12-1980

Studies on the Scorpions of Libya

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STUDIES ON THE SCORPIONS OF LIBYA

by

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A Thesis
Submitted to the
Faculty of The Graduate College
in partial fulfillment of the
requirements for the
Degree of Master of Arts
Department of Biology

Western Michigan University
Kalamazoo, Michigan
December 1980

ACKNOWLEDGMENTS

In the Name of Allah, Most
Gracious, Most Merciful

I would like to express my sincere appreciation to my major advisor, Professor Clarence J. Goodnight, for his supervision throughout the progress of this study and his helpful criticism of this manuscript and stimulating discussion which have contributed greatly to my understanding of scorpions.

Sincere thanks also go to Professor Joseph G. Engemann and Professor William VanDeventer for their helpful comments.

I would also like to express a very deep sense of thanks to the Zoology Department, Faculty of Science, at Al Fateh University, Tripoli, Libya, for providing me with the most generous help to carry out this work.

Gratitude is extended to the Dean of the Faculty of Science, Dr. Tahar Rabte, for his assistance and cooperation.

Special thanks go to my parents and my wife, Amal, for their encouragement and help and also to the graduate students Fardin Oliaei and Julie Medlin for their assistance in drawings and taking pictures.

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1316023

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CHAPTER I

Introduction

Members of the Class Arachnida belong to the Phylum Arthropoda, the joint-footed animals. Members of this class may be found in nearly all areas of the world, tending to be numerous in the warmer areas and less abundant in colder regions.

Among the Arachnids, one order, the Scorpionida, has representatives throughout the warmer regions of the earth. Since the stings of many scorpion species are highly toxic to humans, their biology is of special interest to students who encounter medical problems involving the scorpions.

All species possess a poison sac at the base of the terminal sting. Fortunately only a few are actually dangerous to humans. An exception to this generalization may be found in North Africa where a large percentage of the species have venom which is highly toxic to humans. As a matter of fact, there are areas in which the scorpions constitute one of the most important problems encountered in North Africa, particularly in the interior of the Sahara Desert.

Until relatively recent times, communication in Libya was confined to two separate narrow gauge railroads in the neighborhood of Tripoli and Benghazi, a few roads in the coastal area, and some desert tracks going south. There are now many excellent roads in all areas of the country which make for easy access to formerly inaccessible areas. The largest number of the dangerous species of scorpions are

found in the southern portion of the country, chiefly in the desert. Studies of these areas are now possible.

With the help of Al Fateh University, a collection was made within a few kilometers of Sabha in the heart of the Sahara desert. Because of the good road system in the northern part of the country, collections of scorpions were easily done there.

There are hospitals and clinics in all areas of Libya. The personnel of those establishments were very helpful both in collecting specimens and giving information as to the number of casualties and fatalities from scorpion stings in their areas.

Monographs concerned with the taxonomy and distribution of the scorpions of Algeria and Tunisia have been published (Vachon 1952); however, Libya, which has a number of important species, has scarcely been studied. For this reason, it was decided to make a study of the systematics and distribution of the scorpions of this area of North Africa (Fig. 1).

Geography of Libya

Libya is located on the southern border of the Mediterranean and has an area of approximately 1,780,000 square kilometers (679,358 square miles). Libya has a Mediterranean coastline of nearly 2,000 kilometers in the north. To the east Libya is bounded by Egypt and the Sudan, to the south and southwest by Chad and Niger, to the west by Algeria, and to the northwest by Tunisia (see Fig. 1 and Fig. 4)

Libya represents a part of the great Plateau of Africa, and its geographical affinities are more with Egypt than with Algeria,

Fig. 1. Map showing location of Libya in Africa

Tunisia, or Morocco. The country is characterized by two important geographical features: the Mediterranean and the Sahara Desert. Of these, the Mediterranean influence is confined to the narrow coastal area, while the Sahara influences the remainder of the country.

The climate of Libya is greatly influenced by the Sahara and is characterized by a wide range of weather conditions. In general, the summers (especially inland) are hot and rainless; winters tend to be mild with some cold spells and occasional torrential downpours in the north. The dry, warm conditions increase in intensity from north to south; thus Libya has many indigenous desert dwelling animals and plants. Among the particular abundant and characteristic desert animals are the scorpions.

Three main geographical areas are recognized within Libya: the Jefara, the Jebel Nafusah, and the Jebel Akhdar.

The Jefara: This is a zone of subsidence, lying between the Mediterranean and the fault scarps of the Tripolitanian Jabal. In the northwestern portion, there is a low-lying coastal plain which is succeeded, inland, by a line of hills or rather a scarp edge. Though small in area, the Jefara contains the greater portion of the Libyan population.

Jebel Akhdar (Green Mountain): The eastern portion of Libya along the Mediterranean is an upland plateau. It is a bold, prominent coastline.

Jebel Nafusah: Essentially this is a low plateau which rises gradually and irregularly from sea level in the north and extends south into the Sahara. The surface of this plateau has numerous

artesian basins and hollows. Some of these have oasis settlements and extensive sand deposits. There are no perennial rivers, but there is underground water. The area south of Jebel is known as the Fezzan region, and consists of a vast desert with a few oases, such as, Brak, Sabha, and Marzuk. In the far south lie the central Saharan mountains, the Tibesti ranges.

For so large an area, the Libyan population is small. Late in 1978, the Secretariat of Planning announced that there were 3,014,000 individuals in Libya.

Biology of Scorpions

The class Arachnida, to which the scorpions belong, is one of the divisions of the Phylum Arthropoda, invertebrates characterized by their jointed appendages. It has been estimated that the class Arachnida has approximately 65,000 species, the most familiar of which are the spiders (Order Araneida), the harvestmen or daddy-long-legs (Opiliones), the scorpions (Scorpionida), and the mites and ticks (Acarina); less well known are the pseudoscorpions (Pseudoscorpionida) and the solpugids (Solifugae).

The scorpions, though not so abundant as the spiders, are probably the most notorious of the arachnids. They are so well recognized because of their human associations and their own long history. It is generally believed that they represent the most primitive order of land-dwelling arachnids. Evidence indicates that at least a few genera of very early scorpions actually were aquatic, while others became the first inhabitants of dry land.

Scorpions are agressive, conspicuous forms which, with good reason, are often feared by man. A sting by some scorpions can cause severe reactions or even death on the part of the victim. They are abundant and conspicuous residents of the more arid regions of the earth and are easily recognized by their large pincers and "tail" which is often arched over the back. This "tail" is very mobile and supplied with a poison gland. When the scorpion is threatened, the tail is arched over the back, ready to strike forward. The long association of the scorpion with humans is attested to by its appearance in myths and the place it has been granted in the zodiac.

Scorpions differ greatly in size, varying from the small forms 13 mm. long to the giant species of 200 mm. in length. In appearance, however, they are very similar; in fact, they so closely resemble the extinct Eurypterids that the latter group is often recognized as ancestral to present-day scorpions. This conclusion is not supported by all zoologists, but the resemblance is quite evident.

All scorpions possess a first pair of very large pedipalpi which resemble the "claws" of a lobster rather than the leg-like papli of many other arachnids. These are carried forward and are very effective for both seizing and holding prey. The body of the scorpion is divided into three portions as follows:

The Prosoma: The prosoma (Fig. 2) is uniformly covered with the carapace; the width of the carapace is equal to or even greater than its length. In the center of the carapace there is a median furrow which extends from behind the eyes to the posterior margin where it widens to form a triangular depression. The median eyes are close

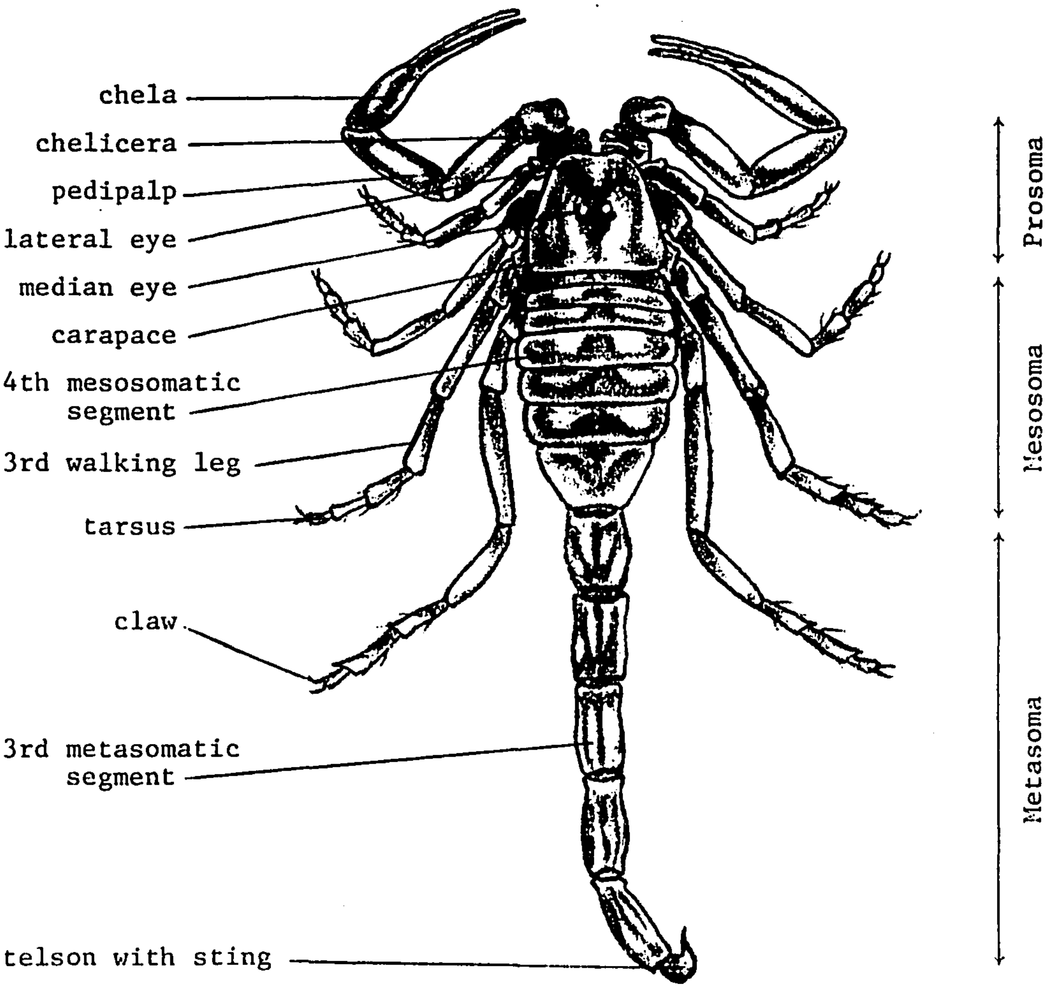

Fig. 2. Dorsal view of Leiurus quinquestriatus

together, and located on a low ocular tubercle which is a short distance from the anterior border of the carapace. There are usually also lateral eyes, forming groups of two, three, four, or five small ocelli. The exact position of the eyes and the number of ocelli vary from species to species. Some few scorpions are blind.

The prosoma bears the appendages, of which there are six. The three segmented chelicerae are small and the distal segment bears teeth which are often used in classification. The six segmented pedipalpi are large efficient weapons and are, as noted previously, characteristic of the members of this order.

The four pairs of running legs vary somewhat in length, the first pair are the shortest, the fourth the longest. Each consists of seven segments: coxa, trochanter, femur, patella, tibia, metatarsus, and tarsus. The coxae are large and in close contact with one another. They form practically the whole of the ventral surface of the prosoma. The two posterior pairs are immovable, but the first two pairs are movable, and have lobes which form accessory mouth parts. The tarsi bear two large curved claws without teeth, and below and between them is a third median smaller claw.

The sternum is a small plate located between the third and fourth coxae, and close behind it is the plate-like genital operculum. Immediately behind this and lying close to the fourth coxae are pectines. These are unusual appendages, found only among scorpions. Their exact function is not clear, but it is generally believed that they are special tactile, or perhaps olfactory organs.

The mesosoma: This area consists of seven segments or somites; the tergites (dorsal portions) of the first six mesosomatic somites are of gradually increasing length, the seventh is trapezoid in shape. The pleura (sort membrane) between the somites becomes very stretched during pregnancy. Only five sternites (ventral portion of somites) are visible. Each of the first four bears a pair of slit-like openings to the respiratory organs, the gill-books (Fig. 3).

The metasoma: This is the "tail" of the scorpion. The five somites of this portion are subcylindrical, with the dorsal tergite and ventral sternite fused to form a ring of chitin. The upper portion of the metasoma has a median groove. The sides and lower surface bear a variable number of longitudinal ridges with small spines. The last segment has the telson, a rounded reservoir which contains the poison gland. It terminates in the sharp curved point of the sting.

Scorpions, like other arachnids and insects, have an impervious integument and possess the ability to retain water. They are mainly nocturnal in habit and live chiefly in warmer climates. They are strongly thigmotactic; thus are usually found under rocks, flat pieces of wood, or in holes which they dig with the specially adapted pedipalps. Because of their nocturnal and subterranean habits, scorpions can survive severe conditions of heat and drought.

Scorpions are aggressive carnivores, readily consuming any soft-bodied insect or arachnid which they may encounter in their nocturnal forays or which may approach them in their retreat. They have even been known to consume small mice and lizards. It is not clear

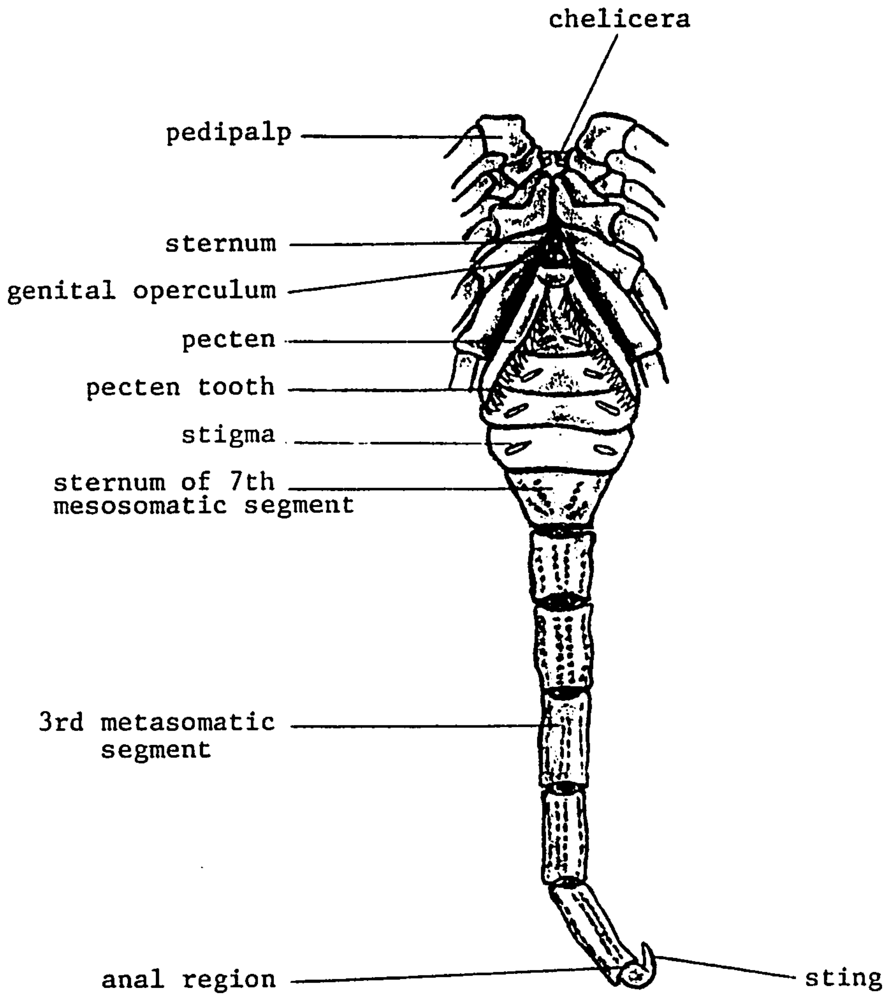

Fig. 3. Ventral view of Leiurus quinquestriatus

exactly how they detect their prey; certainly the eyes are not very useful in nocturnal animals; thus other sense organs must be concerned. There are sensory hairs on the pedipalps, and the pectines appear to be useful for detecting small vibrations. When the scorpion is hungry, it moves slowly supported by the hind legs with the claws open and extended, the tail raised and pointing forward. Most appear to wait for the insects to come to them rather than actively seeking, but this activity varies with the different species.

The mating habits of many scorpions are quite remarkable. Generally, the male is somewhat more slender and with a longer tail than the female. The courtship takes the form of a dance (Promenade a deux) first observed in 1810 by Maccary. When the male encounters a female, he grasps her pedipalpal claws with his, and walks sideways or backwards while she follows. The tails are usually raised, and in some species become entangled. The promenade continues for some time, in some cases for several hours. Finally the male either digs a hole or leads the female to a retreat and both disappear. The male has a special intromittent organ with which he inserts sperm into the genital aperture of the female, and then places a vaginal plug. After this complex activity, the female occasionally consumes the male.

In one South African species, Opisthopthalmus latimanus, the promenade is very brief. Shortly after the beginning of the promenade, the genital operculum of the female opens and somewhat later that of the male also does. The male then deposits a spermatophore upon the soil, then jerks the female over the spermatophore. She

lowers her body, and the spermatophore becomes inserted in her genital aperture.

The fertilized eggs develop within the mother, and the young are born alive. Among some forms in which there is but little yolk, the eggs remain in place and become closely associated with the maternal tissues. At the completion of development, each embryo lies in a diverticulum which has a tubular extension, an umbilical cord, along which nutrient fluids pass from the wall of the mother's intestine. These are lead through the tube to the mouth of the embryo. The embryo has a well developed pharynx with which it sucks the maternal fluid. In those forms in which the eggs have large amounts of yolk, the fertilized eggs pass into the oviduct and develop there, the embryos utilizing the yolk of the egg.

In many species, the young are born during the night. The new born animals are very plump and weak, but somehow mount to the mother's back where they remain until after their first molt, a period which may last from 10 to 16 days. After the first molt, the young remain with the mother for only a few days; then scatter. Growth is by molting, as in all arthropods. The total number of molts before attaining adulthood varies somewhat, possibly seven or eight.

Despite the large number of species of scorpions, only a few can be considered truly dangerous. Along the north coast of the Mediterranean, scorpions of the Family Buthidae are the most venomous. The venom consists of two parts: the insoluble and the soluble. The insoluble portion appears to be a mucoprotein; the soluble portion

contains toxin. The venom is composed mainly of proteins. There are two toxins, named scorpamines, which have a molecular weight between 10,000 and 18,000, depending on the species of scorpion.

Scorpion stings are usually accidental, occurring more at night than day. They can occur almost anywhere. Because women of many arid lands are more sendentary, they are less frequently involved. In children, the consequences are graver than in adults. The sting causes immediate severe local pain which is followed by a prickling sensation. More general symptoms follow: the individual may become agitated, children cry, muscle tone increases, very young children often have convulsions, salivation and perspiration are increased, the pulse rate is gradually increased, the temperature is unstable, and respiratory movements are irregular. If vomiting occurs, it indicates that nerve centers have been attacked by the toxin, and the prognosis is poor.

Sergent (1942) observed that the first symptoms, other than local pain, occur from 5 minutes to 24 hours after the sting, and in most cases between 20 minutes and 4 hours. The interval between the original sting and death varies from several minutes to 30 hours, averaging between 2 and 20 hours. Most of the effects of the toxin can be explained by its selective action on the sympathetic and parasympathetic autonomic centers of the hypothalamus.

Scorpion venom is not a very good antigen, and immunization requires at least 8 months, involving the use of from 400 to 500 telsons. The antivenins are quite specific and must be used as soon as possible after the individual is stung.

The scorpions are indeed the symbol of the desert and few invertebrates seem better suited to survive the rigors of this environment.

Scorpions are found in the warmer parts of the world. In the eastern hemisphere, they occur in the countries bordering the Mediterranean; in America they are in the southern area, and on the west coast go as far north as the 45th parallel. In the southern hemisphere, they are wide-spread, but are lacking from the oceanic islands and New Zealand. Their geographical distribution has been studied extensively. It is of interest because the scorpions represent an ancient group and do not disperse readily to new localities.

The order includes six families and approximately 600 species. About half of the species (Minton 1968) and nearly all of the very poisonous forms belong to the family Buthidae. In North Africa (Fig. 1) (Libya) the most important species are the common yellow scorpion, Buthus occitanus and the fat-tailed scorpion, Androctonus australis.

CHAPTER II

Review of Selected Literature

Early History

Though it is difficult, if not impossible, to know the first writings concerning scorpions, it is a fact that in astrology, a study almost as old as society, the scorpion is closely connected with the beginning and end of life. In astrology, the scorpion is regarded not only as the ruler of the reproductive organs, but also the lord of the house of death. Among the ancient Egyptians, the scorpion was associated with Isis, who was sometimes shown with her head surmounted by a scorpion. The scorpion was often worshiped out of respect for Isis and it was said that women were thus able to walk barefoot or even to lie on the ground without harm from their stings. They were believed to originate from the decaying corpses of crocodiles.

According to Savory (1974), Aristotle, in his best known work, A History of Animals, mentioned scorpions in half a dozen places. Aristotle wrote that the scorpion is "incidentally the only insect with a long tail." He recognized the fact that the scorpions produce living young ones and that all scorpions are not equally venomous.

Savory (1974) also stated that Pliny the Elder (A.D. 23-79) was more dramatic than Aristotle in his account of scorpions, calling them "a horrible plague," and maintaining that their "bite" was

always fatal to girls and usually to women, but dangerous to men only in the morning.

The naturalists of the 16th century, as a group, took the first steps toward an original and independent study of the arachnids. The outstanding feature of this period was the belief in the formidable venom of the tarantula. Tarantism was a genuine belief for many years, and it persisted until so recent a date as the middle of the 19th century. Much of the work following this period was concerned chiefly with spiders.

Sawammerdam (1637-80) published a book in 1669 in which he noted the similarity between the fangs of a spider's chelicerae and the sting of a scorpion's tail (Savory 1974).

In the famous 10th edition of Linnaeus's System Nature in 1758, five species of scorpions are recognized, the first real systematic recognition by an European scientist.

Until the end of the 18th century, the study of arachnids formed a small part of the much larger study of Entomology. It was the French biologist, Lamarck, who coined the work Arachnid in 1802, and recognized the arachnids as being separate from the insects. The foundations of the systematic study of the scorpions were laid by Latreille, Hahn, and Koch (Savory 1974).

Taxonomy

Though the scorpions were recognized as being distinct from other arachnids by Latreille, Hahn, and Koch, these workers did not distinguish among the different groups within the order. One of

the first workers to acknowledge the existence of the many groups was Thorell (1876) who published a paper on the classification of scorpions. Earlier workers had considered the number of eyes as the primary basis of differentiation, but Thorell, basing his work on that of Peters (1861), recognized traits other than the number of eyes and used such characters as the form of the sternum, the armature of the mandibles, and the arrangement of the parts of the "combs" of the males. He recognized four families: Androctonoidae, Telegonoidae, Vejovoidae, and Pandinoidae.

Kraepelin (1899) in Das Tierreich divided the scorpions into six families, an arrangement which has been only slightly modified by later workers. The modifications involved merging two families and promoting one. At present, the families recognized are: Bothriuridae, Scorpionidae, Diplocentridae, Chactidae, Buthidae, and Vejovidae.

Pocock (1902) has an extensive paper, but confines himself mainly to correcting various nomenclatural errors and in describing several species in the collections of the British Museum.

Of value chiefly for its presentation of an overall coverage of scorpions is the article by Millot and Vachon (1949) in Traite de Zoologie. It is more concerned with detailed anatomical descriptions, but a brief summary of the characteristics of the various families is included.

In more recent times, there have been numerous publications regarding the taxonomy of the scorpions. Many of these have been somewhat popular in nature, and thus are not mentioned in this review. Of importance, however, is Etudes sur les Scorpions by Vachon (1952)

published by the Pasteur Institut of Algeria. This study is particularly relevant to this present work because it is primarily concerned with the scorpions of North Africa. Following a detailed description of the anatomy of the scorpions, those characteristics useful for classification are reviewed. He regarded the trichobothria as one of the most important of these characteristics, but he also discussed the relative value of the shape of the cephalothorax, the details of the walking leg structures, the shape and spination of the chelicerae, the lamellae, and the genitalia. The many genera of this order are characterized, and their distribution and virulence are detailed. This work represents one of the most comprehensive of the numerous studies available.

Specific areas of the world have also been studied for their scorpion fauna. For example, within the United States, one of the earliest works on scorpions is that of Nathan Banks (1910). Ewing (1928) summarized the information regarding the forms to be found in the western portion of the United and northern Mexico. Muma (1967) studied the scorpions of Florida, finding five species within that state. Gertsch (1949) has an account of this group in his book, American Spiders. Snow (1970) has a generalized account of the scorpions as well as other arachnids in a semi-popular book.

In Russia, Byalynitskii-Birulya (1917, available 1964) has a detailed account of the scorpions of the Caucasian region. Because this area is the junction of three Eurasian regions, it has a wide diversity of habitats for both plants and animals, and the species found there represent several zoogeographical areas.

The scorpions, as attested by fossil remains, represent one of the oldest of the successful terrestrial animals. Though only a few hundred fossilized specimens are known, it is clear that the scorpions have remained essentially unchanged for hundreds of millions of years; thus the term "living fossils." Vachon (1953) has a detailed discussion of this interesting aspect of the biology of scorpions, but pointed out that despite their long history on the earth, like other animals, they are the products of evolution. Their complex digestive processes and the mode of nutrition of the embryo bear witness to an anatomical evolution of long duration. In this same paper, Vachon discussed many aspects of their biology.

Though observations of their biology can be found in nearly all the accounts of the taxonomy and distribution of scorpions, Vachon's paper is probably one of the best.

Because of the antiquity of this group, their geographical distribution is of great interest. Pocock (1894) studied the geographical distribution, and based his conclusions on Wallace's map of the zoological regions of the world. He noted that the northern limit of scorpions in North America is between the 35th and 40th parallels, and in South America they are known as far south as the 47th parallel. He concluded that at one period, the scorpion families had a very wide range in the northern hemisphere and were able to pass from eastern Asia into western North America. He felt that the scorpions of the Old World extended north in the Europaeo-Asiatic continent, and were able to pass into North America. Due to glacial conditions in later Tertiary times, there was isolation of faunas and the

development of the distinctive types which are known at present.

Savory (1964) pointed out that scorpions are found only in the warmer parts of the world. In the northern hemisphere, they are found in the countries bordering the Mediterranean and in North America they reach on the west coast as far north as the 45th parallel. In the southern hemisphere they are widespread, but are absent from New Zealand, Patagonia, and the oceanic islands.

The Bothriuridae are mainly a South American family, with one genus in Australia. The Scorpionidae, the largest family, are found throughout the tropics. The Buthidae, also widely distributed, include nearly half the American scorpions. The Vejovidae is a small family, chiefly from America, but with one Mediterranean and one Indian species. The Chaerilidae, with but a single genus, is known only from tropical Asia. The Chactidae is mainly an American family, but have some well known forms in France, Corsica, Italy, and Algeria. Cloudsley-Thompson (1968) noted that most scorpion species have a very limited range, except Isometrus maculatus which is ubiquitous in the warmer part of the world and Scorpio maurus which ranges from the Atlantic to India. Few are found at high altitudes.

Because of their medical importance, in some areas there are more deaths from scorpions than from snakes. Much has been written about the scorpions concerning their venomous nature. Of importance in this regard are simple listings of the scorpions found in various areas. Vachon (1966) published a list of the scorpions of Egypt, Arabia, Palestine, Lebanon, Syria, Jordan, Turkey, Iraq, and Iran.

Whittemore and Keegan (1963) discussed the medically important spiders of the Pacific area. They concluded that Mexican scorpions of the genus *Tityus* are of considerable public health importance, but in other areas of the Pacific scorpions do not present a medical problem. They noted that the size of the scorpion is not a good criterion for determination of the medical importance of the species. A large Javanese scorpion, *Heterometrus cyaneus*, has very weak venom. The medical importance of a species depends upon such factors as venom toxicity, amount of venom injected, geographic distribution, and habits.

Abalos (1963) indicated that from a medical veterinary point of view, scorpions are not a problem in Argentina. This is not the case in Mexico where Mazzotti and Bravo-Becherelle (1963) gathered information on the stings of scorpions over a period of 3 years. Though collecting data was difficult, they concluded that scorpions were the most important of the venomous animals of Mexico. While the number of persons who died from scorpion stings is low when compared to the total population, in many areas it is the leading cause of death during certain months of the year.

Goyffon and Vachon (1979) reported on two poisoning incidents in Saudi Arabia. Some pharmacological properties of the venom were considered, and treatments and prophylaxis of stings were briefly discussed.

While there have been many studies of the arachnids of North Africa, there are only a few that are specifically of Libya. Caporiaccio (1937) has a lengthy paper on the biological observations

made by an expedition to Libya. They concentrated their observations on the Fezzan and Tassili. Though mention is made of scorpions, there are no details as to species encountered or as to their role in the ecological systems of the area.

Because of the extreme toxicity of the venom of many species of scorpions, they have long been recognized as an important medical problem. As has been noted previously, some species have venoms which are much more toxic than others. Thus the recognition of species is important. This is the problem of the taxonomists. But along with this problem are those of how to collect, preserve, and study both the animals and their venoms. These problems have been dealt with by many different individuals.

Williams (1968a) suggested a method of preserving scorpions for study by killing them rapidly by dropping them into hot water for 10-60 seconds, then preserving them in a formalin preparation. This method preserves the natural color of the specimens better and avoids the brittleness which is associated with other types of preservation. In a second paper, Williams (1968b) suggested the use of pitfall traps as a method of sampling scorpion populations. This method is suggested as a possible alternative to the more usual sampling methods involving the turning over of surface objects.

No matter how they are collected, the problem of extracting the scorpion venom and studying it remains. Balozet (1954) pointed out that the danger from scorpions is greater than from venomous snakes in French North Africa. The most formidable species are Androctonus australis, Buthus occitanus, Buthacus arenicola, A. amoreuxi, and

A. aeneas. Balozet, in his studies of venoms, extracted the venom by use of electrical excitation of the distal coils of the tail. The venom was then dried and preserved in vacuum ampules where it maintained its potency for several years. The toxicity (LD_{50}, IM, in 20 g. mice) of the various species is: *Buthacus arenicola*, .052 mg.; *Androctonus australis*, .091 mg.; and *Buthus occitanus*, .115 mg. The scorpion with the most toxic venom is not necessarily the one which causes the most accidents. This is explained by the variations in the quantity of venom in the glands and the degree of aggressiveness of the individual scorpion. Antivenom is obtained by immunizing horses. In as much as scorpion venom is a poor antigen, immunization requires 8 months and from 400 to 500 telsons. Not all horses produce serum of a satisfactory titer, and immunization is seldom complete. When administered early, antiscorpion venom used in large quantities does save many lives. Delay in treatment may result in fatalities.

Whittemore et al. (1963) reviewed methods of maintaining scorpions in the laboratory. Specimens must have facilities for hiding or burrowing and adequate supplies of food. The writers described in detail their methods of maintaining them in their laboratory. A modified mousetrap was used for holding the scorpion after it was tranquilized with carbon dioxide. Their data indicated that as much as 66.4% of the venom content of the telson was emitted during electrical stimulation of the species *Centruroides limpidus teconomanus* from western Mexico.

There have been numerous studies of the biochemistry of the venom of various scorpions, and only the most significant of these can be cited. Glenn, Keegan, and Whittemore (1962) studied intergeneric relationships among various scorpion venoms and antivenins. Their results indicated that many species from various parts of the world shared at least one precipitin system. Their aim was to study the possibility of the preparation of a polyvalent antivenin which would be useful against scorpion stings in any part of the world.

Watt (1964), in studying Centruroides sculpturatus, indicated that the crude venom gave positive reactions to several tests for proteins and negative reactions to tests for polysaccharides, and had absorption spectra characteristics of proteins or peptides. There was a low concentration of aromatic amino acids in the venom. The toxic principle was only slowly inactivated. He concluded that the toxicity of the venom of C. sculpturatus is associated with one (or at most two) components. The toxin is a peptide of low molecular weight. He speculates that in some scorpions the toxin is a small molecule bound to a larger, nondialyzable component.

Minton (1968) in his studies reported that the venom is a clear or slightly opalescent liquid and dries to a whitish powder representing 15%-25% of the weight of the liquid venom. The toxin is a basic protein of low molecular weight (11,000-18,000) with a high content of sulfur and basic amino acids, especially lysine. They are denatured by heating to 80° C. Experimental work indicated that venoms of Buthus, Buthotus, and Androstonus caused irritability, salivation, spasticity, gasping labored respiration, and convulsions.

Small animals might die almost immediately.

Miranda et al. (1970), reporting on their work with the structure of scorpion toxins, used proteolytic enzymes to determine the positions of the disulfide bridges of Toxins I and II of Androctonus australis. The four disulfide bridges in the case of Toxin II linked the half cystine residues 12 and 63, 16 and 36, 22 and 46, and 26 and 48. The results of studies with Toxin I supported the hypothesis that the positions are probably the same in all of the scorpion neurotoxins.

Adam and Weiss (1959) were interested in the pharmacology of the venom. Their initial fractionation of crude venom from Leiurus quinquestriatus by paper chromatography and electrophoresis demonstrated the presence of 5-hydroxytryptamine in large amounts.

This is a highly active substance and contributes partially to the pain experienced during experimental application of scorpion venom in man. Solutions of crude venom, when applied to isolated skeletal muscle (frog sartorius or rat diaphragm) produced slow contractions, even in the presence of curare and showed increased responses to direct or indirect electrical stimulation. Prolonged exposure to the venom reduces the responsiveness of the muscle. These observations indicate a similarity to the effects of calcium--which when applied can prevent or reverse the venom actions. They concluded that scorpion venom has more than one pharmacologically active principle. Serotonin (5-hydroxytryptamine) was found in the venom of Leiurus quinquestriatus, and histological examination of the venom glands demonstrated enterchromaffin structures.

In a general discussion of the classification, biology, and venom extraction of scorpions, Bücherl (1946) summarized much previous work. He emphasized that the sensitivity of various animals to scorpion venom is highly variable; for example, some species are resistant: cats, chickens, and turkeys among them. Age is also important in the sensitivity of test animals, with young animals being more sensitive than adults. The symptoms of envenomation are similar in all animals. The mechanism of poisoning by scorpion venom consists primarily of neurotoxic action on the nerve centers, and secondarily of local action of 5-hydroxytryptamine. The symptoms of poisoning in man and experimental animals indicate that the action of the neurotoxin resembles that of parasympatheticomimetic substances and sympatheticomimetic compounds (adrenaline). Most of the effects of the toxin can be explained by its selective action on the sympathetic and parasympathetic autonomic centers in the hypothalamus. The venom provokes fibrillar and fascicular contractions of muscles which tend to increase and become clonic. This results from a central action on the spinal motor neurons. The venom also acts on the respiratory centers in the brain stem, resulting in paralysis. Blood pressure rises, and there is hyperglycemia, sweating, salivation, and mydriasis. Scorpion antivenins are quite specific; thus it is important to be aware of the species involved in the incident. Nonspecific treatment (torniquet, a light incision and sucking) can be helpful.

Patterson (1960) studied the physiological action of the lethal scorpion, Centruroides sculpturatus, a common form in the southwestern United States. The venom, when administered to test animals,

caused hypertension, respiratory failure, and skeletal muscle stimulation. There was no significant action on isolated skeletal muscle preparations. The hypertension resulted, in part, from the release of pressure substances from the adrenal gland. Respiration and skeletal muscle stimulation followed a pattern which tended to suggest an initial peripheral action followed by an action which was dependent on the central nervous system.

In 1975 Walther, Zlotkin, and Rathmayer reported on the action of different toxins from the scorpion, Androtonus australis, on the nerve muscle preparation of a locust. They stated that the parayltic effect of scorpion venoms on arthropods is chiefly due to the presence of specific toxic proteins, "insect" and "crustacean" toxins. These differ from the "mammal" Toxins I and II which are lethal to mice. As in mammals, the paralytic effect of the scorpion crude venom is due to a neurotoxic action. The conclusion was that the muscular excitatory effects of A. australis crude venom and of the toxins derived from it are mainly due to a presynaptic action, that is on the motor nerves. It appears that this toxin is indeed selective for insects.

Finally there is the problem of how to treat the bites of venomous animals. Sutherland (1976) has reviewed this problem as it exists in Australia. He notes that there are three species of scorpions to be found in Australia, all of which can produce painful stings. The problem of envenomation does not seem to be too severe there, for he suggested that most of the stings respond to bathing in warm water and the use of local anaesthetics. Again, this emphasizes the fact

that it is important to know the species involved in the accident, for there is great variation in the toxicity of their venoms.

CHAPTER III

Design and Methodology

In order to investigate the distribution of scorpions in Libya, it was necessary to undertake an intensive collecting trip to the various regions of the country. This was done during the summer of 1979.

The methods used for collecting the scorpions differed from one area to another, depending mainly upon the habits of the different species. The main method utilized for collecting the animals was to turn over surface objects, such as, boards, rocks, loose bark, or logs and trash. For burrowing forms, the animals were collected by digging them out. In the field, the scorpions were picked up by the use of 12-inch long, straight forceps. Upon being collected, the animals were immediately killed and preserved in 70% alcohol. After 24 hours, the alcohol was changed. Field notes were taken at the time of each collection; these notes included detailed locality and habitat information.

Alternative methods of collecting scorpions have been devised by other workers, including that of Russell (1969). His method was based on the fact that some scorpions fluoresce when exposed to ultraviolet light at night. In an attempt to utilize this method, a "safari lite" (Burgess) with an F8T5-BLB fluorescent tube was utilized several times. Unfortunately, the scorpions were not sufficiently abundant to make this an effective device for collecting.

In Mansoura, one specimen was captured when it was detected as the lamp was moved from side to side over rocks. The bright greenish glow of the scorpion's cuticle was easily detected, and the animal was captured with a forceps painted with fluorescent paint.

A trapping has also been used for collecting scorpions, but unfortunately, this also did not prove to be successful in the areas studied.

After the animals were collected, the preserved specimens were taken to the Zoology Department of Al Fateh University and transferred to fresh 70% alcohol. This caution assured the proper preservation of the scorpions and all foreign substance such as sand were removed. Later all the material was brought to the Department of Biology at Western Michigan University for further study.

Many different individuals aided the collection of the specimens. Important data concerning poisoning incidents in the south of Libya were obtained from Sabha Central Hospital (personal communication).

The areas visited for the purposes of field collection were as follows:

<u>Tripoli Province</u>

Tripoli	Yefren
Tajura	Ghiryan
Sabratha	

Fezzan Province

Sabha	Al Garrda
Ghudwa	Edri
Aqar	Gitta
Mahruga	Brak
Mansoura	Marzuk
Obari	

Benghazi Province

Benghazi	Elmerje
Benina	Al Bayda
Elabyar	Sousa
Tukrra	Darnah

Several taxonomic references were utilized for identification. These included the following: Vachon (1952), Kraepelin (1899), Thorell (1876), Pocock (1902), and Byalynitskii-Birulya (1917). Cloudsley-Thompson (1968), Savory (1977), and Comstock (1940) identifications were checked by Dr. Clarence J. Goodnight.

CHAPTER IV

Results and Discussion

Collecting Areas

In an attempt to collect scorpions from as many areas as possible, representative geographical districts of Libya were visited during the summer of 1979.

Areas in which collections were made in the northern part of the country included the following: Tripoli, Tajura, Sabratha, and Yefren. This northern area has a typical Mediterranean climate, characterized by winter rains and very dry summers. The terrain has many low bushes and numerous rocks are scattered over the pavement-like ground. This is particularly true of the areas around Tripoli and Tajura. Near Sabratha, collections were made in an old field where the animals were found under rocks. Near Tajura, where there are orchards of olives and pomegrantes, the scorpions were likewise found under stones.

Yefren is located southwest of Tripoli. This area is mountainous and extremely rocky and arid. There are wells present, and limited areas are cultivated for date palms and some olives. The collections here were made above the town under the rocks of an abandoned stone fence.

In the southern part of Libya, collections were made at Al Garrda, Edri, Ghudwa, Obari, and Aqar (see Fig. 4). Except for

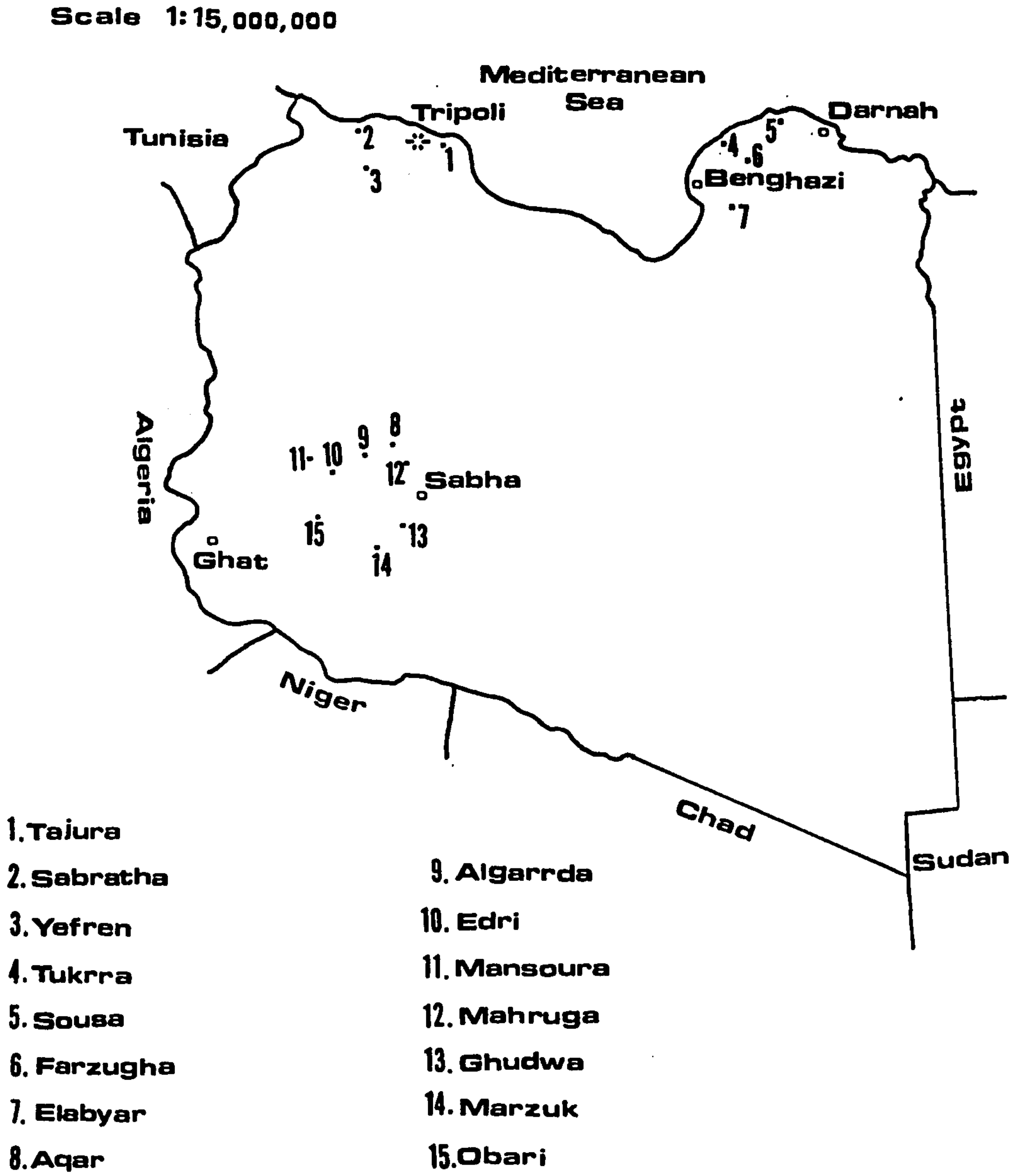

Fig. 4. Map of Libya showing collecting areas

scattered oases, this section of Libya is extremely arid. The ground is desert pavement. Extending from southeast to northwest are a series of high sand dunes. The oases of this area boast small towns which do have date palms and olive trees. In a few irrigated areas, crops such as alfalfa are grown and some truck gardening does occur. The scorpions found here were mainly collected in buildings by the health center employees. The collecting area near Ghudwa (Fig. 4) which is located south of Sabha on the road to Marzuk, was done near irrigated fields. The animals were found under flat rocks.

The third main area in which collections were made is east of Benghazi along the coast in the area known as the Green Mountains. This area appears to be somewhat more moist than the intermediate coastal section. Pines and scrub vegetation are present. The localities from which collections were taken in this area are Tukrra, Sousa, Farzugha, and Elabyar (Fig. 4). The most abundant scorpion in this area was Scorpio maurus (Fig. 13 and Fig. 14), collected near Farzugha, a plateau which is somewhat moister than surrounding areas. S. maurus was dug out of burrows which were easily observed on the ground. This species does not depend on surface cover for shelter, for it is provided with large claws with which it digs burrows in the hard soil.

Classification

The classification of the scorpions is based on the work of Kraepelin (1899) and that of Vachon (1952).

Though the classification of the scorpions has become somewhat more complex in recent years due to the work of many different specialists, the number of families as defined by Kraepelin (1899) has remained constant.

Kraepelin divided the living species into six families:

1. Buthidae
2. Scorpionidae
3. Diplocentridae
4. Chactidae
5. Vejovidae
6. Bothriuridae

Recent estimates place the number of known species of scorpions in the world at approximately 600. These are divided into 70 genera (Vachon 1968). Of these six families, members of only two, the Buthidae and Scorpionidae, are found in Libya. Briefly these two are characterized as follows:

Family Buthidae, Simon, 1879. This family has the largest number of individuals of any family in this order. There are 31 known genera with some 307 species. Members of this family have the widest geographical distribution of any scorpion family.

These scorpions are characterized chiefly by their possession of a triangular sternum. A tarsal spur is usually present on the third and fourth pairs of legs, and there are three or five lateral eyes on either side of the head. The "hands" may or may not be keeled, and the "fingers" are usually long and slender. The last segment of the

tarsi of the legs is not terminated by lateral lobes and there is usually a spine below the sting.

Four subfamilies are recognized within this family: Buthinae, Kraepelin, 1899; Ananterinae, Pocock, 1900; Centrurinae, Kraepelin, 1899; and Tityinae, Koch, 1845. Representatives of Ananterinae, Centrurinae, and Tityinae are neotropical. Three genera of the subfamily Buthinae are found in Libya. These are Buthus, Androctonus, and Leiurus. Four species are found in Libya: B. occitanus (Fig. 9 and Fig. 17), A. australis (Fig. 5 and Fig. 15), A. aeneas (Fig. 7 and Fig. 16), and L. quinquestriatus.

Family Scorpionidae, Pocock, 1893. Members of this family are only second in number to those of the family Buthidae. There are over 147 species grouped into 16 genera. These scorpions are not so dangerous as the Buthids.

Members of this family possess a large pentagonal sternum with lateral margins that are nearly parallel. There are no spurs at the end of the first tarsal segment of the third and fourth legs. But three lateral eyes are present, and the hand is flattened. There is rarely a spine under the sting.

Within this family are several subfamilies: Lisposominae, Lawrence, 1928; Urodacinae, Pocock, 1893; Hemiscorpioninae, Pocock, 1893; Scorpioninae, Pocock, 1893; Ischnurinae, Pocock, 1893; and Terscorpioninae, Birula, 1917. Most scorpions of this family are the subfamily Scorpioninae. But a single genus and species of Scorpionidae is found in Libya, this is Scorpio maurus (Fig. 13 and Fig. 19).

Results of Collections

Five species of scorpions were collected in the various parts of Libya which were visited. These were: Androctonus australis, Androctonus aeneas (the black scorpion), Leiurus quinquestriatus, Scorpio maurus, and Buthus occitanus.

Table 1 summarizes the collections. As can be noted from Table 1, L. quinquestriatus was collected only in Fezzan, and S. maurus was found only in the Green Mountain area.

Table 1

Collecting Data

Area	Species	Locality	No. of Individ- uals
Northern area	A. australis	Tripoli	4
		Tajura	1
		Sabratha	3
		Yefren	2
	A. aeneas	Tripoli	1
		Tajura	2
	B. occitanus	Yefren	1
Eastern northern area	A. australis	Tukrra	1
		Sousa	1
	A. aeneas	Tukrra	1
	S. maurus	Farzugha	12
	B. occitanus	Elabyar	5
Southern area	A. australis	Al Garrda	2
		Edri	1
		Ghudwa	5
		Obari	1
	A. aeneas	Ghudwa	2
	L. quinquestriatus	Aqar	2
		Mahruga	4
		Mansoura	6
		Marzuk	1
		Al Garrda	2
	Total		60

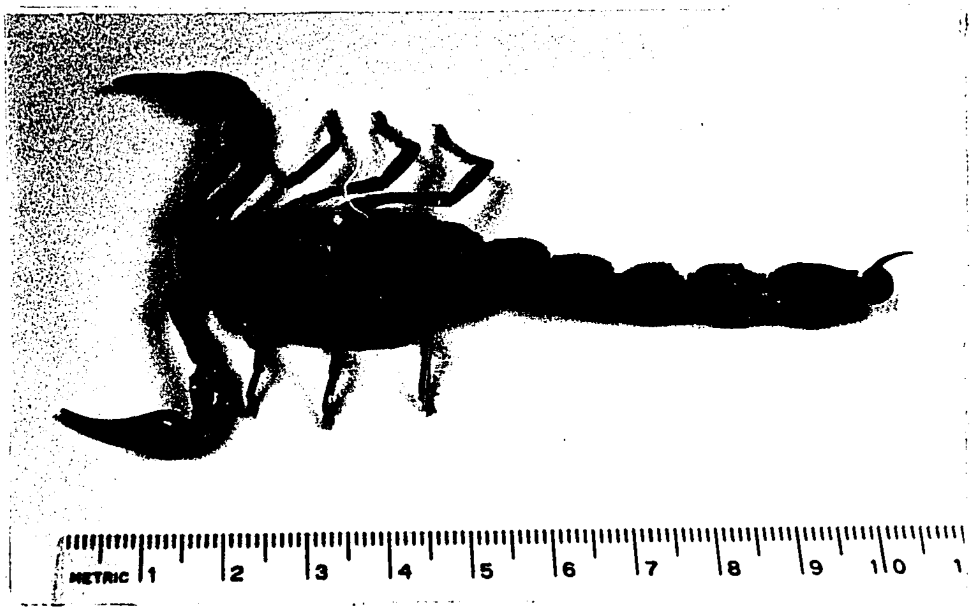

Fig. 5. <u>Androctonus australis</u> (dorsal view)

Fig. 6. <u>Androctonus australis</u> (ventral view)

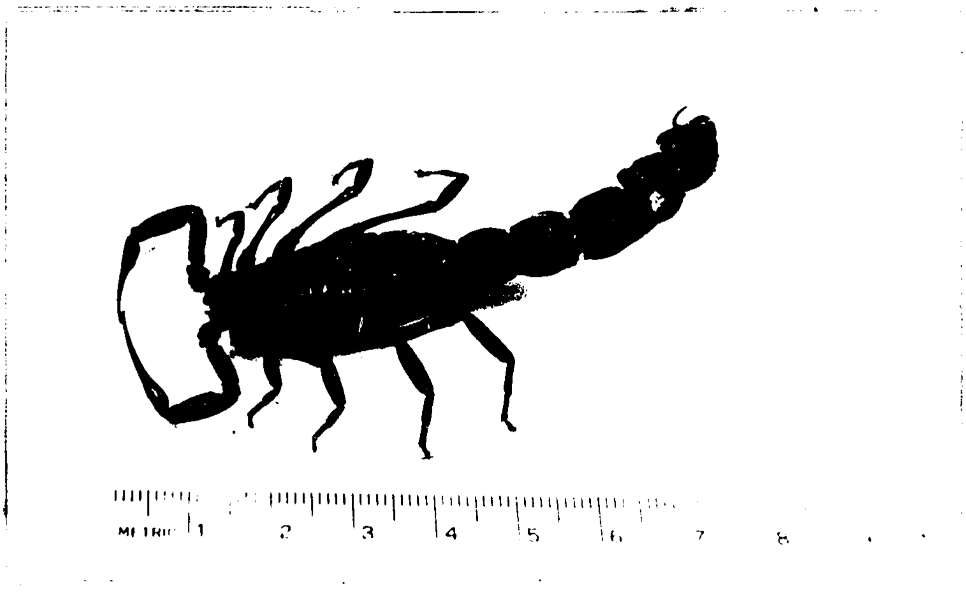

Fig. 7. <u>Androctonus aeneas</u> (dorsal view)

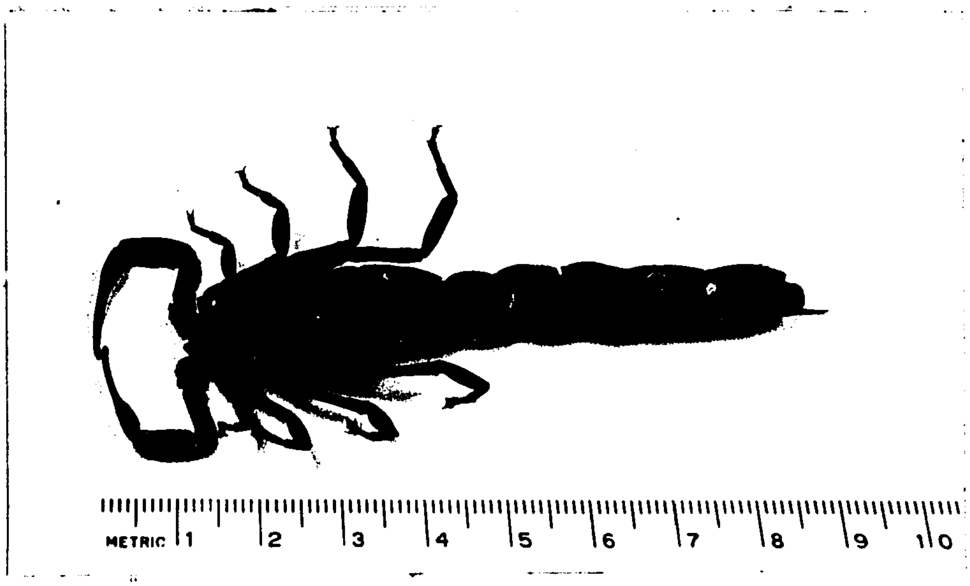

Fig. 8. <u>Androctonus aeneas</u> (ventral view)

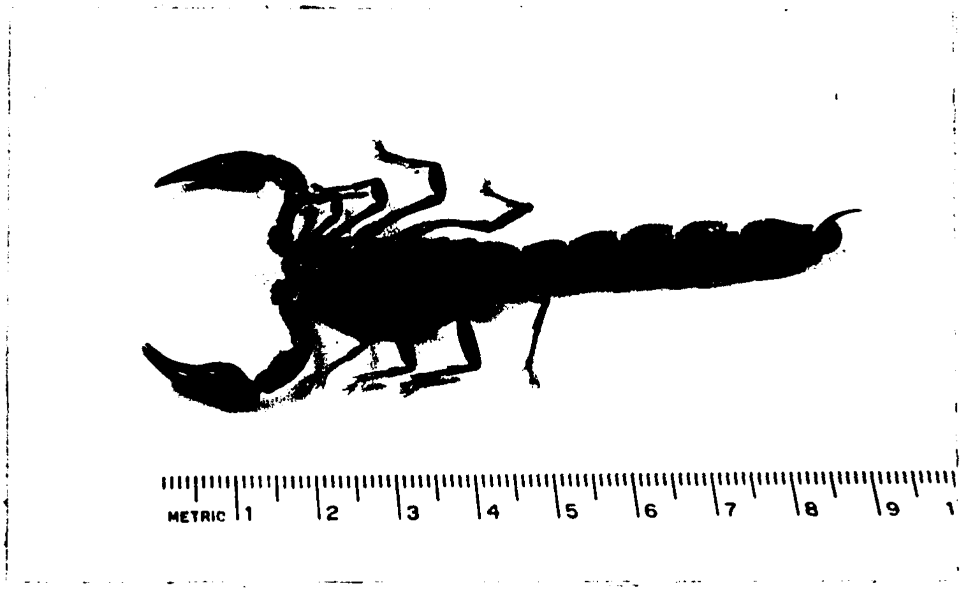

Fig. 9. Buthus occitanus (dorsal view)

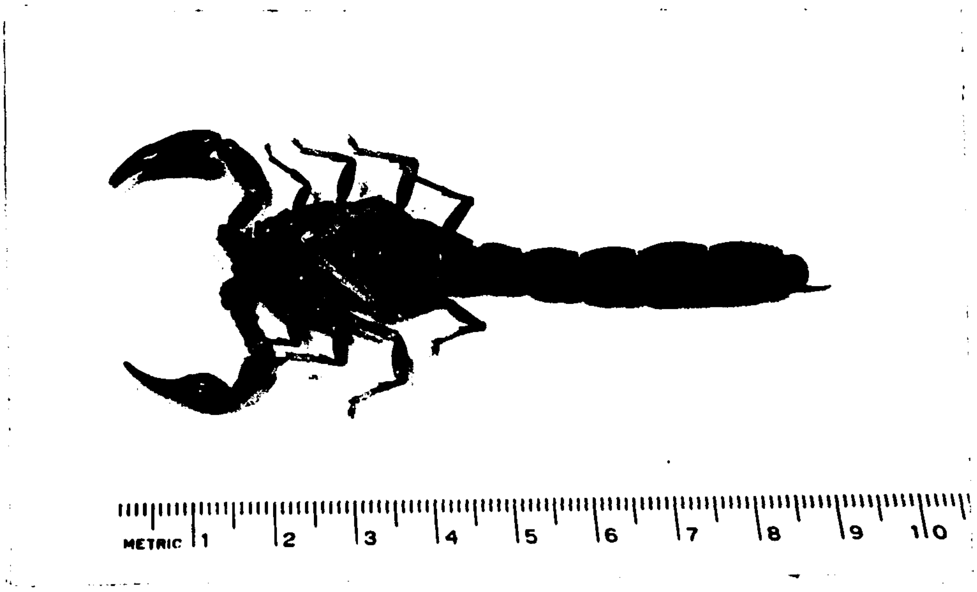

Fig. 10. Buthus occitanus (ventral view)

Fig. 11. <u>Leiurus quinquestriatus</u> (dorsal view)

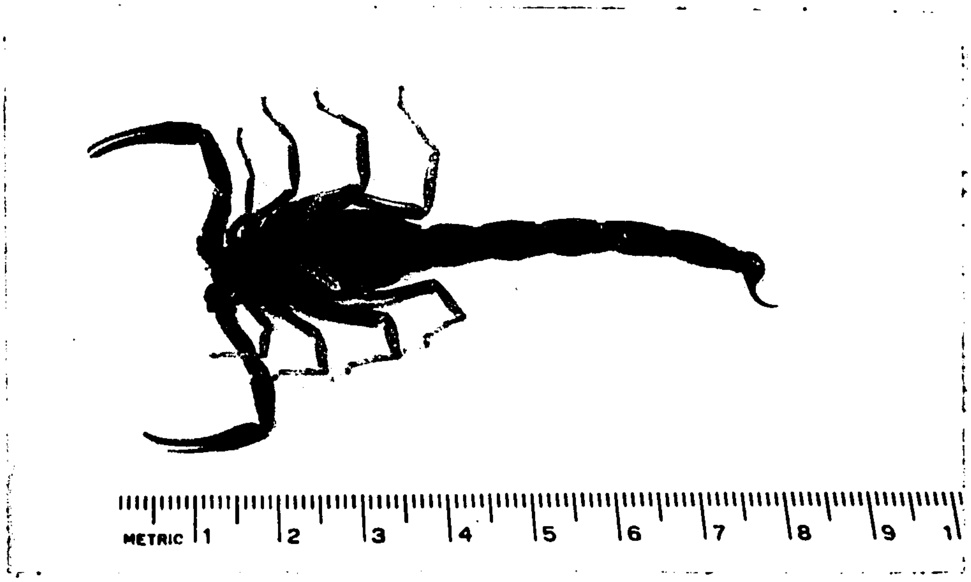

Fig. 12. <u>Leiurus quinquestriatus</u> (ventral view)

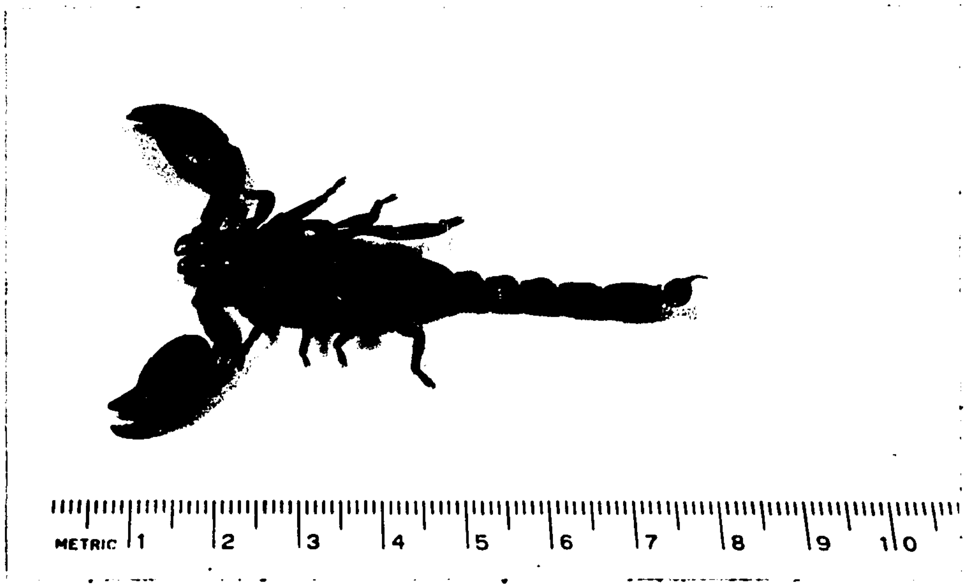

Fig. 13. Scorpio maurus (dorsal view)

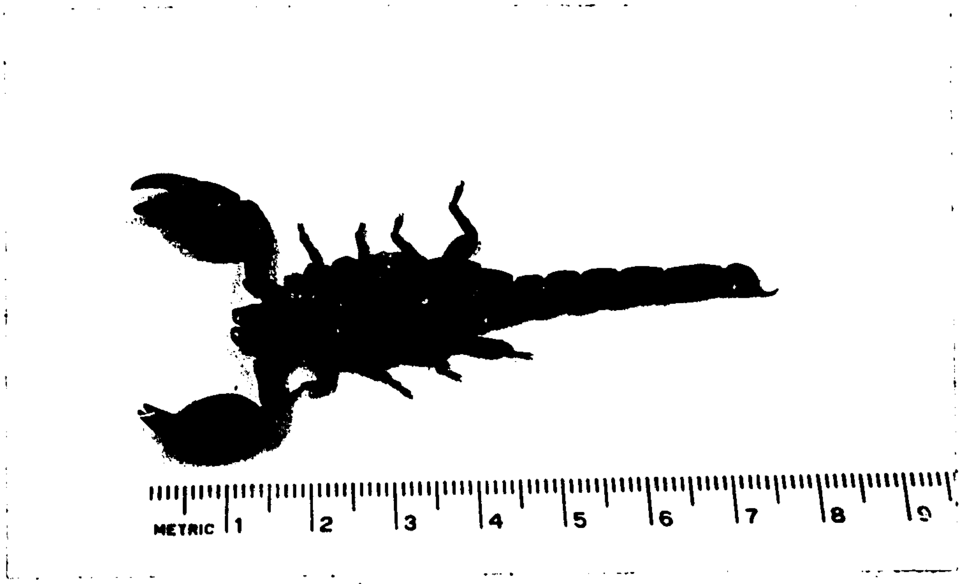

Fig. 14. Scorpio maurus (ventral view)

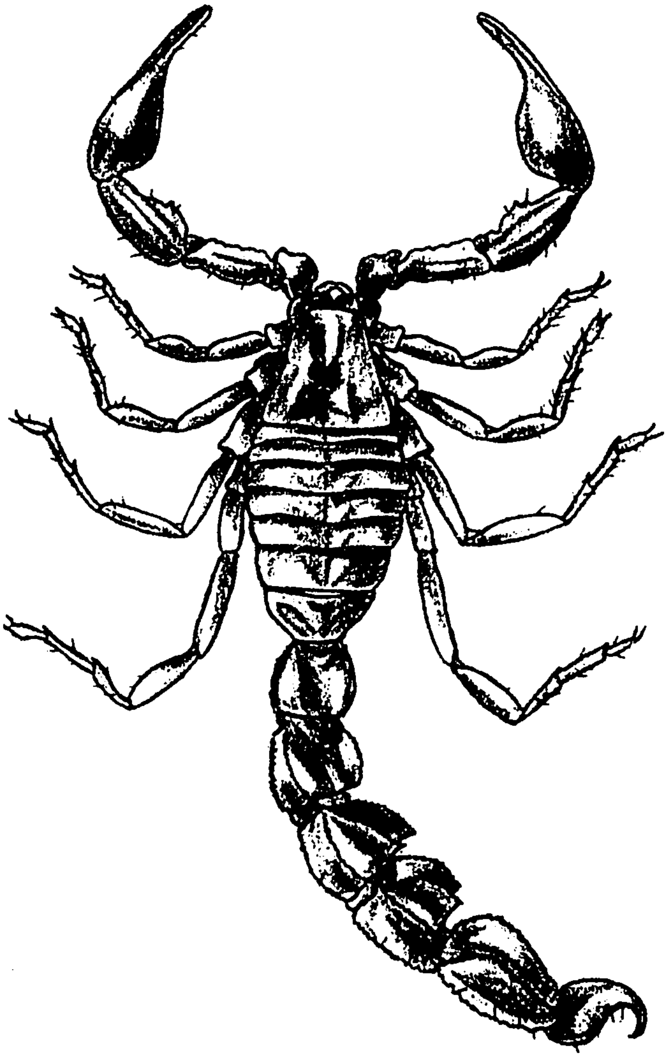

Fig. 15. Androctonus australis (dorsal view)

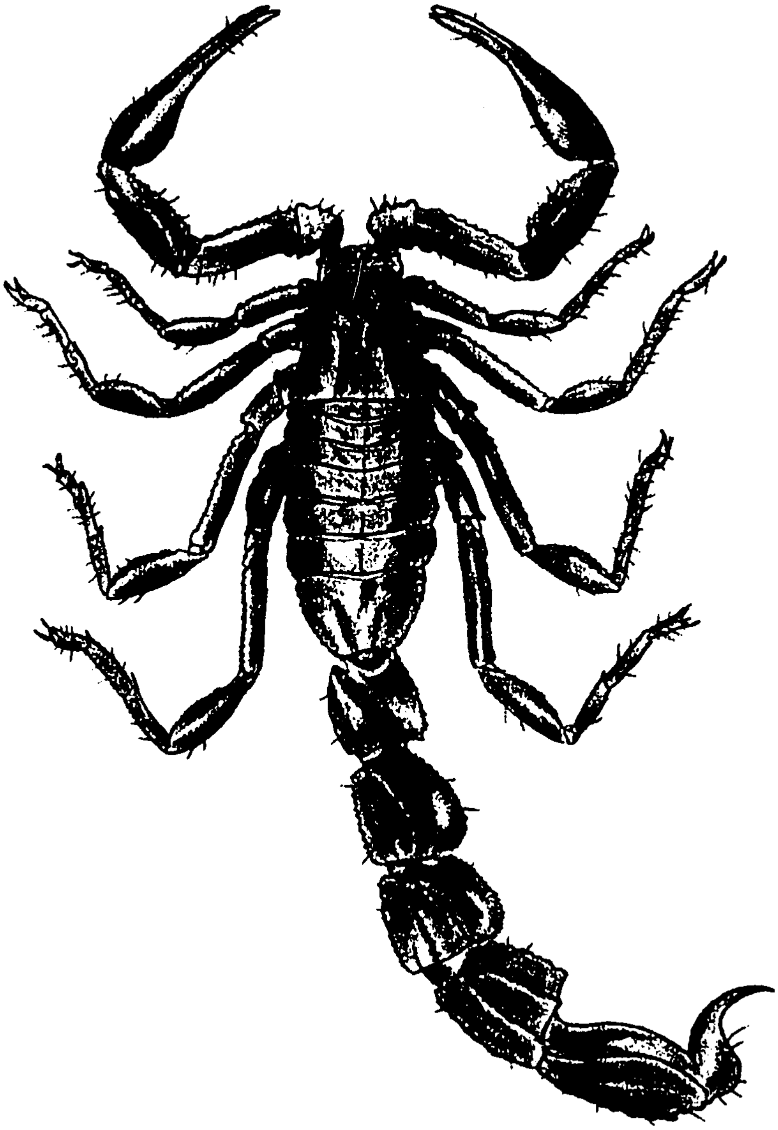

Fig. 16. Androctonus aeneas (dorsal view)

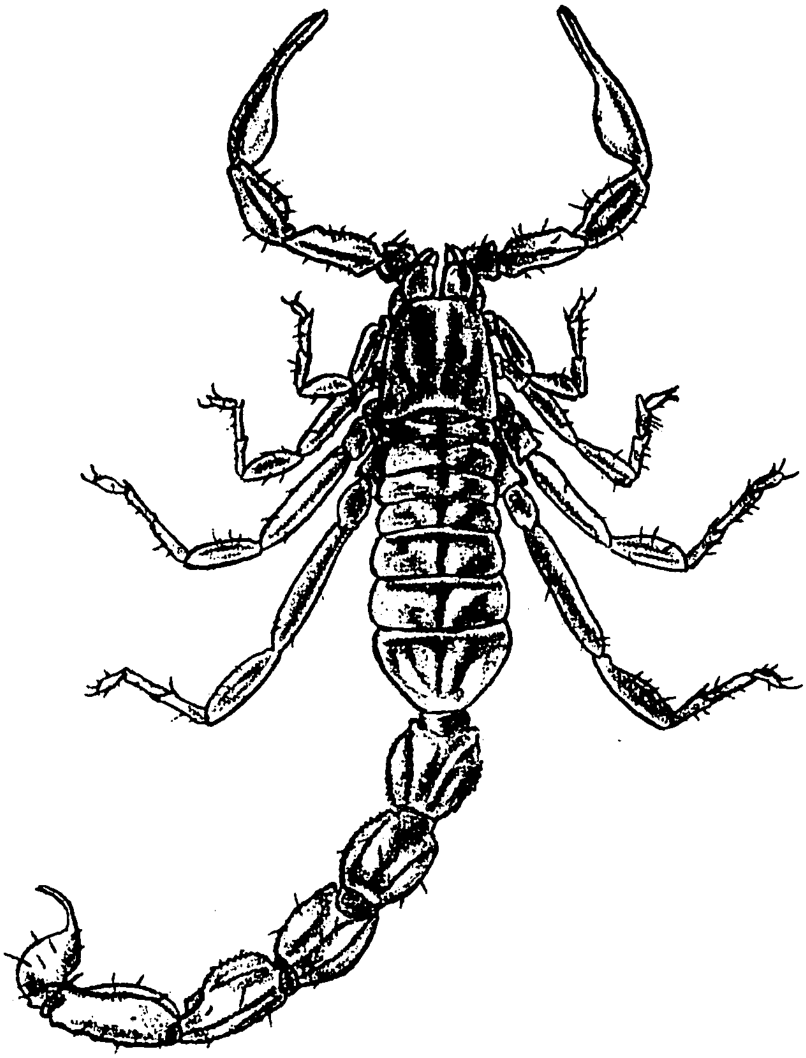

Fig. 17. Buthus occitanus (dorsal view)

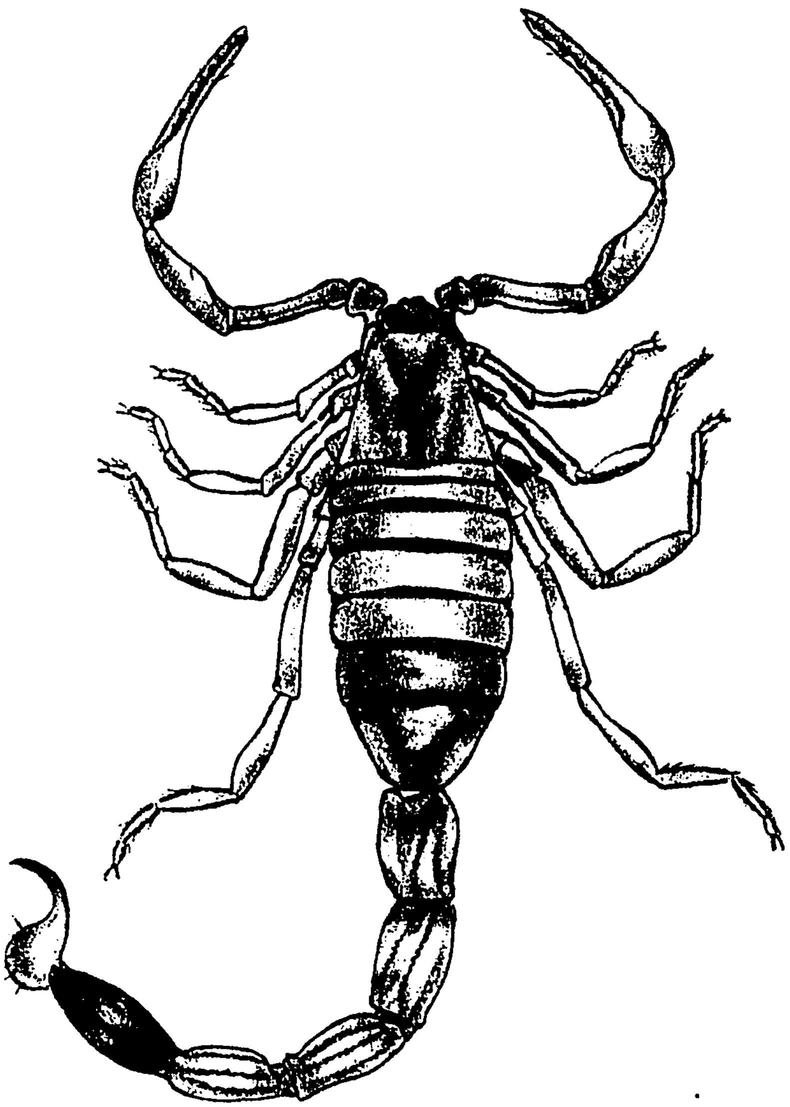

Fig. 18. Leiurus quinquestriatus (dorsal view)

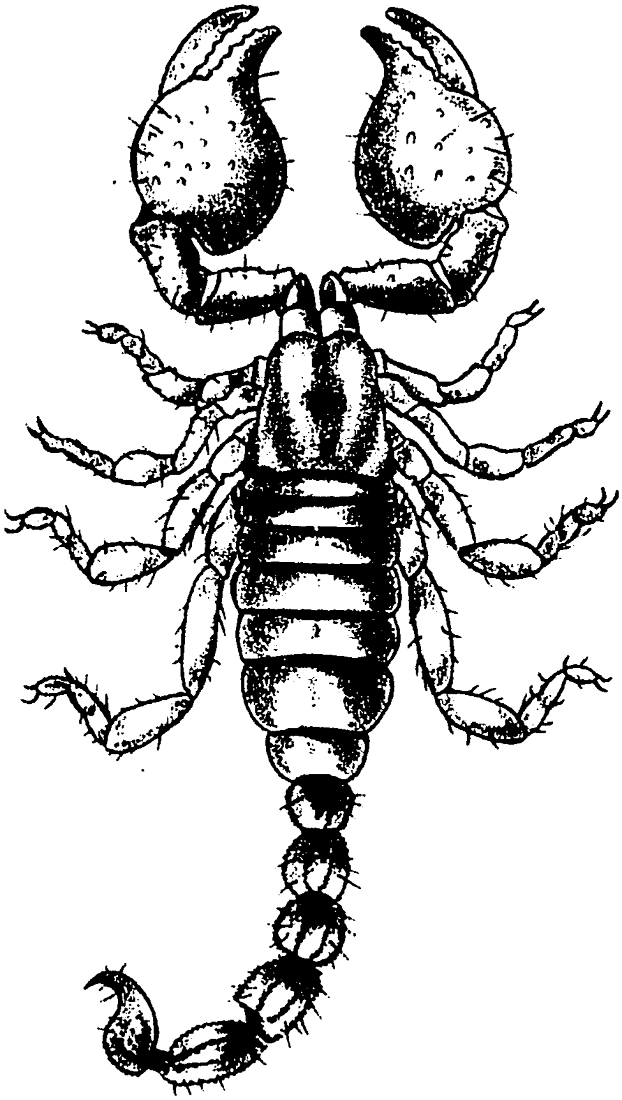

Fig. 19. Scorpio maurus (dorsal view)

Toxicology

In general, scorpion stings are incurred accidentally; more often at night than during the day, and more often when the weather is stormy, the temperature elevated, and with a hot wind blowing. The portions of the body most often stung are the appendages, or at times, the neck or head of a sleeping individual.

Though often fatal to adults, most healthy individuals survive stings satisfactorily; unfortunately, such is not always the case with young children.

Following a sting, the individual first experiences severe local pain. Gradually the person becomes more and more agitated. This agitation does not yield well to tranquillizers or sedatives. Very young children often have convulsions. The pulse rate is increased and becomes progressively arhthymic. Respiratory movements are irregular. Death, when it occurs, is due to respiratory paralysis.

The venom consists of two portions: an insoluble and a soluble. The insoluble portion has the consistency of a mucous and appears to be a mucoprotein. The soluble portion contains the toxin. This latter part contains two toxins, scorpamines, which are basic proteins of low molecular weight. The venom is a poor antigen.

The venom apparatus of the scorpion consists of two glands, each one possessing a venom canal which leads to the pit of the stinger, ending in a small opening at the outer side of the stinger. The venom glands are saclike. High columnar glandular epithelial cells

are attached to a basement membrane. These cells have small, rounded nuclei at their bases. The venom as elaborated in the cells is at first granular, with agglutination of a granular portion, thicker droplets are formed at the middle of the cell body. The final stage of the venom production results in thick droplets breaking off the apical cell wall and being extruded into a central lumen. The ejection of the venom is controlled by the scorpion and is very rapid.

Experiments as to the general toxicity of the venom is determined by the LD_{50} in mice. The degree of sensitivity of the test animals varies with their age and general health. Thus when measuring the LD_{50} of a venom, only mice of known weight and age are employed. Toxicity also appears to vary with the scorpion's geographical origin, for example, the toxicity of A. australis has been shown to vary greatly, depending on the area from which it comes. The most toxic species have LD_{50}'s of 2.5/mg/KG when injected intramuscularly in mice. The venom of L. quinquestriatus, a common form in the southern part of Libya, has an LD_{50} of 6.5.

Also variable is the quantity of venom ejected. For example, the quantity ejected by L. quinquestriatus is less than that of A. australis, but its potency is higher. The venom of A. australis is considered to be as toxic as that of a cobra and has been known to kill an adult in 4 hours and a dog in 7 minutes.

The effect of the sting of Scorpio maurus is considered to be relatively harmless, but nevertheless individuals who have acquaintance with them regard them with considerable fear. Individuals in

the area of Farzugha indicated that due to numerous stings by this species on their hands, their hands had become swollen and arthritic, making movements very difficult.

In the southern part of Libya where Leiurus quinquestriatus (Fig. 11 and Fig. 18) is relatively common, the stings are a problem as indicated in the table of deaths taken from the records of the Central Hospital in Sabha (Table 2).

In the Fezzan there are many clinics which receive people who have been stung by scorpions. When the treatment is promptly administered, using 10 cc (10 ml.) of antivenom, most recover and are released. In some cases, however, possibly due to the delay in the use of antivenom, people have died. In two days of traveling in Wadi Shatti, the writer heard three reports of deaths from scorpions. One was a man of 60 years and two were children. It is reasonable to believe that there are more deaths than appear in the statistics gathered by the hospital.

Conclusions

During the course of this research, an attempt was made to increase our knowledge of the distribution and ecology of the scorpions of Libya. To accomplish this purpose, a collection of scorpions was undertaken over different areas of Libya. Geographically and ecologically, Libya is divided into three belts or zones. Scorpions were collected from each of these zones.

The following species were identified from this work:

Table 2

Deaths Due to Scorpion Stings in Sabha (Libya) 1973-1977
(Data from the Central Hospital of Sabha)

Year	Month	Number of Deaths Reported
1973	August	2
	September	1
1974	August	2
	September	1
1975	May	2
1976	June	1
	July	2
	August	2
	September	2
1977	May	3
	June	1
	July	1
	August	1
	September	1
	Total	22

Androctonus australis (Linnaeus)

Androctonus aeneas C. L. Koch

Buthus occitanus (Amoreaux)

Scorpio maurus Linnaeus

Leiurus quinquestriatus (Hemprich and Ehrenberg)

S. maurus was found only in the northeastern area of Libya in the Green Mountains. L. quinquestriatus was most abundant in the oases of the Sahara, and A. australis was found in all areas studied.

Two species, L. quinquestriatus and A. australis, the fat-tailed scorpion, appear to be responsible for the majority of deaths from scorpion stings that occur in the Fezzan, which is in the south.

Future efforts in studying these animals should be devoted to a better understanding of not only the chemistry of the venom but also its mode of action. Indications are that the virulence of the toxin varies greatly within the same species, depending on the area from which the animals are taken. At present, those species most feared by the inhabitants are the ones that occur in the southern reaches of Libya.

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