IDENTIFICATION AND ADAPTATION OF TERMITES IN THERE TERMITERIAN

BY

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A PROJECT SUBMITTED TO THE
DEPARTMENT OF BIOLOGY
NIGER STATE COLLEGE OF EDUCATION MINNA

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APPROVAL PAGE

This project has been carefully read and approved as meeting the requirement for the award of Nigerian Certificate in Education (N.C.E) in the Department of Biology, Niger State College of Education, Minna.

Project supervisor — Sign/Date: 20th-10-2016

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Determination is the driving force leading to the overcoming of any challenges one may come across in life. Put Almighty Allah first, and then convince yourself that it is possible, you can do it, after all others have done it. We must register our gratitude to Allah (SWT), the sovereign and sustenance of the universe for making it possible for us to have successfully completed this programme. May His infinite mercy continue to perfect on the gentle soul of our most beloved one, Muhammad (SAW) who was sent as a messenger to the world with the message of truth. We wish to express our unlimited appreciation to our supervisor in person of Mall. Gana Ndako who shows his much concerned toward the success of this research work. May the favors of Almighty God be upon him and his family (Ameen). Our special thanks goes to the members of our family for their understanding and support we enjoyed during the course of our study, most especially our parents. This work shall remain incomplete if we did not recognize the moral support we enjoyed from our collique and lots of others that we could not mention their names.

We appreciate you all.

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ABSTRACT

This study was aimed at identifying the termite diversity on a 20km stretch of farmland between C0E Minna and Butu villages in Chanchaga local government area of Niger state, as well as to determine their adaptation mode of feeding was carried out between the month of May and September, 2016. Termites were collected from mound, leaf litter and mound trails. Overall, seven species of termites belonging to two Families were identifed. The species identified include; Macrotermes bellicosus; Curptotermes curvignathus, Nasutitermes havilandi; Odontotermes sp; Nasutitermes arboretum, Amitermes evencifer; and Microtermes spp; Among these, Microtermes bellicosus is the most dominant but was not found to attack crops while N. havilandi, Odontotermes sp., Nasutitermes arboretum, Amitermes evencifer, and Microtermes spp. were recognized as pests of various crops and valuables of humans in their homes.

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Termite or white ant, common name for a soft-bodied social insect of the order Isoptera. Termites are easily distinguished from ants by comparison of the base of the abdomen, which is broadly joined to the thorax in termites; In ants, there is only a slender connection joining these segments. In addition, the antennae of termites are beadlike or threadlike, while ant antennae are elbowed. Termites have chewing mouthparts. They feed chiefly on wood, from which they obtain cellulose. In primitive species cellulose is converted into various sugars by specialized gut protozoans and in the more highly evolved termites by specialized bacteria living symbiotically in the termite's digestive tract. Termites undergo gradual metamorphosis. The nearly 2,000 species are mostly tropical, and some build huge mounds to house their colonies. These mounds is up to 40 ft (12.2 m) high with characteristic feature of the landscape in parts of Africa and Nigeria in particular.

Termites are important components of tropical and sub tropical ecosystems. They are a group of social insects that belong to the Phylum Arthropoda, Class insecta, and Order Isoptera. (Mitchell, 2003). Termites mostly feed on dead plant materials generally in the form of wood, leaf litters, soil or animal dung. Termites are prime example of insects that display decentralized, self organized system, swarm intelligence and co-operation among colony members to exploit food sources and environment that could not be available to any single insect acting alone (Osipitan and Oseyemi, 2012). A typical colony contains nymphs (semi matured young),

workers, soldiers and reproductive individuals, sometimes containing several egg laying queens. Although termites play a beneficial role in ecology, they are also destructive and are a major threat to crops and household properties (Edwards and Mill, 1986). About ten percent of the estimated species of the insects are economically significant as pests that can cause serious structural damage to buildings, crops or plantation forests. The most important termite pest genera in Africa include Odontermes, Macrotermes, Pseudacanthotermes, microtermes, Ancistrotermes, Allodontermes, Amitermes, Trinervitermes and Hodotermes (Mitchell 2003). (Bong 2012) reported that the wood feeder especially Copotermes curvignathus are the main termite species that infest palm plantation and living Agricultural plants. Termites are highly voracious and destructive and cause substantial damage to homes and other wooden structures in our environment. In severe infestation, structural integrity of a building and the safety of the occupiers could be threatened. Termites live a very cryptic life in the soil or wood, building tunnels, aggregate soil into mounds and transferring particles from different layers, a behaviour that alter the physical structure of Agricultural lands and wood structures (Bong 2012). Crops such as yam and cassava, sugarcane, groundnuts sorghum and maize (Sand 2007) (Wood, 2008) and (Logan 2009) are prone to infestation and damage by termites. They also attack grain stores and commonly responsible for mortality of tree, seedlings in forestry and cause considerable damage to buildings and other wooden structures like fence posts and utility poles. Foraging activities in termites is a social procedure (Traniello and Buscher, 2005) (Olugbemi and Malaka, 2004), where the activities of hundreds or thousands of individuals are coordinated by trail pheromones, which stimulate foragers to leave the nest and orient themselves to a food find. Accordingly, a scouting termite returns to the nest after locating food in a trail laying posture, and discharging

sterna gland pheromone (Kaib, 2000). (Traniello 2004) stated that exploratory activities for food are randomly carried out by workers of Reticulitermes sp. with rewarded individuals returning to the nest in trail laying posture.

1.2 Statement of Research Problem

Identification is the key to any termite management strategy and thus it is important to obtain samples of soldier termites and winged adults. Winged ants are often mistaken for winged termites, but several characteristics can be seen with the naked eye that will help differentiate the two insects. Ants have two pairs of transparent wings of unequal size, while termites have four equal-sized wings that generally fold over the back. In addition, the region of the body behind the wings is "pinched" in ants but completely straight in termites. Termites are sometimes referred to as "white ants" because they look like ants but they are found in a mud tube. The researchers intend to collect these white termites and used them for identification purpose.

1.3 Aims and objectives of the study.

- To collect and identify species of termite found in the study area, using suitable identification keys
- To identify the pests species of termite found in the study area.
- To ascertain mode of feeding of the termite.

1.4 Limitation and Scope.

The study was conducted in Minna metropolis, Niger State, located within longitude 633'E and latitude 93'N, with a land mass of 88 Km^2. The vegetation of the area reflects that of Savannah zone, dominated by grasses with scattered trees species. The climate presents two distinct seasons, a rainy season between April and

October, and, a dry season (November-March) completely devoid of rain. The study was carry out on a 10km stretch of farm land between Beji and makunkele in Bosso local Government are of Niger state. Niger State experiences distinct dry and wet seasons with annual rain fall varying from 1,100mm in the Northern and Southern parts to 1,600mm. The maximum temperature usually not more than 94^{c} is recorded between March and June, while the minimum is usually between December and January. The rainy seasons last for about 150 days in the northern parts to about 120 days in the southern parts of the State. Generally, the fertile soil and hydrology of the State permits the cultivation of most of Nigeria's staple crops and still allows sufficient opportunities for grazing, fresh water fishing and forestry development.

Three major soils types can be found in the State. These include the ferruginous tropical soils, hydromorphic soils and ferosols. The most predominant soil type is the ferruginous tropical soils which are basically derived from the Basement Complex rocks, as well as from old sedimentary rocks. Such ferruginous tropical soils are ideal for the cultivation of guinea corn, maize, millet and groundnut.

Hydromorphic or waterlogged soils are largely found in the extensive flood plain of the Niger River. The soils are poorly drained and are generally grayish or sometimes whitish in color due to the high content of silt. Ferosols which developed on sandstone formations can be found within the Niger trough. Their characteristic red color enriched with a clay sub soil is noticeable in the landscape. Termite hills dot the landscape, particularly between Minna, Bida and Beji. These can be seen along the major highways in the state. The Southern Guinea Savannah vegetation covers the entire landscape of the state. Like in other states of similar vegetation, it is characterized by woodlands and tall grasses interspersed with tall dense species. However, within the Niger trough and flood plains occurred taller trees and a few oil palm trees. In some areas, traces of rain forest species can be seen.

CHAPTER TWO

LITERATURE REVIEW

2.1 Biology of Termites

Termites live in a true social group with a division of labour among the different caste of individuals: reproductive adults, soldiers and workers (Noirot, 2000). Termites have a complex life cycle with the development of individuals that look and behave differently from other members of the group. According to (Edwards and Mill 2006), there are three general developmental stages: egg, immature and adult in termite's life cycle known as incomplete metamorphosis. The role of the winged adult is dispersal and reproduction, the actual work of the colony and expansion of the colony`s foraging is done by the caste of workers, while the soldiers defend the colony (Forschler and Jenkins, 2000). Winged adults alates or swarmers represent a primary caste of individuals within the termite colony. They disperse from their colony of origin in a series of flights or swarms at precise time of the year. Adults are attracted to lights, where pairing begins. The swarmers on reaching the ground shed their wings and started searching for a suitable place to initiate a colony. The males are attracted to the females by a scent or pheromone. They dig into the wood or moist soil depending on the species and form a chamber. Mating occurs within the nuptial chamber, and the queen once fertilized, initiates the new colony as she begins to lay eggs.

2.2 Ecology of Termites

Termites are a highly successful group of true social animals, as evidence by their worldwide distribution and evolutionary persistence (Paul and Rueben, 2005). They

serve an important ecological role in the decomposition of cellulose materials that cannot be chemically broken down without the present of the enzyme, cellulose (Pearce, 2007). According to (Bignel 2000), primitive termites do not produce sufficient cellulase for survival, but contain protozoans in their gut that aid in cellulose breakdown. This interaction is an obligate mutualism for both termite and protozoan (Bignell, 2000). Higher termites (Termitidae) do produce sufficient cellulase in their mid gut to digest adequate nutrition from cellulose, but still form mutualism with both bacteria and fungi biota (Abe 2000). Under natural conditions in the desert, termites feed on dead plant materials, including roots, leaf litters, grass, cactus skeletons, dungs and humus (Jones and Nutting, 2009). According to Su and (Scheffrahn 2010), although the feeding activity of termites is critical to the recycling of nutrients in the ecosystem, unfortunately they infest human made structures and damage lumber, sheetrock , wallpaper, wood panel and furnitures. Termites spend their entire life in soil or within their source of food, and once removed from their protected environment and favourable humidity, they die (Edwards and Mill, 2006). According to (Lee 2002), termites do not feed on concrete, stucco, fiberglass insulation or other non organic materials. However, they can damage these materials and use them to line and support their shelter tubes. Termites can be categorized based on habitat:

Damp wood,

Dry wood

And subterranean.

Damp wood and dry wood can be pest under certain situations. The damp wood termites Paraneotermes simplicicornis (Banks) require more wood moisture than is provided by ambient humidity. Under natural conditions, they are restricted to moist

wood in contact with the damp soil Light, The dry wood termites are pests of sound dry structural lumber or wood furniture. They require no contact with the soil and live entirely within their food source (Scheffrahn, 2010). The subterranean termites is the most widespread and destructive group. They derived their name subterranean termites because of their association with the soil. They construct underground tunnels to move about in search of food. Subterranean termites can be pervasive pest and account for about 80% of loses to wooden structures.

2.3 Economic Importance of Termites.

Destructive Effects of Termites

The destructive effects of termites to man, whenever they interact with each other is very enormous. It includes the damages done to the timbers used in buildings and for other purposes (Scheffrahn, 2000); Sornnuwat, 2006). (Lee and Wood 2002), (Pearce 2007), and (Ahmad and Yaacob 2007) reported that some of the termites species involved are the soil inhabitants. In addition to the attacks on buildings, termites also damage man made fabrics (textile materials), plastics (polytene, polyvinyl chloride), and some metal foils (Howse, 2000). Termites are among the most important insect pests in certain forest and many of the destructive species live in the soil, for example the species that cause most damages in Ausralian forest, Coptotermes acinaciformis is a soil inhabitant (Gay and Galaby, 2000). The economic loss may be great as (Gay and Galaby 2000) estimated in Virgin Eucalyptus pilularis, forest termite Coptotermes acinaciformis caused 92% of the total loss. (Harris 2000), reported that in parts of Africa damages to trees are common, however the introduced trees particularly Eucalyptus species are severely attacked. In April 2011, wood eating termites were reported to have consumed more than $220,000 worth of Indian rupee notes. (Ohiagu 2009), gives a lot of

information on termite as a major pest in Nigeria. The major termite pest species is Macrotermes. This termite lowers yield of plants in light soils with low moisture. Estimates of loses reported from various locations in the northern states of Nigeria ranges from 5 – 18%. The areas involved are Samaru (Kaduna State), Bakura (Sokoto State) and Hadeija (Jigawa State). (Ohiagu 2009) also reported damage done by termites to three major cereals crops, maize, millet and Sorghum in various parts of Northern Nigeria. (Harris 2000), reported that Macrotermes bellicosus attack the root of seedlings in Nigeria, while Macrotermes subhyalinus cut the stems of rice as the plant ripen and this causes loses from 15–20% per plot. (Sands 2007) reported 40% yield loss of cassava due to termites attack in Nigeria, and the species involved are Pseudo canthotermes, Odontermes, Ancistotermes and Nucrotermes. Mounds formed by termites make proper preparation of fields for cultivation difficult, they also interferes with traffic, if formed on the tracks or along the roads. The mounds can also form a source of termite infestation of field crops (Reddy2010) (Piper, 2007). Termites cause denudation of grass land, they even compete with livestock in the removal of grass. (Ohiagu 2009) in Nigeria reported a grass removal rate of about 81Kg per hectare per annum for Trinervitermes germinatus at Mokwa.

Beneficial Aspects of Termites

In spite of the destructive activities of termites, man should not look upon termite as being totally harmful, they too have their place and uses within the environment, where they exist (Abe 2000). (Chatterjee 2002) and (Eggleton 2007), stated that among the beneficial aspect of termite is decomposition, they cause to dead wood in the forest, which would have pile up and suffocate young plants, and through the decomposition they increase mineral component of the soil, by introducing into the

soil mineral nutrients of the dead woods, also the burrowing they made in the soil increase water absorbent of the soil.

(Harris 2000) reported that termite mounds have been used in making bricks for building, pottery, for plastering walls and for surfacing roads and pavements. The hard materials of the mound are also used in making tennis courts. (Lee and Wood 2008), reported that termite mound material is useful in construction of ovens.

Termite has been considered as a source of energy. Termite can produce up to two litres of hydrogen from digesting a single sheet of paper, making them one of the planets most efficient bioreactors. Termites achieve this high degree of efficiency by exploiting the metabolic capabilities of about 200 different species of microbes that inhabit their hindgut. The microbes in the termites gut efficiently manufacture large quantities of hydrogen, the complex lignocelluloses polymers within the wood are broken down into simple sugars by fermenting bacteria in the termite's gut, using enzymes that produce hydrogen as a bye product.

Termites themselves have been used as food in certain parts of the world. In countries where termites are found in large numbers, the inhabitants capture the flying forms for food. The Alate termites are nutritious, with a good store of fats and protein (Engel and Krishna, 2004). (Ene 2003), reported that 90.6% Alate termites are eaten by people in West Africa. Termites tend to form a useful source of animal protein in places where meat is scarce (Harris, 2000). He also reported the composition of roasted flying termite to be Ash 6.42%, Fat 44.40%, Protein 36.0%, Chitin 5.09%, and 560 per hundred grammes caloric value.

Termites serve as ecological indicator. Termite knolls has been used as an indicator of underground water, also a well developed, active, permanent colony of mound building termites has been considered as an indicator of underground springs in proximity in India IHP, (1990). Termites are important in habitat formation as

shown in their role in hollowing timbers and thus providing shelter and increased wood surface area for other creatures. Large termite mould play a significant role in providing habitat for plants and animals, such as smaller animals and birds, and a growing medium for woody shrubs with root system that cannot withstand inundation for several weeks. Few zoos hold termites in captivity, due to the difficulty in keeping them captive and the reluctance of the authorities to permit potential pests e.g. Zoo Basel in Switzerland hold two African termites (Macrotermes bellicosus). Their populations exist and thrive.

Termites serve as a source of income to people wherever they exist, for instance termites are commonly sold in Tropical African markets and they can also be pressed to extract cooking oil (Ene, 2003). The large population of termite nests are collected by inhabitants in rural areas, and used as poultry feeds, especially for domestic fowls, thereby making their flesh more delicious (Harris, 2007); (Marthur, 2006).

CHAPTER THREE

METHODOLOGY

3.1 Study Area: Location

The study was carried out on a 10km stretch of farmlands between Beji and Makunkele along Zungeru Road in Bosso Local Government Area of Niger state, Nigeria. The study area was selected because of the heavy presence of termitaria.

3.2 Climate

The State experiences two distinct seasons the dry and wet seasons. The annual rainfall varies from about 1,600mm in the south to 1,200mm in the north. The duration of the rainy season ranges from 150 210 days or more from the north to the south. Mean maximum temperature remains high throughout the year, hovering about 32F, particularly in March and June. However, the lowest minimum temperatures occur usually between December and January when most parts of the state come under the influence of the tropical continental air mass which blows from the north. Dry season in Niger State commences in October.

3.3 Soils and Vegetation:

Three major soils types can be found in the State. These include the ferruginous tropical soils, hydromorphic soils and ferrosols. The most predominant soil type is the ferruginous tropical soils which are basically derived from the Basement Complex rocks, as well as from old sedimentary rocks. Such ferruginous tropical soils are ideal for the cultivation of guinea corn, maize, millet and groundnut. Hydromorphic or waterlogged soils are largely found in the extensive flood plain of the River. The soils are poorly drained and are generally grayish or sometimes

whitish in colour due to the high content of silt. Ferosols which developed on sandstone formations can be found within the Niger trough. Their characteristic red colour enriched with a clay sub soil is noticeable in the landscape. Termite hills dot the landscape, particularly between Minna, Bida and Kontagora. These can been seen along the major highways in the state. The Southern Guinea Savannah vegetation covers the entire landscape of the state. Like in other states of similar vegetation, it is characterized by woodlands and tall grasses interspersed with tall dense species. However, within the Niger trough and flood plains occur taller trees and a few oil palm trees. In some areas, traces of rain forest species can be seen

3.4 Materials

The materials used include a brush, 70% alcohol in a bottle, hand lens, dissecting microscope and a white paper.

3.5 Sampling Method

Sampling was done during the rainy season of the year 2016 (between May to June, 2016). Five farms were randomly selected for sampling chiefly due to the heavy presence of termitaria. Sampling was also carried out on uncultivated areas of the study sites and this was done every two weeks within the sampling period. Termites were collected from different habitats such as mounds, weed residue, under leaf litter, under opaque bark of trees and logs. Termites were also collected from unhealthy plants. Vials of collected termites were labelled and all possible observations on their habitat including the mound characteristics or trail pattern were noted. Termites were collected with the aid of a brush as they rush out of their mounds when the top were cut open with a matchet.

3.6 Preservation

The collected termites were preserved in 70% alcohol and taken to the laboratory for identification.

3.7 Identification

Termites were identified using various identification keys present in the Lab of the department of Biology, School of Sciences, Niger State College of Education Minna. Identification was done with the aid of a hand lens and microscope. Most of the specimens were identified to the species level based on the morphology of the soldier caste. Most of the features used include: color appearance, shape of mandibles, shape of head capsule and labrum, number of abdominal segments, number of antennal segments, type of mandible, number of bristles on labrum, number of bristles near the fontanel, presence of teeth on mandibles. These features were compared with the picture gotten from the internet and Textbooks.

CHAPTER FOUR

4.0 Results and Discussion

On the whole, seven species of termites belonging to two Families were recorded from the study area. The species recorded include those that trails on plant and therefore recognized as pest species. The species recorded include:

Macrotermes

Odontotermes

Caltatermes

Entermes

Macrotermes bellicosus

The identification of this species was based on the soldier caste. The head is very large. Length of head with mandibles is between 6 to 8 mm. the head is conspicuously distended. Mandible is strong, fully developed and sabre shaped. Pronotum saddle shaped with a distinct anterior lobe. Labrum with an anterior translucent lobe. Eye is absent.

Behaviourally, they are very aggressive, build large epigeal mound, and are relatively large species. It belongs to:

Family: Termitidae

Sub-family: Macrotermitinae

Genus: Macrotermes

Species: *Macrotermes bellicosus*

Fig.1 Name: *Macrotermes bellicosus* minor worker, which is paler and smaller than the major workers

Fig.2 A major soldier of the termite *Macrotermes carbonarius*

Fig.3 Major workers of the termite *Macrotermes carbonarius*

Coptotermes curvignathus

This species was collected from trails made on tree trunk and is therefore recognized as a pest species. The identification of this species was based on the soldier caste. They have brownish-yellow, oval shaped head capsule with head capsule with scattered bristles. They have long sabre shaped slashing mandibles and are strongly incurved at the apical. The left mandible has three crenulations at base while right mandible is without crenulations. Labrums are yellowish in colour and have a distinct pair of long bristles on the tip and few bristles on the disc. They also have large fontanels with two long bristles at the rim. The antenna is sixteen segments and the abdomen has ten segments.

Behaviourally, they excrete a white fluid from their fontanelle when disturbed or attacked. The species belong to:

Family: Rhinotermitidae

Sub-family: Coptotermitinae

Genus: Coptotermes

Species: *curvignathus*

Name: *Coptotermes curvignathus.*

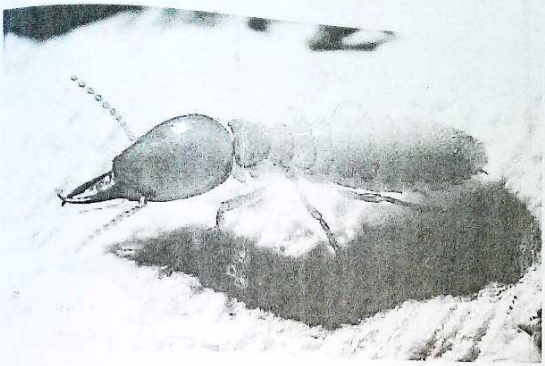

Fig.4 *Coptotermes curvignathus*

Nasutitermes havilandi

This species was detected based on their mud trails from the ground to tree trunk. The species was identified based on soldier caste. The head (without rostrum) is ovallike and width is longer, wider than length. Their mandibles have been reduced to nasus. The head reddish-yellow to brownish yellow with a pair of bristles on posterior of the head and four

short bristles on side of rostrum base. Dorsal profile of the head capsule is nearly straight. Rostrum is short and cone shaped and the tip of the rostrum is reddish-brown and darker than the head. Nasus without rudimentary teeth. They have ten abdominal segment and thirteen antennal segments.

Behaviourally, they are glue squirting termite. They are relatively small species with the worker being larger than the soldier. The species belongs to:

Family: Termitidae

Sub-family: Nasutitermitinae

Genus: Nasutitermes

Species: *havilandi*

Name: *Nasutitermes havilandi*

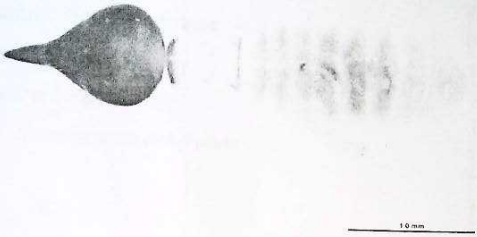

Fig.5 *Nasutitermes Havilandi Soldier*

Fig.6 *Nasutitermes havilandi Worker.*

Nasutitermes arboretum

This species built an arboreal carton nest on tree branches. The identification was also bases on the soldier caste. The head (without rostrum) are sub- circular. Dorsal

profile of head capsule show a shallow concave at the middle. It is larger than *Nasutitermes havilandi.*

Behaviourally, they show similar features with Nasutitermes havilandi. The species belongs to:

Family: Termitidae

Sub-family: Nasutitermitinae

Genus: Nasutitermes

Species: *arboreum*

Name: *Nasutitermes arboretum.*

Fig.7 *Nasutitermes arboreum Soldier*

Odontotermes sp.

These species were collected on a mound built on the decaying wood. the identification was based on the soldier caste. head is reddish brown, labrum light reddish brown, antennal light brown with yellow tinge at the base, dark brown distally. rest of the body yellow with brownish tinge. head with a few bristles along

the periphery. postmentum with few bristles in the anterior half. pronotum, legs and abdomen sparsely hairy with a few bristles. head broadly oval and narrowed anteriorly. post mentum much longer than broad. Antennal with 16 segments, second nearly twice as long as third and forth combined.

Labrum tongue shaped, lateral side slightly convex, converging anteriorly into a rounded tip. mandibles long, slender, tips slightly incurved, left mandible with a prominent anteriorly directed tooth near the base. pronotum is saddle shaped. the species belongs to:

family: termitidae

sub-family: odontotermitinae

genus: odontotermes

name: *odontotermes sp.*

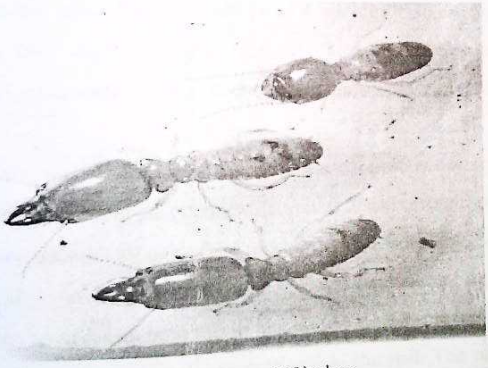

Fig.8 *Odontotermes sp.* Soldier and Worker.

CHAPTER FIVE
SUMMARY AND CONCLUSION

5.1 Summary

The study examined the identification and adaptation of terminte in their Termiteria with the recognition of five different species between makunkele and Bosso in BossoLocal Government Area in Niger State which is well known for termite activities. It's also examined the adaptive features of the individual termite in the study area.

5.2 Conclusion

Termites construct termitaria which are edifices of various shapes depending on the species. these edifices help combating erosion, apart from the fertility that termites add to the soil. they also serves as a source of food (protein supplement in the body). This study on a Identification of termites species were able to identify four species of termites in the study area with macrotermes bellicosus dominating the area.

From the review, termites have been known to exist for several years and its study only known within past century. Termites are known all over the world and several families and species exist. The most prominent among these termites is the Isoptera. Generally, termites are the principal decomposer of organic materials thereby helping to recycle nutrient in our soils. Their role as nutrient recycler in our environment helps to balance nutrients in the soil. The particle size selection aids the re-arrangement of soil which brings about an improvement in some physical properties.

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