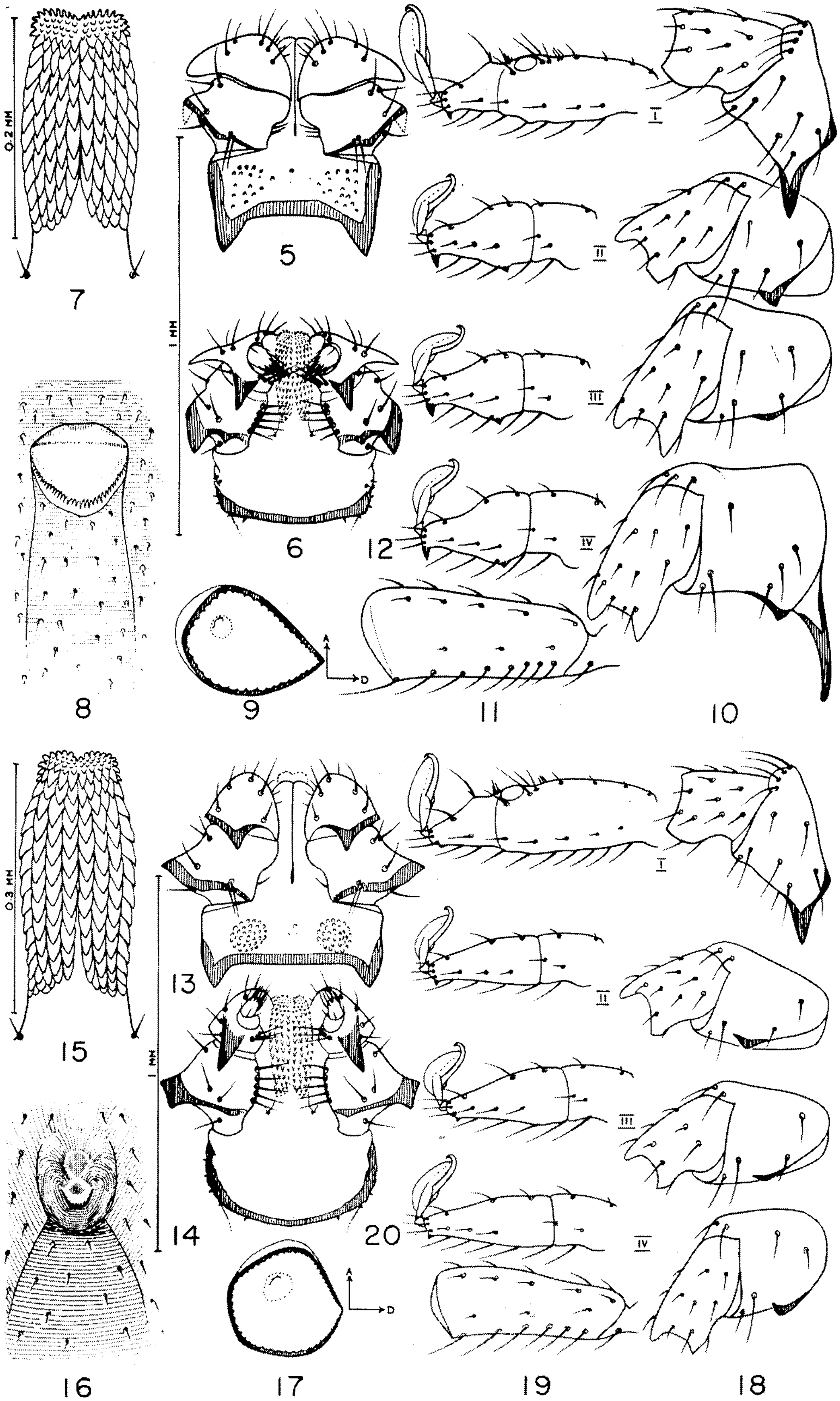
Fig. 16. Female genital area.

Fig. 17. Female spiracular plate (A - anterior; D = dorsal).

Fig. 18. Female coxae and trochanters I to IV.

Fig. 19. Female femur IV, internal view.

Fig. 20. Female tarsi I to IV, external view.



Figs. 5-20. Haemaphysalis (K.) psalistos sp. n.

PLATE VII

Figs. 21-28. *Haemaphysalis* (*K.*) *psalistos* sp. n. paratype nymph.

Fig. 21. Dorsal view.

Fig. 22. Ventral view.

Fig. 23. Capitulum, dorsal view.

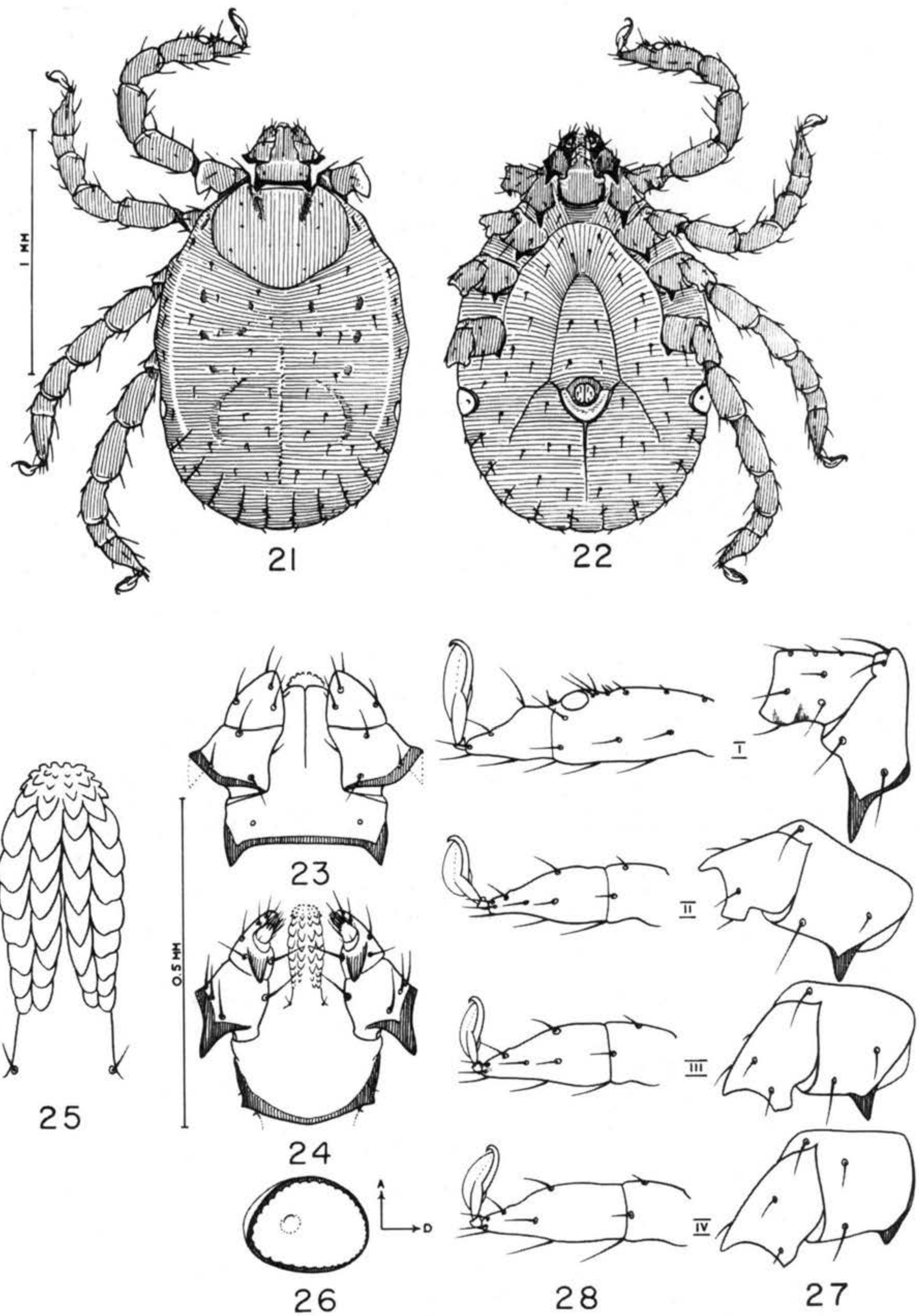
Fig. 24. Capitulum, ventral view.

Fig. 25. Hypostome, ventral view.

Fig. 26. Spiracular plate.

Fig. 27. Coxae and trochanters I to IV.

Fig. 28. Tarsi I to IV, external view.



Figs. 21-28. Haemaphysalis (K.) psalistos sp. n. paratype nymph.

PLATE VIII

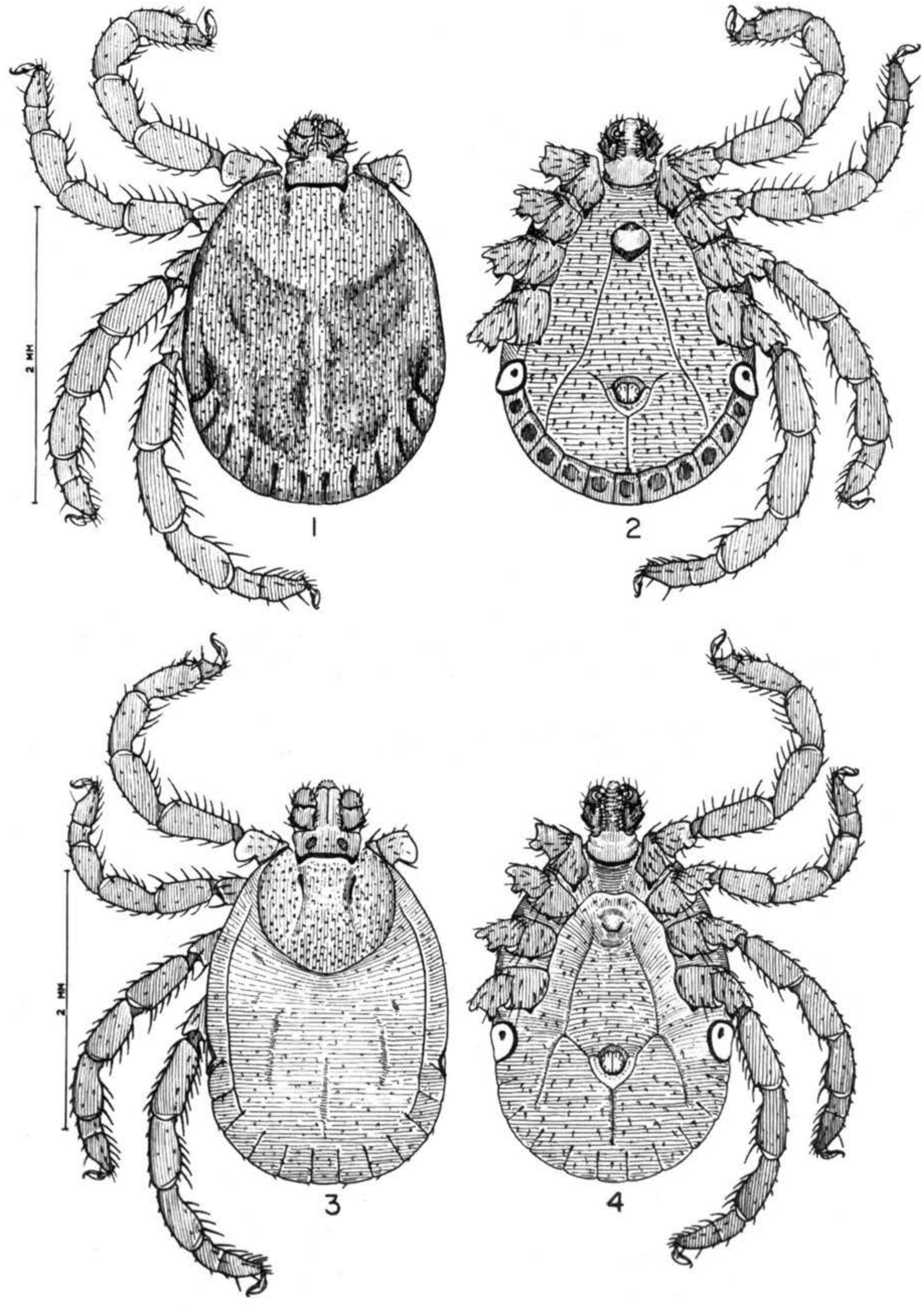
Figs. 1-4. *Haemaphysalis* (*Kaiseriana*) *susphilippensis* sp. n.

Fig. 1. Male, dorsal view.

Fig. 2. Male, ventral view.

Fig. 3. Female, dorsal view.

Fig. 4. Female, ventral view.



Figs. 1-4. _Haemaphysalis_ (_Kaiseriana_) _susphilippensis_ sp. n.

PLATE IX

Figs. 5-20. *Haemaphysalis* (*K.*) *susphilippensis* sp. n.

Fig. 5. Male capitulum, dorsal view.

Fig. 6. Male capitulum, ventral view.

Fig. 7. Male hypostome, ventral view.

Fig. 8. Male genital area.

Fig. 9. Male spiracular plate (A = anterior; D = dorsal).

Fig. 10. Male coxae and trochanters I to IV.

Fig. 11. Male femur IV, internal view.

Fig. 12. Male tarsi I to IV, external view.

Fig. 13. Female capitulum, dorsal view.

Fig. 14. Female capitulum, ventral view.

Fig. 15. Female hypostome, ventral view.

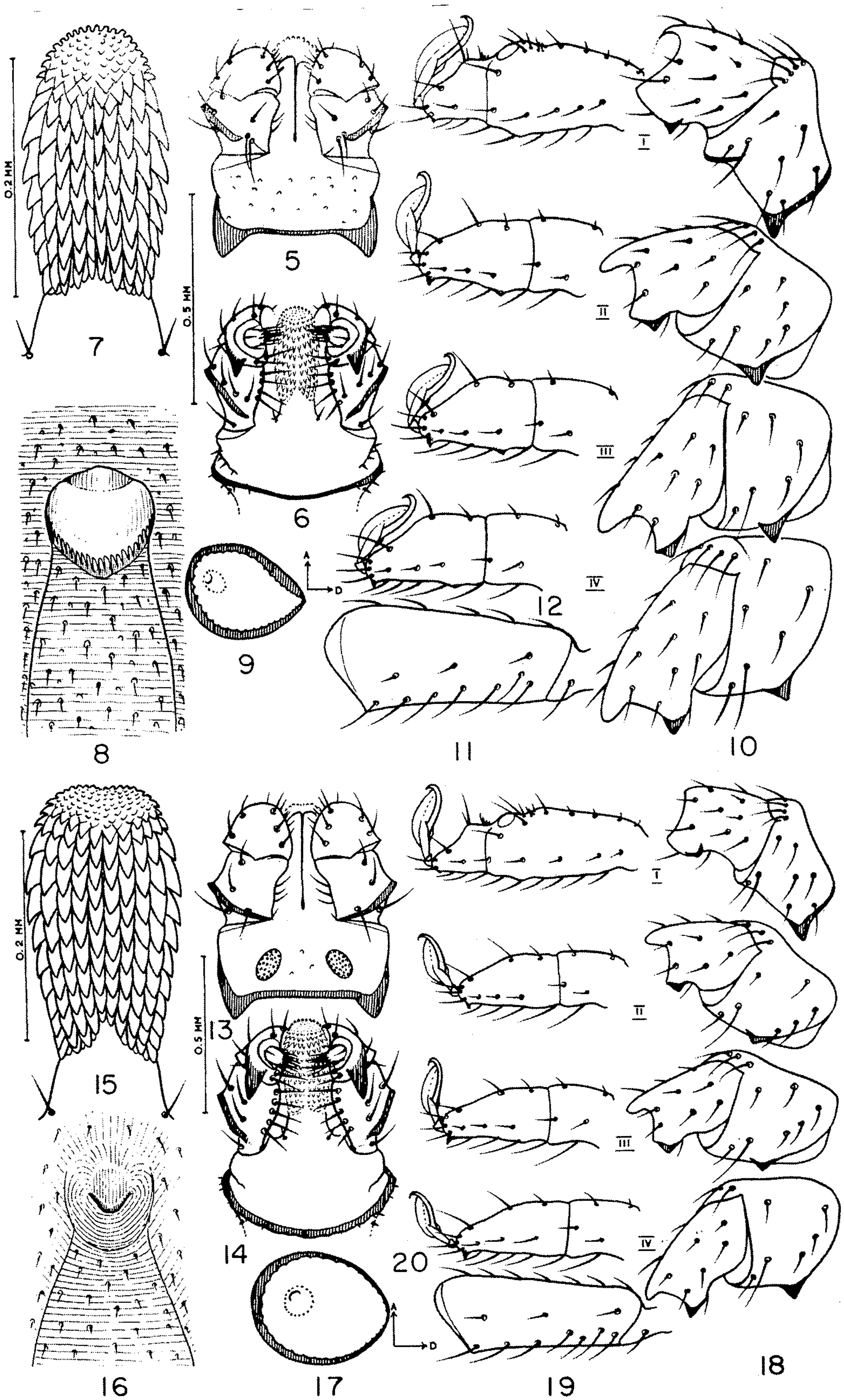
Fig. 16. Female genital area.

Fig. 17. Female spiracular plate (A = anterior; D = dorsal).

Fig. 18. Female coxae and trochanters I to IV.

Fig. 19. Female femur IV, internal view.

Fig. 20. Female tarsi I to IV, external view.



Figs. 5-20. Haemaphysalis (K.) susphilippensis sp. n.

VITA

Dale W. Parrish

Candidate for the Degree of

Doctor of Philosophy

Thesis: THE OCCURRENCE, GEOGRAPHICAL DISTRIBUTION AND WILD VERTEBRATE HOST RELATIONSHIPS OF TICKS (IXODOIDEA) ON LUZON ISLAND, PHILIPPINES, WITH DESCRIPTIONS OF THREE NEW SPECIES

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