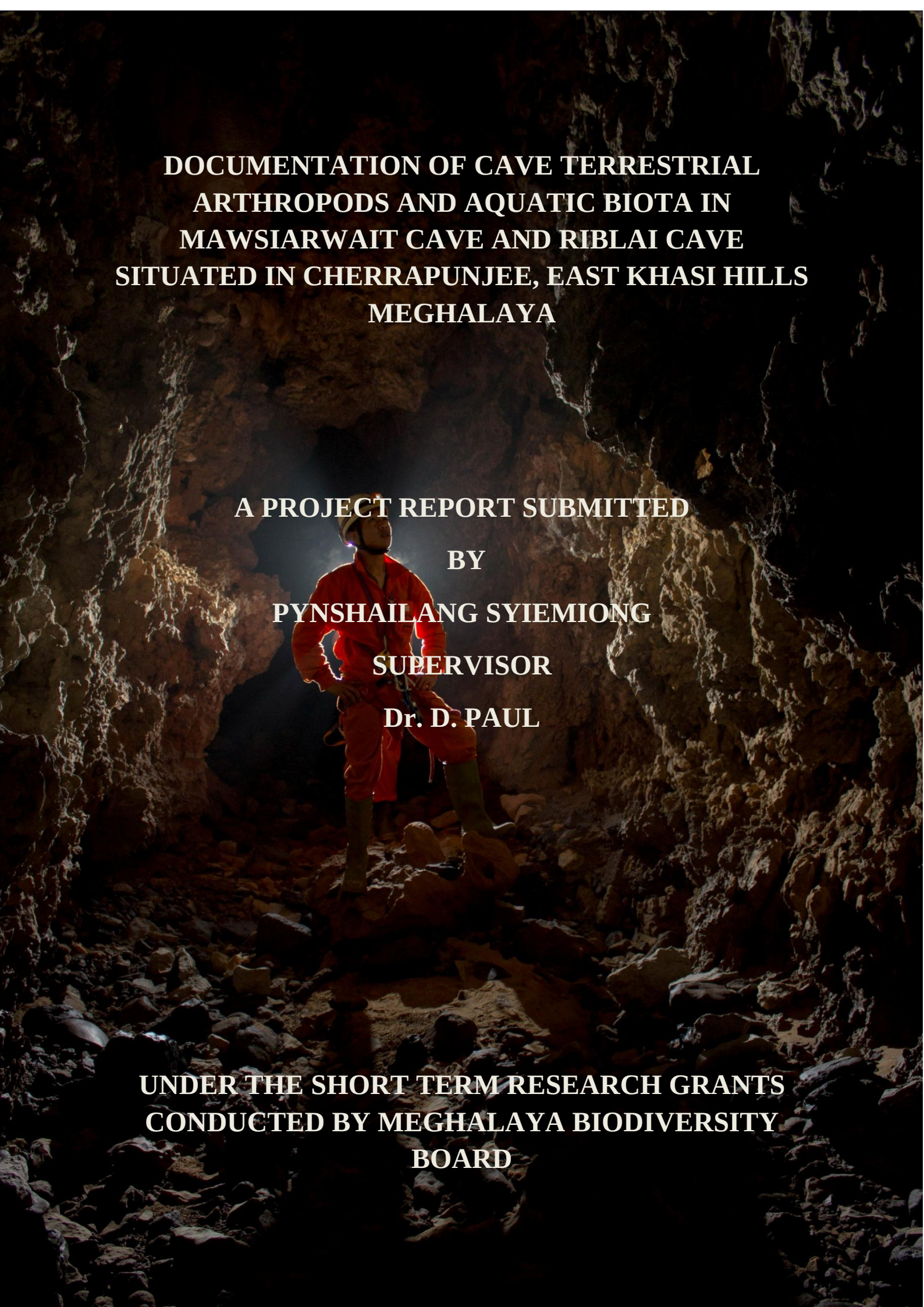
DOCUMENTATION OF CAVE TERRESTRIAL ARTHROPODS AND AQUATIC BIOTA IN MAWSIARWAIT CAVE AND RIBLAI CAVE SITUATED IN CHERRAPUNJEE, EAST KHASI HILLS MEGHALAYA



A PROJECT REPORT SUBMITTED

BY

PYNSHAILANG SYIEMIONG

SUPERVISOR

Dr. D. PAUL

UNDER THE SHORT TERM RESEARCH GRANTS CONDUCTED BY MEGHALAYA BIODIVERSITY BOARD

2015-2016

DECLARATION

I**PynshailangSyiemiong**hereby declares that the work entitled, **"Documentation of Cave Terrestrial Arthropods and Aquatic Biota in Mawsiarwait Cave and Riblai Cave Situated inCherrapunjee, East Khasi Hills, Meghalaya"** is my original work. It is the record of work done by me, under the supervision of Dr. D. Paul. The whole work is carried out by the financial assistance from the Meghalaya Biodiversity Board Office under the Short Term Research Grants for a period of one year 2015 – 2016.

This is being submitted in partial fulfilment under the terms and condition laid down by the office of Meghalaya Biodiversity Board.

Place: Shillong

Dated: 15th May, 2016 **PYNSHAILANG SYIEMIONG**

(Prof.D.PAUL)

Meghalaya Biodiversity Board **Supervisor**

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1. Introduction

Meghalaya, a Sanskrit word for *"the abode of clouds"* is among the seven states in North East India. It covers an area of approximately 22,430 square kilometers. This state lies between is bounded to the south by the Bangladeshi divisions of Mymensingh and Sylhet, to the west by the Bangladeshi division of Rangpur, and to the east by Indian Assam state.The state is the wettest region of India, recording an average of 12,000mm (470in) of rains a year. About 70% of the state is cover in forest. The Meghalaya subtropical forests, eco-region encompasses the state; its mountain forests are distinct from the lowland tropical forests to the north and south. The Meghalaya forest are well known for its rich biodiversity in flora and fauna. Meghalaya has predominantly an Agrarian economy with a significant commercial forestry industry. The important crops are potatoes, rice, maize, pineapples, bananas, papayas, spices, etc. The state is geologically rich in minerals.

The state of Meghalaya is mountainous, with stretches of valleys and highland plateaus, and is geologically rich. It consists mainly of Archean rock formations with rich deposits of valuable minerals like coal, limestone, uranium and sillimanite. Meghalaya has many rivers. Most of these are rainfed and seasonal. The important rivers in the Garo Hills region are Daring, Sanda, Bandra, Bhogai, Dareng, Simsang, Nitai and Bhupai. In the central and eastern sections of the plateau, the important rivers are Khri, Digaru, Umiam, Kynshi (Jadukata), Mawpa, Umiam or Barapani, Umngot and Myntdu. In the southern Khasi Hills region, these rivers have created deep gorges and several beautiful waterfalls. The elevation of the plateau ranges between 150m (490ft) to 1,961m (6,434ft). The central part of the plateau comprising the Khasi Hills has the highest elevations, followed by the eastern section comprising the Jaintia Hills region. The highest point in Meghalaya is Shillong Peak overlooking the city of Shillong. It has an altitude of 1961m. The Garo Hills region in the western section of the plateau is nearly plain. The highest point in the Garo Hills is Nokrek Peak with an altitude of 1515m.

1.1. Flora and Fauna

The floral diversity of Meghalaya is well reputed for its richness and has been a centre of attraction for many botanists. The presence of a large number of primitive flowering plants has prompted Takhtajan (1969) to name it the 'Cradle of Flowering Plants'. Meghalaya harbors about 3,128 species of flowering plants and contributes about 18% of the total flora of the country, including 1,237 endemic species (Khan et al., 1997). A wide variety of wild cultivable plants, edible fruits, leafy vegetables and orchids are found in the natural forests of Meghalaya. However due to overexploitation, deforestation, and habitat destruction, many endemic and threatened species are now mainly confined to the protected areas and sacred groves. The region is a habitat for many botanical curios and rarities. Among insectivorous plants *Nepenthes khasiana* and two species of *Drosera*(*Droserapeltata* and *Droseraburmanii)* are important. *Nepenthes khasiana* is endemic to Meghalaya and listed in Appendix I of CITES and placed in Schedule VI of the Wildlife (Protection) Act, 1972. The Khasi and Jaintia hills are considered to be the centre of diversity for several primitive families such as *Elaeocarpaceae, Elaeagnaceae, Anonaceae, Ranunculaceae, Piperraceae, Menispermaceae, Caryophyllaceae, Lauraceae, Myricaceae, Lazarbiaceae* and primitive genera like *Sarcandra, Corylopis, Myrica, Magnolia* and *Michelia*.

Faunal diversity is also well represented by the presence of a variety of vertebrates (about 958 species and sub species belonging to 451 genera), and about 4580 species and sub species of invertebrates belonging to 2094 genera. Meghalaya is the home for 7 species of Primates, of which,Hoolock gibbons is one that has been classified as Endangered (EN) under the ICUN Red List. Meghalaya also has three of the six largest cats recorded in the world, Tiger *(Pantheratigriss*), Leopard (*Pantherapardus*),and the Clouded Leopard (Neofelisnebulosa). The forests of Meghalaya also support other species of Mammals like Gaur-Indian Bison (*Bosgaurus*), Hog Deer (*Axis porcinus*), and Asian Elephant (*Elephas maximus*). There is a wide variety of birds in Meghalaya with about 659 species of which, 34 species found in Meghalaya forest are globally threatened species. The reptiles' fauna of Meghalaya are generally influenced by the Indo-Chinese elements. The diversity of reptiles comprises of 12 species ofturtles and tortoises, 26 species of lizards and 56 species of snakes. Amphibians, Pisces and Mollusca are also found in large number with in the state. Within the Northeastern state, Meghalaya is also

abundance with Amphibian having up to 33 species. approximately, 500 species of butterflies found in Meghalaya and some of them are rare. Due to the presence of caves in the southern limestone ridges, Meghalaya has a rich bat fauna and some unique species are present (Thabah et al. 2005, Ruedi et al.,2012).

1.2. Geology of Meghalaya

Geologically the Meghalaya plateau comprises of rocks from the oldest Precambrian gneissic complex to the recent alluvium formations. The Precambrian gneissic complex comprising paragneisses and orthogneisses, migmatites. The stratrigraphic sequence is as the Cretaceous –Tertiary sediments, the Sylhet trap, the Lower Gondwana rocks, the Shillong Group of rocks and the Precambrian gneissic complex (Basement gneiss).The Precambrian gneissic complex comprising para and orthogneisses, migmatites and the Shillong Group of rocks comprising mainly quartzites are exposed in the central, eastern and northern parts of the Meghalaya plateau. They are intruded by basic and ultrabasic intrusives and late techtonic granite plutons.The lower Gondwanarock of Permo-Carboniferous age are recognized at the western part of Garo Hills and consists of pebble bed, sandstone, and carbonaceous shale. The Sylhet trap of middle Jurassic age comprising mainly of basalt, rhyolites, acid tuffs, is exposed in a narrow E-W strip along the southern border of Khasi Hills.The Cretaceous – Tertiary sediments occupying southern part of the Meghalaya plateau comprises of the Khasi Group (arenaceous facies), the Jaintia Group (calcareous facies) and the youngest formation the Garo Group which is represented as Simsang, Bagmara and Chengapara formations. Besides these the DupiTilla group of mid-Pliocene age occurs in the western part of Garo Hills and towards south of Khasi Hills (Figure 1). Isolated patches of older Alluvium overlie the Tertiary rocks along the southern and western borders of the State. The recent Alluvium formation is mostly found in the river valleys of Garo & Khasi Hills Districts.

Million Years Before Present (approx.)	Geological Age	Geological Events in Meghalaya	Main Tectonic Events
1.8 to 0	Pleistocene / Holocene	Valley alluvium deposition and terracing	Oblique compression of Indian sub-continent against Asia. Continued faulting and uplift
		unconformity	
23 to 1.8	Miocene - Pliocene	Deposition of delatic Surma Tipam & Dupi Tila coarse clastic delta sediments	Shillong Plateau & Himalayan uplift. Development of Naga fold and thrust belt
		unconformity	
34 to 23	Oligocene	Rapid deposition of Barail & Garo Group coarse delatic sediments around margins of Shillong Plateau	Shillong Plateau uplift and development of Disang Through to SE of Meghalaya
40 to 34	Late Eogene	Sedimentation of Kopili Formation shales and sandstones	Indian sub-continent collides with Asian plate and causes Disang fold belt, Naga thrust etc. to start forming
65 to 40	Paleocene to Middle Eocene	Shelf sedimentation of Langpar and Shella limestones and clastics in shallow warm seas around margins of Shillong Plateau	Rapid northward drift of Indian sub-continent towards Asia. Oblique ocean subduction along Java Trench and northward subduction beneath Asia
75 to 65	Late Cretaceous	Sandy and conglomeratic fluvial and shallow marine sedimentation of Khasi Group flanking Shillong Plateau	Continued drifting of Indian continental margins
		unconformity	
145 to 107	Late Jurassic Early Cretaceous	Extrusion of Sylhet Trap volcanics along Dauki Fault zone and alkaline intrusions at Sung	Break-up of Gondwanaland with rifting apart of Indian sub-continent from surrounding continents
		unconformity	
690 to 480	Neo-Proterozoic to Early Paleozoic	Granite plutonism and basic dyke intrusion	
		unconformity	
2050 to 1000	Paleo- to Meso Protozoic	Sedimentation of Shillong Group clastics with muddy lower part and sandy upper part	Folding and low grade metamorphism
		unconformity	
2500 to 2050	Archean Paleo-Proterozoic	Formation of Gneissic Complex metamorphics	Multiple deformation and high grade metamorphic episodes

Figure 1: Geological history of Meghalaya and Plate Tectonic setting(based in part on Geological Survey of India 2009 & Plate Tectonic Maps from IMT 2000)

Within the Jaintia Group the shelf facies sediments (Jaintia Group) are calcareous and fossili-ferous of Eocene age. Under the Jaintia Group, Langpar Formation with intercalated shale thin limestone overlies the Mahadek Formation in Cherrapunjee and Therriaghat sections. It has been recorded that within the Jaintia Group there is a tertiary coal occurrence. The Jaintia Group is comprised of Shella Formation and overlying Kopili Formation.

The Shella Formation of the Jaintia Group is around the Shella-Ishamati area, East Khasi Hill District of Meghalaya (Figure 2). It is the lowermost lithounit of the Jaintia Group and comprise of three alternating sandstone and limestone. Therria sandstone is the lowermost member of the formation; it is characterized by the coarse grained sandstone with intercalated limestone. Overlying the Therria sandstone is the Lakadong limestone follow by Lakadong Sandstone. The Lakadong sandstone is overlain by the Umlatdoh limestone and Umlatdoh limestone is overlain by Narpuh sandstone. Narpuh sandstone is characterized by its dirty white, fine grained to coarse grained with calcareous girt and thin limestone. The Narpuh sandstone is overlain by Prang limestone which is the uppermost Shella formation. It is characterized by hard, compact, highly fossliferous and massive limestone (Bora 2013).

1.3. Karst and Caves of Meghalaya

Meghalaya has a large number of caves in the Jaintia, Khasi Hills and Garo Hills districts and they developed along the entire limestone region (Figure 2). They are amongst the longest cave systems in the world. Meghalaya holds the top ten longest and deepest limestone caves in India. The longest is the (Krem)LiatPrah cave system) in the Jaintia Hills, which is 31,070 m (101,935 ft). The word "Krem" means cave in the local Khasi language. The highest density of caves found to date is in Jaintia Hills, with the Nongkhlieh Ridge near Sutnga being the home of the most spectacular ones (Brooks et al.,.2009). Meghalaya plateau as it is located in the northeast flank of peninsular India. It is one of the rainiest, most tectonically active areas in the world and hosts the richest type of karst phenomena in India. The combination of its regional uplift, associated river incision, head ward erosion and chemical weathering, has lead to the development of diverse landforms. This hasresults in deep valleys with magnificent waterfall contrasting with mature undulating hills and kart topography over short distances (Prokop., 2014).

The exploration of the Caves of Meghalaya is currently undertaken for both scientific and recreational pursuits, and there are still many unexplored and partially explored caves in the state. The annual international caving expedition,supported by Meghalaya Adventurers Association (MAA) is known as "Caving in the Abode of the Clouds Project". The expedition team has been exploring the caves of Meghalaya since 1992. During this period1005 caves have been explored or partially explored to yield in excess of 450 kilometres of surveyed cave passage, with much more still waiting to be discovered.

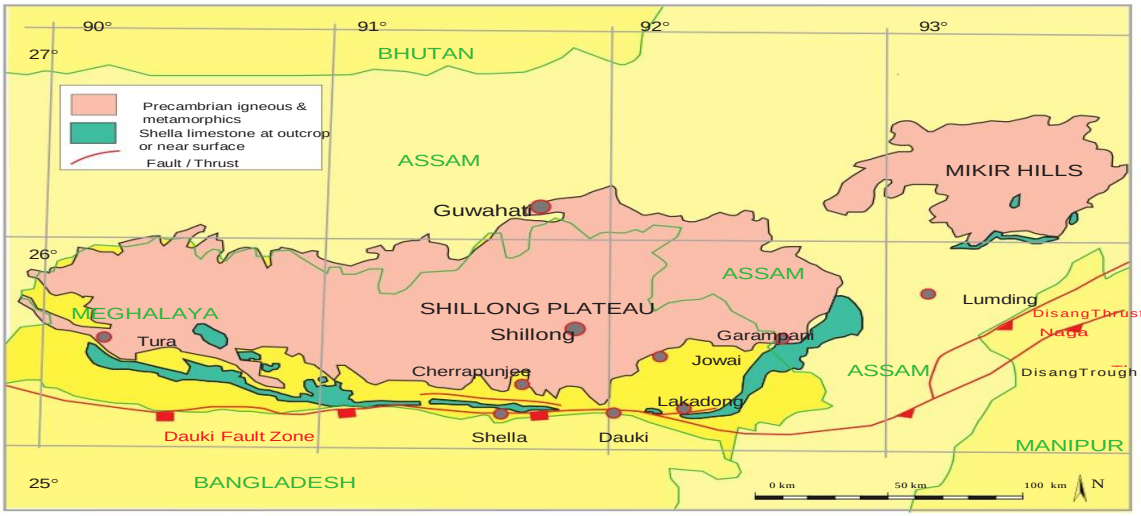

Figure 2: Regional geological map of Meghalaya showing main structures and Shella Limestone Occurrance. Based in part on Geological Survey of India (1981 & 2009)

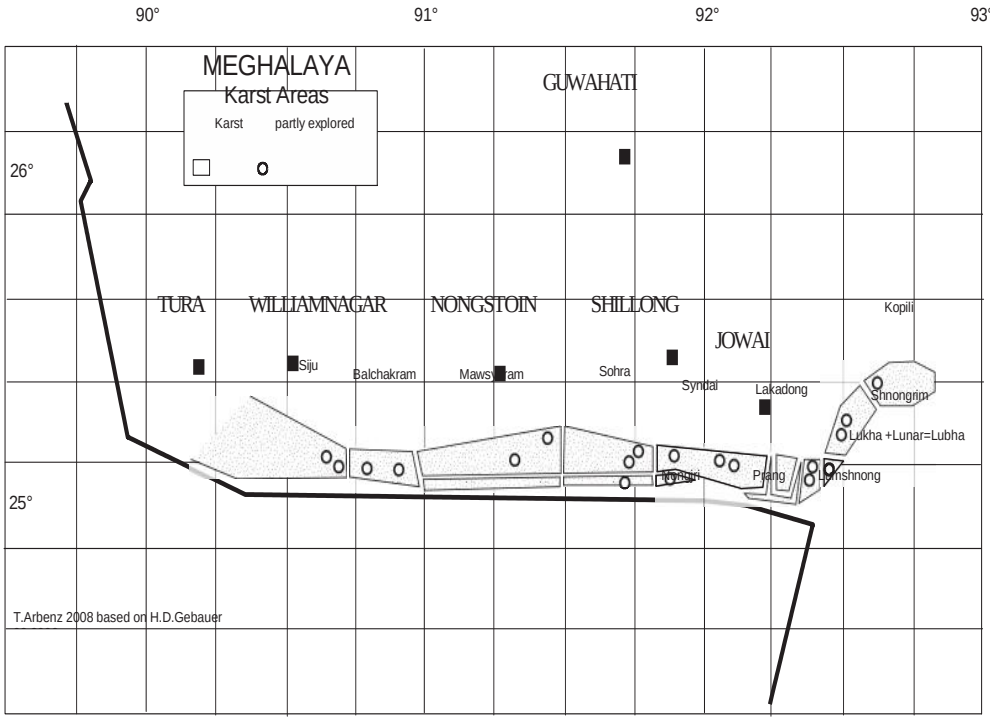

Figure 3: Map of the karst regions in the southern fringes of the Meghalaya plateau

2. REVIEW OF LITERATURE

Beneath the earth surface lies an underground world of caves full of astonishing creatures and a remarkable environment carved into different shapes and sizes. Caves form in different rock types depending on the topography and climate of the area. In karst area, carbonate rock (limestone or dolomite) and water, create most of the longest cave system in the world. Underground water that drains throughout the caves collects carbon-dioxide and becomes acidic and slowly with time dissolves the carbonate rocks and forms a cavern. Stalactites and Stalagmites are formed by the dripping water re-depositing minerals from dissolved rocks. The environment inside the cave depends mainly on the daily seasonal and long term surface climatic changes which inturn provide stable, shelter and moist refuges for animals thatlive undergrounds.

The subterranean ecology i.e. the study of the underground habitats, the flora and fauna can becategorized based on the degree of their dependence on the environment that ispresent there. For some organisms caves act as a place of shelter and a place of hunting for food and they aretermed as Trogloxenes, Those organisms that completea greater part of their life cycle inside the caves are termed as Troglophiles and those that can only survive in caves are termed as Troglobites.Troglobitesorganisms have evolved special adaptative featuresessential for survival in the subterranean environment. Some of these are loss of pigmentation, partial or total loss of eyes, and development of long antennae or legs.The subterranean cave organisms are abundant and arthropods make up the majority of all cave organisms. In India there have been few biospeleologicalsurveys of cave organisms and the few reports are mainly from the North-Eastern part of India in the state of Meghalaya.

Biswas, 2009; In his study on **"**The biodiversity of KremMawkhyrdop of Meghalaya, India, on the verge of extinction"expressed how the irresponsible way of coal mining and limestone quarrying affect the biodiversity of the cave leading to extinction of cave fauna. During his research on Mawkhyrdop cave, few species were found inside the cave and some of his findings within the Mawkhyrdop cave are troglophiles.

Harries,et al., 2008: In his paper "A Review of the biospelelogy of Meghalaya" stated that the quantity and length of caves in Meghalaya exceeds that of any other

known karst region of India. He also observed that taxa with pronounced troglomorphic characteristics appear to be relatively common in Jaintia Hills region of eastern Meghalaya and rare elsewhere in the state, but taxa with partial troglomorphy are widespread throughout Meghalaya. In some cases there is evidence of troglophiles which reproduce, feed and complete their life cycle inside the cave. There is a wide range of taxa which occur regularly within caves and should be considered as significant components of the cave ecosystem regardless of troglomorphy.

In 1922, during their visit to Siju cave, Kemp and Chopra spent about three weeks in examining the cave fauna, topography and geology of the cave. They did a detailed study of the species that are present in the Siju cave. In their publication (Kemp and Chopra, 1924)entitled “The Siju Cave, Garo Hills, Assam. Part 1“, a complete list of the species that are found inside the cave at different depts have been described in detail. They reported a total of 102 species. However, of the 102 species that they discovered in Siju cave, most of them are known to occur on the surface environment but the number of species recorded to be a true cavernicolous is extremely low.

3. Objective and Sampling Method

3.1 Objective: Collection and Identification of cave fauna in Mawsiarwait and Ri-Blai caves.

3.2 Sampling

- Collectionof terrestrial and aquatic biota through hand picking, pit fall traps.
- Collection of aquatic fauna by plankton net, bottle trap.
- Sampling of soil fauna by modified Berlese Tullgren apparatus.

3.3 Method of Collecting and Preserving

3.3.1 For collection of terrestrial arthropods inside the cave Pitfall trap, Hand picking and Berlese Tullgren funnel is used.

Pitfall trap:

1. A container made up of plastic bottle or a beaker is used and a pit of required length is made.
2. The length of the bottle should be of the same length with the pit, so that the rims of the bottle should be on the same level with the soil surface.
3. A pit of 15cm to 30cm is dug to immerse the plastic bottle or beaker.
4. A soapy water or ethyl alcohol is used to trap the Arthropods that fall into the trap.
5. Bait is also used and kept inside the Plastic bottle or Beaker to lure the Arthropods into the trap.
6. Pit fall trap are widely used for collecting ground dwelling arthropods such as ant, cricket, spider, etc.

Hand picking:

1. It is a simple method of collecting Arthropods at first sight.
2. Gloves are used to protect the hand while picking up the Arthropods.
3. Arthropods that have been picked are kept in a 100ml plastic bottle containing ethyl alcohol for storing.
4. The specimens collected are then separate accordingly in the laboratory and kept in separate vials containing ethyl alcohol.

Berlese Tullgren funnel:

1. The funnel is a large rectangular box with insulated walls, open at the bottom and supported on 4 legs.
2. Overall dimension including legs, are (4×1 ½ ×3) feet (Lenght×Breadth×Height). Heat is provided by three- four 100W bulb mounted on the interior ceiling of the rectangular box.
3. The funnel is placed into the rectangular box through a hinged door in the front of the box and above the funnel a 100W bulb is wired, and a nylon mesh is placed on the mouth of the funnel to hold the soil.
4. A random amount of soil sample of (5×5×5 cm, Lenght×Breadth×Height) is collected from the study sites and brought to the laboratory and a small amount of soil is pour into the funnel.
5. At the bottom of the funnel, a vials containing 70% of ethyl alcohol is placed to collect and preserve the specimen.
6. The soil is placed in the rectangular box for 24 hour under the three to four 100W bulbs for 48 hours.
7. The specimens are then collected in the vials after 48 hours for identification.
8. The reason for keeping the soil for 48 hours under a light of 100W bulb is that soil dwelling organism tends to move downwards away from the direct light, organism leaving the soil fall into the vials.

3.3.2 For collection of aquatic biota inside the cave Plankton net and Bottle traps are used

Plankton net:

1. Plankton nets is made with a metal frame which act as a mouth of the net and hold the net, at the bottom of the net, a vial is attached for collecting of micro-organism and other aquatic biota that are trap inside the vial.
2. In deep pond and streams Plankton net are sweep randomly or a specific sites is selected and kept the Plankton net for.
3. In shallow stream the plankton net is held facing upstream for a good catch.
4. Micro-organism and aquatic biota that are collected inside the vials and net are then preserved in a bottle container having ethyl alcohol.

Bottle trap:

1. A clear plastic bottle is used and modified into a fyke.
2. Bottle trap is used to trap small aquatic biota.
3. The bottle trap should always be placed upstream in flowing water, in case of standing water a fixed placed is selected to set the trap.
4. Inside the bottle bait is kept to lure the aquatic biota into the trap.

Collection of arthropods and aquatic biota either for study or documentation is an important part for the entomologist or for those who study the cave environment. Arthropods and Aquatic biota are found almost everywhere and can be collected in any season, a good knowledge of how and when to collect and preserve the arthropods is needed by applying good technologies methods and studies. This willprovides the essential data and samples for future reference in research

3.4 Preservation of the Specimens

Wet preservation (Liquid preservation):- Specimens can be preserved in liquid such as ethyl alcohol (70-80%) or formalin (4%). Small glass or plastic vials containing the preservatives are used for storing of specimens. The vials should be handled carefully and tight fitting of the cap and sealing with paraffin wax to reduce evaporation of the preservative is essential. Labels may be inserted into the vials after writing the date of collection, location and host etc. either by water proof pen or pencil.

3.5 Study sites

3.5.1 Cave 1: Mawsiarwait Cave (Krem)

On the month of May, 2015 (dated 21st – 23rd), a first field survey was done on Mawsiarwait Cave. This was a pre field survey before the real documentation was carried out so as to know the inside structure of the caves for safety measures. A final sampling at Mawsiarwait cave was carried out in the month of June.2015 (dated 24th – 25th). During the sampling, data was collected and digital photographs were taken for the study and as evidence.

For the field survey at Mawsiarwait cave, a team of four members was formed as it is the minimum number required for entering the cave and to fulfill all the criteria that cavers must follow during the exploration inside the cave, that is,for safety and to easily carry out the exploration.

3.5.2 Cave 2: Ri-Blai Cave(Krem):

On the month of November, 2015 (dated 26th – 28th) a first field survey was done on Ri-Blai Cave. This was a pre field survey before the real documentation was carried out, so as to know the inside structure of the caves for safety measures. A final sampling at Ri-Blai cave was carried out in the month of December, 2015 (dated 18th – 19th). During the sampling, data was collected and digital photographs were taken for the study and as evidence.

For the field survey ofRi-Blai cave, a team of four members was formed as it is the minimum number required for entering the cave and to fulfill all the criteria that cavers must follow during the exploration inside the cave. That is, for safety and to easily carried out the exploration.

4. GENERAL DESCRIPTION OF INSECT AND ARTHROPODS

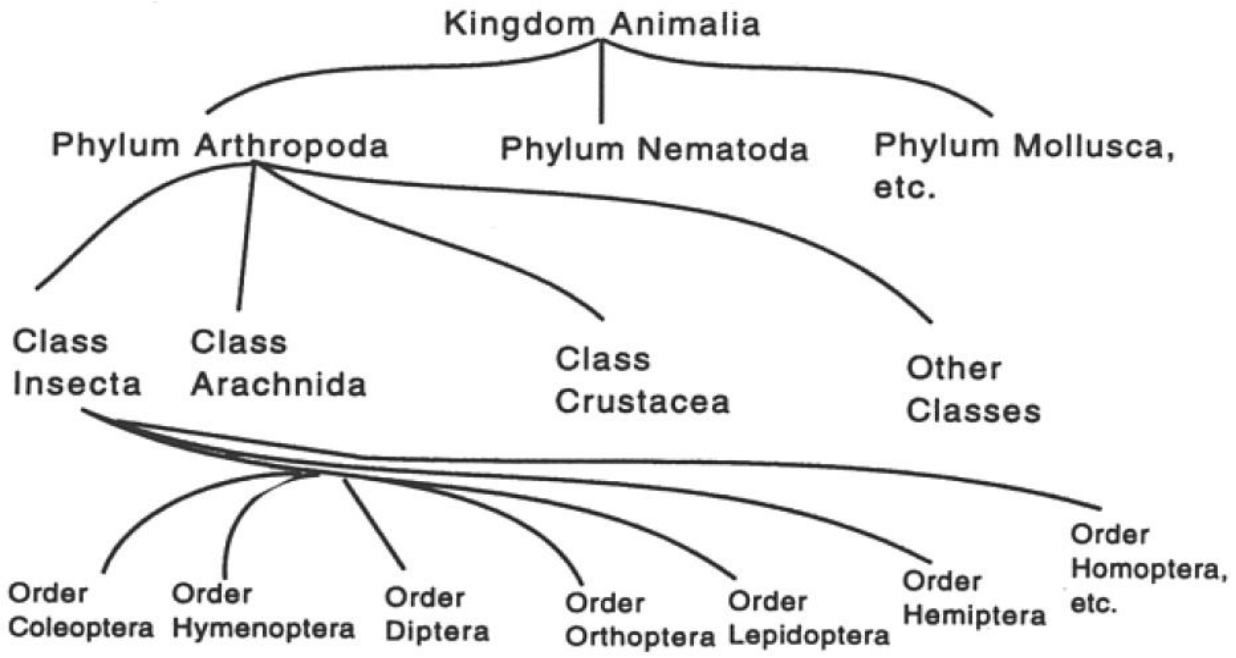

Figure 4: A Phylogeny of selected invertebrate groups with a focus on the arthropods

4.1 Insects

The insects are the dominant group of animals on earth today. They far surpass all other terrestrial animals in number, and they occur practically everywhere. Several hundred thousand different species have been described-three times as many as there are in the rest of the animal kingdom. The insects can be found in almostall types of environment and adapt themselves to the condition of the presence environmental factors that surrounds them; they are of great value to man and society in terms of food, medicine, nutrient cycle, in agricultural sector insect helps in pollination and suppress pest population, scientific research and many other services.

Insects have lived on the earth for about 300 million years, compared to man who have live for 2 million years. During their 300 million years of presencein this earth, insects have a greater diversity compared to any invertebrates in respect of structural modifications, habitat and ecological niche, they have evolved in many aspect such as morphologically, physiologically and become adapted to almost every different types of environment, so that they can reproduced, search for food and protect themselves against predator. Based on their morphological diversity,

they have been classified under 33 orders under the class-Insecta and phylum-Arthropoda.

4.1.1 Origin of Insect

The first sign of life on earth were single celled organism that lived in the oceans around 3500 million years ago. The first land living animals were emerging from the ocean as scavengers perhaps to escape aquatic predators about 420 million year ago. The most successful of all land living animals are the insects. Of all the species on earth 73.5% are invertebrates and most of these are insects and they are the most successful creatures adapting to the early environment on land.

4.1.2 Basic anatomy of an Insect

Insectsarebuilt on a segmental plan and their characteristic feature consist of a hard jointed exoskeleton which is form by the cuticle and is continuous through the body and consists of a series of hard sclerites joined to each other by a flexible membrane which are also cuticular. The function of sclerites is to give precise movement of the neck. The body is segments into three regions – the head, thorax and abdomen in which the various basic parts of the segments may be greatly modified such as the walking legs are on the three thoracic segments. In the head the appendages are modified for antennae and mouth parts as sensory and feeding purposes, and in the abdomen there are no appendages except modified as the genetalia and some pregenital appendages are present in apterygota.Insect have two pair of wings which are the lateral outgrowth of the body wall located dorsoventrally between the nota and pleura. The fully developed wings of an insect appear as thin, rigid flops attached to the meso and metathoracic segments.

4.1.3 Head

The head of an insect is composed of a series of segments with different specialization i.e. for food gathering, sensory perception and neutral integration. The head bears the eye (compound and ocelli, antennae and mouthparts (Figure: 1).

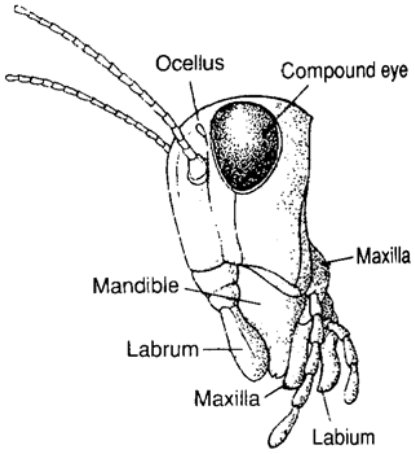

Figure 5: Insect Head

- **Mouthpart:**Mouthparts are the organs concerned with feeding, comprising the unpaired labrum (upper lip) in front, a median hypopharynx (tongue) behind the mouth, a pair of mandibles (upper jaws) and maxillae (lower jaws) laterally, and a labium forming the lower lip. Mouthparts that are enclosed internally are called endognathous. The mouth parts that are externally visible are called ectognathous.
- **Antennae:** Antennae vary greatly among insects both in length and functions. Antennae function almost exclusively in sensory perception i.e motion and orientation, odor, sound, humidity and a variety of chemical cues. The most common types of insects antennae are Setaceous, Clavata, Filiform and Aristate (Figure: 2a-2d).

Figure 6a: Odonata

Figure 6b: Coleoptera

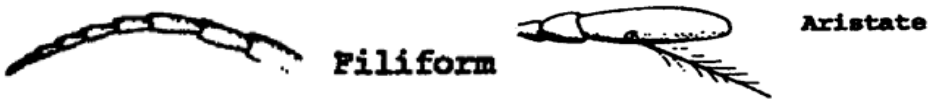

Figure 6c: Lepidoptera Figure 6d: Diptera

4.1.4 Thorax

The insect thorax is divided into three parts: the prothorax, mesothorax and metathorax, each segment consist of sclerites. Each of the thorax parts contained one pair of legs and wings are found only on the mesothorax and metathorax segments. The legs are group into three types the fore-legs located on the prothorax, the mid-legs located on the mesothorax, and the hind-legs on the metathorax. Each of these legs has six major components i.e., coxa, trochanter, femur, tibla, tarsus and pretarsus (Figure: 3a-3b).

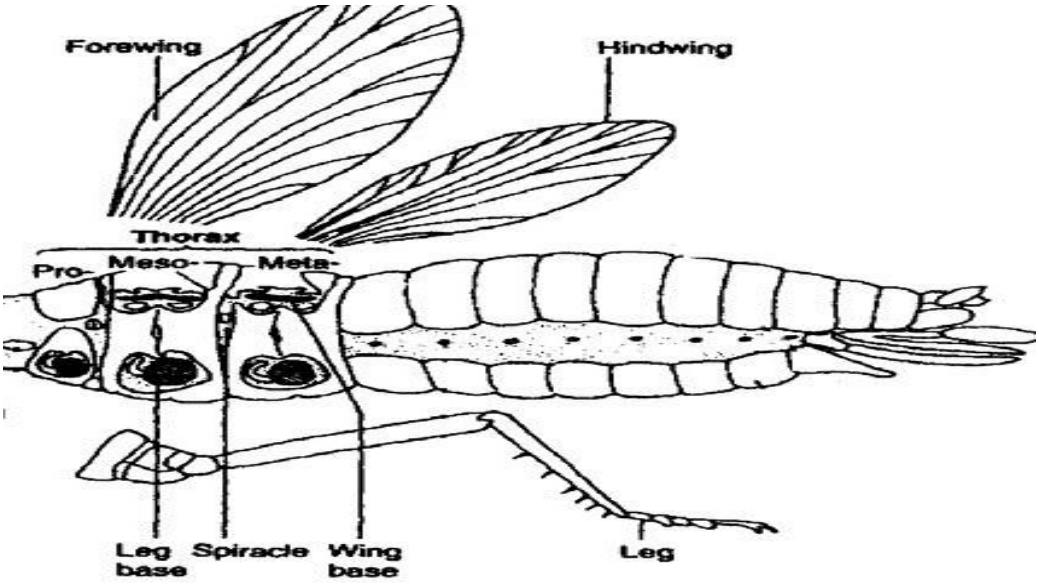

Figure 7a: Insect Thorax

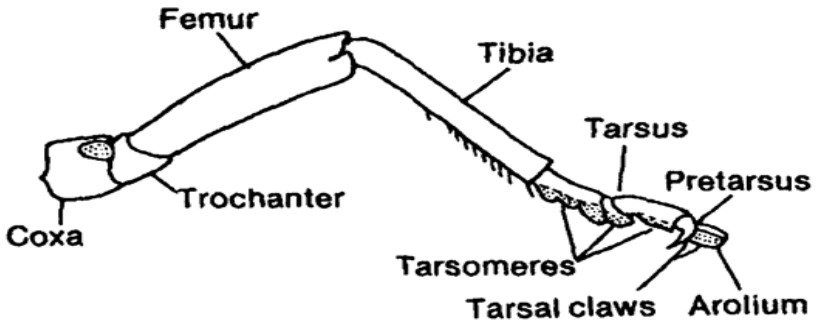

Figure 7b: Insect Legs

4.1.5 Abdomen

The abdomen of an insect can split into two parts, the dorsal and the ventral abdominal segments. The abdomen is the most flexible parts of the body, abdomen usually have 10 or 11 segments. The abdomen holds all the digestive or reproductive organs, but the posterior abdominal segments are modified for mating and ovipositor. The abdominal segments of an adult insect are without appendages except for those who are concerned with digestion and reproduction and a pair of terminal usually sensory cerci (Figure: 4).

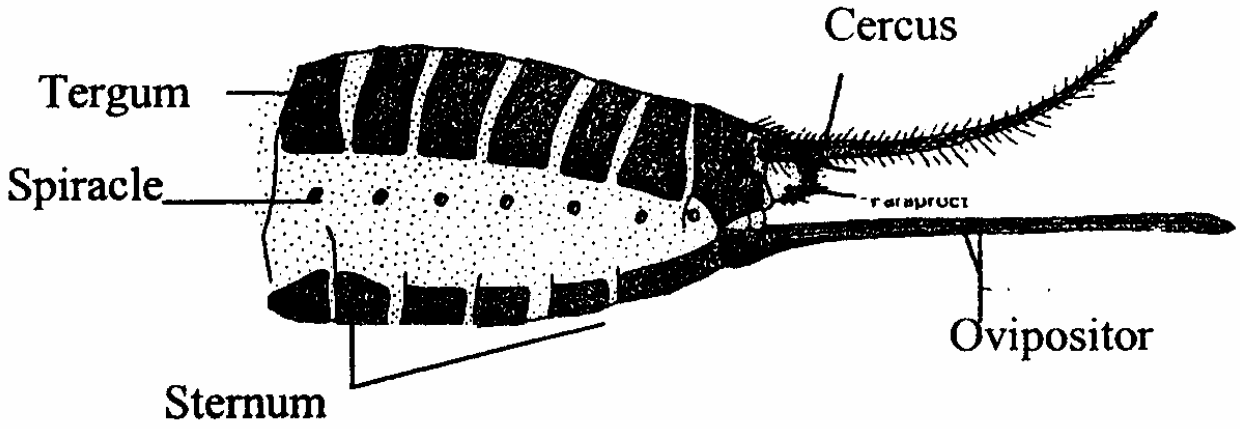

Figure 8: Insect Abdomen

4.2 Chelicerates

Chelicerates is a sub-phylum of the phylum Arthropoda and there are three class under the subphylum Chelicerates, namely; Merostomata, Pycnogonida and Arachnida. The Chelicerates have two distinct body region, the anterior prosoma (ce[halothorax) and posterior opidthosoma (abdomen) that may be divided into mesosoma and metasoma. Chelicerates don't have antennae; they all have four pairs of uniramous waling legs on the first tagma. The sub-phylum includes a variety of animals such as spider, scorpion, horseshoe crab and the unusual sea spider. In almost all Chelicerates, they are predators

4.2.1 Arachnida

Arachinida is a class of phylum Arthropoda. The class Arachnida is one of the major class and it contain 12 orders, among these 12 order Scorpiones is considered to be a primitive and evolved without much change in its morphology and it is termed as a good example of "living fossils". Arachnids are also called Chelicerate Arthropods. Class Arachnida differs completely from other classes that fall under the phylum Arthropods. The body of members of class Arachnida basically composed of 18 somites and divided into a prosoma of six units and an opisthosoma of twelve units. The prosoma ventrally possesses six pairs of appendages, the chelicerae, the pedipalps and four pairs of legs.

4.3 Myriapoda

Myriapoda is a sub-phylum of the phylum Arthropoda. There are four group of centipede like creature known collectively as myriapods but their relationship to each other is not clearlu understood. Nearly 13,000 species of arthropods are classified in the class Myriapods, Myriapods are terrestrial form and only some are marine. Most Myriapods live in humid environment, and can be found in soil, in leaf litter, or under stone and wood. Species under Myriapods can have from a fewer ten to nearly 200 pairs of appendages. Chilopods have only one pair of legs per body segment, while two pair of legs in one body segment is in the case of Diplopoda species.

4.3.1 Diplopoda(millipedes)

Diplopoda are a class within the phylum Arthropod. Millipedes are usually found in damp places. That is, in moss, under stones, under leaves, in rotten wood, in soil in the above ground and in caves with similar conditions. Millipedes are elongated, wormlike animals with 30 or more pairs of legs and the body segments bear two pairs. The body is cylindrical or flattened in shaped and they have a short antennae, the head of most millipedes is convex above bearing a large epistomal area and flat beneath. Most millipedes are scavengers and feed on death and decaying matter of plants, they lay their eggs during summer and in winter they are in protected situation. The eggs are usually white and hatch within afew weeks; newly hatch millipedes have only three pairs of legs.

4.4 Crustacea

Crutacea is another sub-phylum of the phylum arthropods and it consists of eight sub-class and some of the species that are found in the Mawsiarwait and Ri-Blai cave fall under the sub-class Malacostraca and Isopoda. They form a heterogeneous group within the class. Nearly all of them are aquatic and breathe by means of gills. The head and the thoracic portion of the body is sometimes fused into a Cephalothorax. The head bear two pairs of antennae,usually one median eye and two lateral eyes and three pairs of biting mouthparts. The appendages vary in numbers, a pair of segments is found on each segments of the Cephalothorax Some species of the crustacea class are free swimming or live as parasites on fish or larger organisms and they can be found on both marine and freshwater forms.

4.4.1 Malacostraca

Malacostraca is the largest of the six class of crustacean, it include wide diversity such as Decapoda (crab, lobster, crayfish, shrimp),*Euphausids*(krill), etc. They are abundant in all marine and freshwater bodies. They are segmented animals, having a common body plan comprising 20 body segments and divided into head, thorax, and abdomen. Malacostracans are characterized by the presence of an abdominal appendages, three tagmata, afive segmented head an eight segmented thorax and anabdomen with six segments and a telson each body segment bear a pair of jointed appendages. Most species of malacostraca have distinct sexes (gonochorism) and some exhibit hermaphroditism. The female genital

gonopores are located on the sixth thoraicic segment, while the male gonopores are on the eighth segment and in small number of species, on the seventh.

4.4.2 Isopoda

Most of crustaceans are aquatic and the isopods are one of the few groups of which some members are terrestrial. Isopoda are marine animals living under stone and they have evolved through the evolutionary transition from marine to terrestrial habitats. The isopods are small, slightly dorsoventrally flattened gray or brown organisms with numerous legs, called pereopods. Their bodyis divided into the head, the leg bearing thorax and the abdomen. The length of the isopods ranges from approximately 5 to 15 mm. Isopods are distributed globally and they are found in a wide range of habitat ranging from marine to freshwater and terrestrial, but they are best found in rotting woods and log and in damp area. Terrestrial arthropods play a significance role in many tropical and temperate ecosystems by aiding in the decomposition of plant material and dead organisms through mechanical and chemical means. Many species of isopods have the behavior to defend themselves by rolling into a ball and that also helps conserve moisture.

5. Results

5.1 Study site

5.1.1 Site description Mawsiarwait Cave(Krem)

Mawsiarwait cave, Mawkawir, near Mawsahew (West of Sohra). East Khasi Hills Meghalaya	Latitude: 25º15'16.71" Longitude: 91º39'22.11" Elevation: 1089m Atmospheric temperature ºc: 19.5±0.2 Soil temperature ºc: 16.03±0.27 Soil pH: 5.94±0.13 Surface water pH: 6.8±0.22

Figure 9: Entrance (Mawsiarwait cave)

KremMawsiarwait before known as cave Mawshyrpait meaning a Whetstone or sharpening stone, is located in Mawkawir village in the southern part of East Khasi Hills district of Meghalaya, the distance from the capital city Shillong to Mawkawir is 70 km and takes around three hours by car. The cave has multiples entrances and they intersect with the main passage from the main entrance almost at a right angles to form a short maze. The entrances of the cave are surrounded by a dense jungle, with in the main entrance there is a small man-made-reservoir, which is used by the villagers and tourists for bathing as it is believed by the villagers that the water

coming through this cave contain some medicinal properties that are able to heal some skin diseases and other sicknesses.

The dimensions of the cave vary from 7-12 feet Width to narrow crawls of only 3-6 feet and being a horizontal cave has a rivulet that runs throughout the year. The cave is actively formed by water and it is inaccessible during monsoon season, large boulders are found in main passage. The cave is formed in calcareous sandstone, therefore stalagmites and stalactites 5 to 30 cm long are found in some parts of the cave.

On the two days of exploration inside the caves we were able to document terrestrial and aquatic species. Photographs of these species have been taken to support identification.

5.1.2 Fauna of Mawsiarwait Cave(Krem)

Figure 10: *Crytodactyluskhasiensis* (Mawsiarwait Cave)

Figure 11: *Trachyiulusmimus* (Mawsiarwait Cave)

Figure12: *Raphidophoridae specie*(Mawsiarwait Cave)

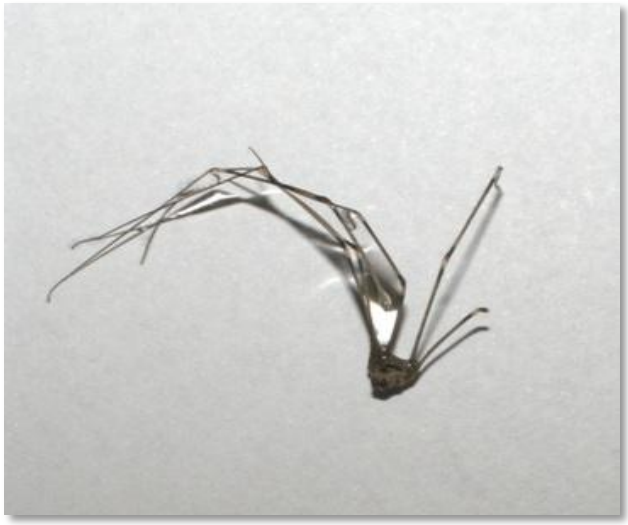

Figure 13: *Phalangiidae* Daddy long legs (Mawsiarwait Cave)

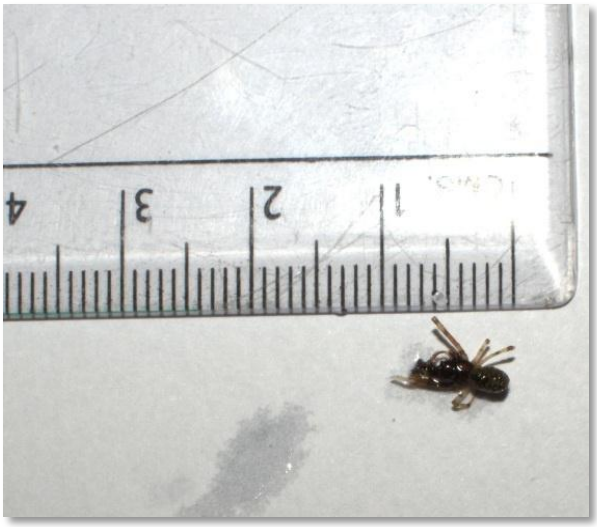

Figure 14: *Callobius*(Mawsiarwait Cave)

Figure:15*Arachnida* (Mawsiarwait Cave)

Figure 16: *Heteropoda species* (Mawsiarwait Cave)

Figure 17: *Potamon*(Mawsiarwait Cave)

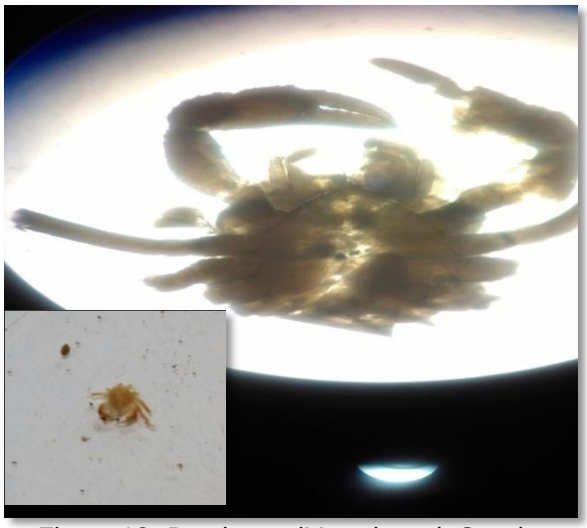

Figure 18: *Brachyura* (Mawsiarwait Cave)

5.1.3 Site description of Ri-Blai Cave(Krem)

Ri-Blai cave, Bairong, near Wahlong (South of Sohra) East Khasi Hills Meghalaya	Latitude: 25º12’13.30” Longitude: 91º43’06.35” Elevation: 416m Atmospheric temperature ºc: 18.9±0.2 Soil temperature ºc: 19.03±0.27 Soil pH: 5.97±0.13 Surface water pH: 6.6±0.22

Figure 19: Entrance (Ri-Blai cave)

KremRi-Blai meaning God protected cave is located in the southern part of East Khasi Hills district of Meghalaya near the village of Wahlong, the distance from the capital city Shillong to Wahlong is 78 km and takes around three an half hours by car. Ri-Blai cave is surrounded by a broad leaves forest and Areca nut tree. The main entrance of the cave is about 30 feet wide and 15 feet high, the route from the main entrance to the first chamber is very steeply down-sloping to vertical and the ground is covered with loose soil and rocks which make it very difficult to get into the chamber.

Being a vertical cave, the dimensions of the cave varies from chamber to chamber along with different heights of the vertical shafts. The first chamber of the cave is about 100-130 feet wide to 50-80 feet high, below the first chamber lies

another chamber which is connected by a vertical shaft of 25 meters and a double drop of 8 meters and 10 meters to the second chamber which then continues as a horizontal passage that stretches a few hundred meters some which have been explored and the rest has been left untouched.

During the two days of exploration inside the caves, we were able to document terrestrial and aquatic species. Photographs of these species have been taken to support identification.

5.1.4 Fauna of Ri-Blai Cave(Krem)

Figure 20:*Raphidophoridae* (Ri-Blai Cave)

Figure 21: *Cubaris species* (Ri-Blai Cave)

Figure 22 : *Heteropoda*(Ri-Blai Cave)

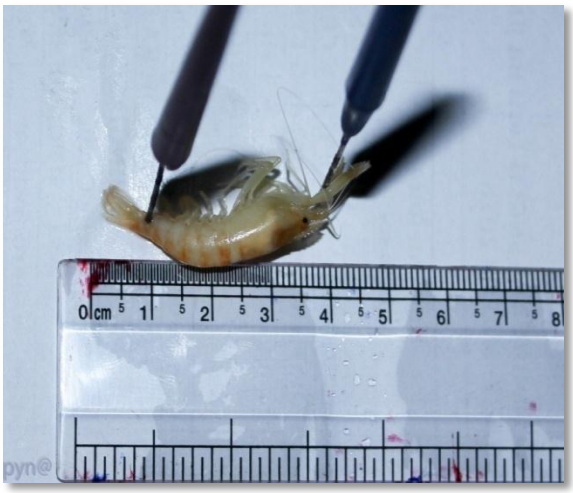

Figure 23: *Macrobranchiumcavernicola* (Ri-Blai Cave)

Figure 24: *Trachyiulusmimus,* Adult (Ri-Blai Cave)

5.2 Description of species found in Mawsiarwait and Ri-Blai Cave

Arachnida (spiders): Spiders of the genus Heteropoda are among the commonly recorded species of the meghalaya cave. Spider of this genus is found in both Mawsiarwait cave and Ri-Blai cave (Figure:8, 9, 10, 11, 16). They are abundant and are commonly found on the passage wall and ceiling near the entrance and deep within the cave where there is absence of light. Two species of spiders of the genus Heteropoda are present Heteropodarobusta (Fage, 1924) which can be found in the western part of the state (Garo and West Khasi Hills) while Heteropodafischeri(Jaeger,2005) appears to be predominant in the eastern part of the state especially inJaintia hills. In Mawsiarwait cave Heteropoda sp. was seen to carry an egg sack on her belly, the sack is in the shape of small disc/biscuit of white colour maybe 3-4cm in diameter. (Fage,(1924); Kemp and Chopra,(1924) have recorded that in Siju cave Hetropodarobusta was abundant and seen to be reproducing nor feeding of prey.Heteropodafischeri, aspecies of huntsman Spider, was first identified from the caves of Jaintia Hills, Meghalaya (Jaeger 2005). Early reports document Heteropodafischeri preying upon brown Rhaphidophorid cave crickets in Jaintia Hills (Harries et al.,2008) and later from other cave within the Jaintia Hills region (Biswas and Harries 2011).

Brachyura (crabs): The fresh water crabs was found to be common in the surface stream outside the cave and deep within the cave, the Potamon sp. (Figure: 17, 18) was found in the Mawsiarwait cave and it is already an adult but the white crab that was found 180 meters inside the Mawsiarwait cave is very small and white colour. A reason for this white crab to be white in colour might be in the juvenile stage or trying to adapt itself to the environment inside the cave which lack the presence of light (Figure:18).

Palaemonidae (Shrimp): Shrimps are often abundant and are present wherever there is water, even in small standing water within the cave as well in active flowing streams. The shrimp Macrobrachium cavernicola (Figure: 23)was found in a pool in the Ri-Blai cave from point of 400 meters. The shrimp Macrobrachium hendersoni and Macrobrachium cavernicola were recorded from siju (Kemp, 1924 and Lindberg, 1960) reported on the shrimp *Macrobrachium cavernicola*.

Isopoda: One isopod Cubaris sp. (Figure: 21) was recorded during the field visit to Ri-Blai cave, it was found at a distance of between 350 to 400 meters from the entrance in a slightly wet area. There is less abundance and occurrence of isopods inside the Ri-Blai cave and they have not been observed in Mawsiarwait cave. Usually isopods are widespread and abundant in cave as cave fauna, but the absence of isopods in Mawsiarwait cave might be to the reason of perennial flow of water from this cave into the open area. In monsoon season the water level is high and the high flowing velocity of the stream making it hard for the isopods to live, and reproduce inside the cave, since there is lack of food and decaying vegetation or animals inside the cave, which might been washed away by the running water during the monsoon seeason. Four species(*Porcellioassamensis, Cubariscavernosus, Cubarisdobakholi, Burmoniscuskempi*) have been recorded with in Meghalaya caves (Collinge, 1916; Chopra, 1924; Lindberg, 1960).

Diplopoda (millipedes): Millipedes of Trachyiulus species (Figure: 11, 24) have been recorded in both Mawsiarwait and Ri-Blai Cave. Millepedes are widespread and abundant especially in driers area away from the stream. Their feeding habit is mainly on dead bats, snakes, insects and guano and faeces of other death organic matter of animals and plants. Millipedes species of *Trachyiulusmimus* was recorded from Siju in 1922 (Silvestri,1924).

Orthoptera (crickets):Orthoptera are found in almost all the caves with in Meghalaya, Rhaphidophoridae Species (Figure: 12, 20) are found in both Mawsiarwait and Ri-Blai cave. They can be easily found on the walls and ceiling within a few hundred meters from the entrance of the cave and also deep inside the cave in dry passage along with other cave fauna, their occurrence is most significant particularly below the bat roosts. Orthoptera strongly attract to meat bait. Harries, (2008) recorded some Orthoptera from Umthloo cave (2005).

Chrodata (gecko): The genus Cyrtodactylus currently comprised of seven species: *C*. *fasciolatus*(Blyth), *C*. *gubernatoris*(Annandale), *C*. *khasiensis*(Jerdon)*, C*.*malcomsmithi*(Constable), *C*. *marcuscombaii*(Darevsky, Helfenberger, Orlov andShah), *C*. *martinstolli*(Darevsky, Helfenberger, Orlov& Shah) and *C*. *nepalensis*

(Schleich&Kästle). But in the recent years more species have been added to the genus Cyrtodactylus. Cyrtodactyluskhasiensis (Figure: 10) has been found in Ri-Blai cave within 100 meters inside on the wall of the cave. *CyrtodactylusKhasiensis* is wide spread among the areas of North-Eastern India, Xizang (Tibet), Myanmar and Bangladesh. Its presence inside the cave might be related to abundant of prey or as a shelter and hideout from predator living in the surface environment, and their habitat is mainly in dry area on the walls and the ceiling of the cave.

Table 1: Number of species that is found in Mawsiarwait and Ri-Blai cave

Phylum	Sub-phylum	Class	Number of species found in both the caves	Number of species found in Mawsiarwait Cave	Number of species found in Ri-Blai cave
Arthropods	**Chelicerates**	**Arachnida**	**5**	**4**	**1**
Arthropods	**Myriapoda**	**Diplopoda**	**2**	**1**	**1**
Arthropods	**Crustacea**	**Malacostraca**	**3**	**2**	**1**
		Order-Isopoda	**1**	**-**	**1**
Arthropods		**Insecta**	**2**	**1**	**1**
Chrodata		**Reptilia**	**1**	**1**	**-**

Figure 25: Side passage(Mawsiarwait cave)

Figure 26: Mycetophilidae(Mawsiarwait cave)

Figure 27: Gypsum (Ri-Blai cave)

Figure 28: 1st Vertical Shaft(Ri-Blai cave)

Figure 29: SRT 1st Vertical Shaft (Ri-Blai cave)

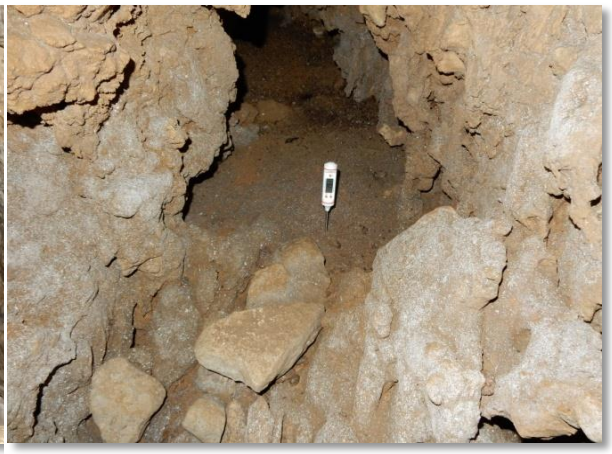

Figure 30: Measuring soil Temperature (Ri-Blai cave)

Figure31: Flora (Ri-Blai cave)

Figure 32: SRT 2nd Vertical Shaft (Ri-Blai cave)

Figure 33: Main passage (Mawsiarwait cave)

Figure 34: Fossils (Mawsiarwait cave)

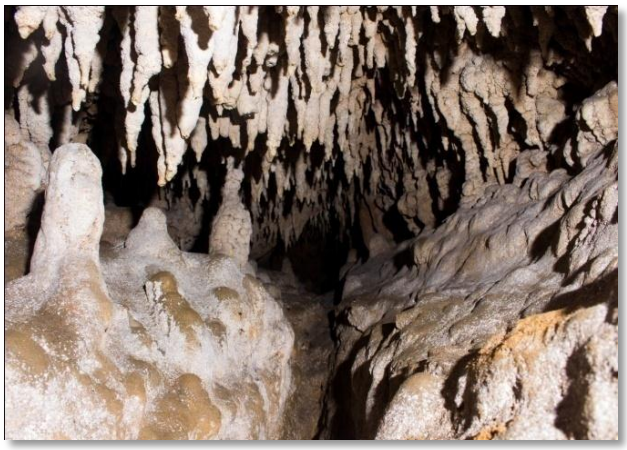

Figure 35: Stalactites (Mawsiarwait cave)

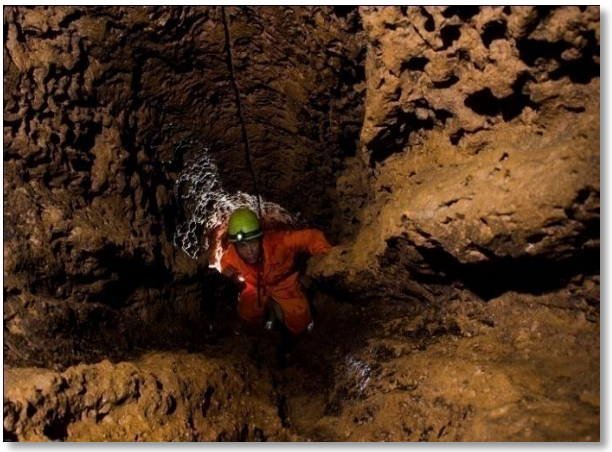

Figure 36: Pipe passage (Mawsiarwait cave)

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6. Discussion

The present study in Mawsiarwait and Ri-Blai cave led to the discovery of 14 species, five species fall under the class Arachnida, two species under the class Diplopoda. Under the sub phylum Crustacea three species of the class Malacostraca have been discovered and only one species under the order Isopoda, two species under the calssInsectaand one reptile.

The Insecta species are found in both the cave (Mawsiarwait and Ri-Blai cave). They are abundant and can be foundinside the cave ceiling wall and floor; they are not a true troglophile but they have evolved with long antennae and legs and they can be class as troglobite.Arachnida are predominant in both the cave, four species have been discovered in Mawsiarwait cave and only one in Ri-Blai cave. Heteropoda that have been found in Mawsiarwait cave is seen carry an egg sack. In similar case a heteropodarobusta is seen carrying an egg sac in caves in the West Khasi Hill and Heteropodafischeri in a cave in thejaintia hill(Harries et al., 2008).Trachyiulus species found in both the caves, they are seen to be abundant in drier area and below the bat roost. They help in decomposition of death organic matter inside the cave. Trachyiulux species have been recorded in Siju cave by Kemp and Chopra.

The white crab in (Figure 18)that present inside the Mawsiarwait cave might or have been transport mainly from rainfall runoff as adults or another possibility might be that the female crab carrying the eggs have been transported from the outside environment into the cave during monsoon season and release the eggs inside the cave and due to the absence of light inside the cave, the egg that are released cannot hatched because the environment is not favoring them and this lead to a high mortality rate leading to the survival of only one or two infants. The white crab found in Mawsiarwait cave is seen to lack pigmentation. Thebody is seen to have a well-developed apron, cheliped, paddle fins, carapace but the eye could not be seen properly from the observation under a microscope,an explanation for the eyes is they might be folded back into the socket or lack the formation of the eyes. With respect to their abundance and occurrence and their distribution deep inside the cave, it is believed by many speleologists that crab should be consider as troglophiles.Freshwater crab *Maydelliathephusafalcidigitis* (formerly *paratelphusa (Barytelphusa) falcidigitis*) was found to be common in Siju in 1922 (Kemp,1924) and

was present deep into the cave (730 m). Shrimp (*Macrobrachiumcavernicola*) can be found in any area where water can be easily available it was recorded in Ri-Blai cave few hundred meters from the cave entrance. It was consider as apartial troglomorphic due to reduce in eye size and reduced pigmentation

Most of the 6800 species of brachyurans are marine but one-fifth of all crabs on earth are strictly freshwater, this makes the freshwater crabs the largest assemblage within the Brachyura and they are the rich species of all decapods crustacean groups (Ng et al., 2008). Freshwater carb as a group showed very high number of endemic species in India with three near threaten and vulnerable (IUCN 2001).Terrestrial orsemi-terrestrial species (*Phricotelphusahockpingi* (CR) and *Johorapunicea* (CR)), aquatic species (*Johoratiomanensis* (NT) and *Heterothelphusafatum* (VU)), cave-dwelling species (*Stygothelphusabidiensis*(VU)), highland species (*Johoragapensis* (VU)), and species onsmall islands (*Johorasingaporensis* (CR) and *Parathelphusa reticulate*(CR)) all are vulnerable to disturbance and pollution (Ng and Yeo, 2007)

The conservation of freshwater crabs relies heavily on preservingpatches of natural forest large enough to maintain good waterquality because many species of these decapods are extremely sensitiveto polluted or silted water and cannot survive exposure. Giventhis, it is of concern that water quality of drainages isdeteriorating even in key natural habitats (Ng, 1988, 1989, 1990a,b, 2008; Brook et al.,., 2003; Tan et al.,2007; Yeo et al., 2008b).

7. Conclusion

Throughout the field visit and survey in the Mawsiarwait and Ri-Blai caves, some species have been recorded identified and preserved. The abundance and frequency of the terrestrial and aquatic biota inside the cave varies from species to species depending on their feeding habit and the environmental condition inside the cave. Caves in Meghalaya, either sandstone cave or limestonecave are the home for rare and endangered fauna but they have been threatened by anthropogenic activities and natural causes. Caves within Meghalaya have been a centre of attraction for national and international biospeleologists for their research. Fauna and Flora present inside the caves may often be found as accidental trogloxenes, but some very rare species are true Troglobites (Kottelat, et al., 2007) and a few species appear to be oftroglomorphic characteristic. Rapid ongoing industrial development and exploitation within Meghalaya is creating a new urgency to conduct research on the biospeleology of the region with a view to assessing conservation status (Harriers et al., 2015).It has been stated that the biological studies of Meghalaya caves have raised more questions than answers. It was suggested that one of the most important question that arises is how are the cave animals likely to be influenced by changes caused by human activities such as limestone extraction and coal mining. The cause of the difference in cave fauna between east and west is not yet clear, since the Meghalayan limestone is not a continuous band but is divided by deep incised valleys. So it is possible that the difference in caves species occur because the communities are effectively isolated in separate islands of limestone. Alternatively, the differences might be partly due to climate. The information on the relationship of cave vertical range to species richness would suggest that deeper caves are of higher biological / conservation importance than shallow caves (Harries et al.,2012).

Environmental problems like deforestation have a great impact on altering the environment and the biodiversity inside the caves, another problem that affecting the biodiversity inside the caves is Acid Mine Drainage a runoff from coal mines and open coal storage area, that leeches into the soil and flow into the river. Caves are not just the home to a wide variety of fauna and flora but some caves also act as a reservoir for the villagers to fulfill their daily needs, mainly in drinking water supply.Therefore conservation of cave biota is important for it aesthetic value, and

the most important is that Meghalaya is the home of the most important karst of the Indian continent and has ahigh potential for studies and research in the future.

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Table

1. Introduction

Meghalaya, a Sanskrit word for *"the abode of clouds"* is among the seven states in North East India. It covers an area of approximately 22,430 square kilometers. This state lies between is bounded to the south by theBangladeshi divisions ofMymensinghandSylhet, to the west by the Bangladeshi division ofRangpur, and to the east by IndianAssamstate.The state is the wettest region of India, recording an average of 12,000mm (470in) of rains a year.About 70% of the state is cover in forest. The Meghalaya subtropical forests, eco-region encompasses the state; its mountain forests are distinct from the lowland tropical forests to the north and south. The Meghalaya forest are well known for its rich biodiversity in flora and fauna. Meghalaya has predominantly an Agrarian economywith a significant commercial forestry industry. The important crops are potatoes, rice, maize,pineapples, bananas, papayas, spices, etc.The state is geologically rich in minerals.

The state of Meghalaya is mountainous, with stretches of valleys and highland plateaus, and is geologically rich. It consists mainly of Archean rock formations with rich deposits of valuable minerals like coal, limestone, uranium and sillimanite. Meghalaya has many rivers. Most of these are rainfed and seasonal. The important rivers in the Garo Hills region are Daring, Sanda, Bandra, Bhogai, Dareng, Simsang, Nitai and Bhupai. In the central and eastern sections of the plateau, the important rivers are Khri, Digaru, Umiam, Kynshi (Jadukata), Mawpa, Umiam or Barapani, Umngot and Myntdu. In the southern Khasi Hills region, these rivers have created deep gorges and several beautiful waterfalls. The elevation of the plateau ranges between 150m (490ft) to 1,961m (6,434ft). The central part of the plateau comprising the Khasi Hills has the highest elevations, followed by the eastern section comprising the Jaintia Hills region. The highest point in Meghalaya is Shillong Peak overlooking the city of Shillong. It has an altitude of 1961m. The Garo Hills region in the western section of the plateau is nearly plain. The highest point in the Garo Hills is Nokrek Peak with an altitude of 1515m.

1.1. Flora and Fauna

The floral diversity of Meghalaya is well reputed for its richness and has been a centre of attraction for many botanists. The presence of a large number of primitive flowering plants has prompted Takhtajan (1969) to name it the 'Cradle of Flowering Plants'. Meghalaya harbors about 3,128 species of flowering plants and contributes about 18% of the total flora of the country, including 1,237 endemic species (Khan et al., 1997). A wide variety of wild cultivable plants, edible fruits, leafy vegetables and orchids are found in the natural forests of Meghalaya. However due to overexploitation, deforestation, and habitat destruction, many endemic and threatened species are now mainly confined to the protected areas and sacred groves. The region is a habitat for many botanical curios and rarities. Among insectivorous plants *Nepenthes khasiana* and two species of *Drosera*(*Droserapeltata* and *Droseraburmanii)* are important. *Nepenthes khasiana* is endemic to Meghalaya and listed in Appendix I of CITES and placed in Schedule VI of the Wildlife (Protection) Act, 1972. The Khasi and Jaintia hills are considered to be the centre of diversity for several primitive families such as *Elaeocarpaceae, Elaeagnaceae, Anonaceae, Ranunculaceae, Piperraceae, Menispermaceae, Caryophyllaceae, Lauraceae, Myricaceae, Lazarbiaceae* and primitive genera like *Sarcandra, Corylopis, Myrica, Magnolia* and *Michelia*.

Faunal diversity is also well represented by the presence of a variety of vertebrates (about 958 species and sub species belonging to 451 genera), and about 4580 species and sub species of invertebrates belonging to 2094 genera. Meghalaya is the home for 7 species of Primates, of which,Hoolock gibbons is one that has been classified as Endangered (EN) under the ICUN Red List. Meghalaya also has three of the six largest cats recorded in the world, Tiger *(Pantheratigriss*), Leopard (*Pantherapardus*),and the Clouded Leopard (Neofelisnebulosa). The forests of Meghalaya also support other species of Mammals like Gaur-Indian Bison (*Bosgaurus*), Hog Deer (*Axis porcinus*), and Asian Elephant (*Elephas maximus*). There is a wide variety of birds in Meghalaya with about 659 species of which, 34 species found in Meghalaya forest are globally threatened species. The reptiles' fauna of Meghalaya are generally influenced by the Indo-Chinese elements. The diversity of reptiles comprises of 12 species ofturtles and tortoises, 26 species of lizards and 56 species of snakes.

Amphibians, Pisces and Mollusca are also found in large number with in the state. Within the Northeastern state, Meghalaya is also abundance with Amphibian having up to 33 species.Approximately, 500 species of butterflies found in Meghalaya and some of them are rare. Due to the presence of caves in the southern limestone ridges, Meghalaya has a rich bat fauna and some unique species are present (Thabahet al. 2005, Ruediet al.,2012).

1.2. Geology of Meghalaya

Geologically the Meghalaya plateau comprises of rocks from the oldest Precambrian gneissic complex to the recent alluvium formations. The Precambrian gneissic complex comprising paragneisses and orthogneisses, migmatites. The stratrigraphic sequence is as the Cretaceous –Tertiary sediments, the Sylhet trap, the Lower Gondwana rocks, the Shillong Group of rocks and the Precambrian gneissic complex (Basement gneiss).The Precambrian gneissic complex comprising para and orthogneisses, migmatites and the Shillong Group of rocks comprising mainly quartzites are exposed in the central, eastern and northern parts of the Meghalaya plateau. They are intruded by basic and ultrabasic intrusives and late techtonic granite plutons.The lower Gondwanarock of Permo-Carboniferous age are recognized at the western part of Garo Hills and consists of pebble bed, sandstone, and carbonaceous shale. The Sylhet trap of middle Jurassic age comprising mainly of basalt, rhyolites, acid tuffs, is exposed in a narrow E-W strip along the southern border of Khasi Hills.The Cretaceous – Tertiary sediments occupying southern part of the Meghalaya plateau comprises of the Khasi Group (arenaceous facies), the Jaintia Group (calcareous facies) and the youngest formation the Garo Group which is represented as Simsang, Bagmara and Chengapara formations. Besides these the DupiTilla group of mid-Pliocene age occurs in the western part of Garo Hills and towards south of Khasi Hills (Figure 1). Isolated patches of older Alluvium overlie the Tertiary rocks along the southern and western borders of the State. The recent Alluvium formation is mostly found in the river valleys of Garo & Khasi Hills Districts.

Million Years Before Present (approx.)	Geological Age	Geological Events in Meghalaya	Main Tectonic Events
1.8 to 0	Pleistocene / Holocene	Valley alluvium deposition and terracing	Oblique compression of Indian sub-continent against Asia. Continued faulting and uplift
		unconformity	
23 to 1.8	Miocene - Pliocene	Deposition of delatic Surma Tipam & Dupi Tila coarse clastic delta sediments	Shillong Plateau & Himalayan uplift. Development of Naga fold and thrust belt
		unconformity	
34 to 23	Oligocene	Rapid deposition of Barail & Garo Group coarse delatic sediments around margins of Shillong Plateau	Shillong Plateau uplift and development of Disang Through to SE of Meghalaya
40 to 34	Late Eogene	Sedimentation of Kopili Formation shales and sandstones	Indian sub-continent collides with Asian plate and causes Disang fold belt, Naga thrust etc. to start forming
65 to 40	Paleocene to Middle Eocene	Shelf sedimentation of Langpar and Shella limestones and clastics in shallow warm seas around margins of Shillong Plateau	Rapid northward drift of Indian sub-continent towards Asia. Oblique ocean subduction along Java Trench and northward subduction beneath Asia
75 to 65	Late Cretaceous	Sandy and conglomeratic fluvial and shallow marine sedimentation of Khasi Group flanking Shillong Plateau	Continued drifting of Indian continental margins
		unconformity	
145 to 107	Late Jurassic Early Cretaceous	Extrusion of Sylhet Trap volcanics along Dauki Fault zone and alkaline intrusions at Sung	Break-up of Gondwanaland with rifting apart of Indian sub-continent from surrounding continents
		unconformity	
690 to 480	Neo-Proterozoic to Early Paleozoic	Granite plutonism and basic dyke intrusion	
		unconformity	
2050 to 1000	Paleo- to Meso Protozoic	Sedimentation of Shillong Group clastics with muddy lower part and sandy upper part	Folding and low grade metamorphism
		unconformity	
2500 to 2050	Archean Paleo-Proterozoic	Formation of Gneissic Complex metamorphics	Multiple deformation and high grade metamorphic episodes

Figure 1: Geological history of Meghalaya and Plate Tectonic setting(based in part on Geological Survey of India 2009 & Plate Tectonic Maps from IMT 2000)

Within the Jaintia Group the shelf facies sediments (Jaintia Group) are calcareous and fossili-ferous of Eocene age. Under the Jaintia Group, Langpar Formation with intercalated shale thin limestone overlies the Mahadek Formation in Cherrapunjee and Therriaghat sections. It has been recorded that within the Jaintia Group there is a tertiary coal occurrence. The Jaintia Group is comprised of Shella Formation and overlying Kopili Formation.

The Shella Formation of the Jaintia Group is around the Shella-Ishamati area, East Khasi Hill District of Meghalaya (Figure 2). It is the lowermost lithounit of the Jaintia Group and comprise of three alternating sandstone and limestone. Therria sandstone is the lowermost member of the formation; it is characterized by the coarse grained sandstone with intercalated limestone. Overlying the Therria sandstone is the Lakadong limestone follow by Lakadong Sandstone. The Lakadong sandstone is overlain by the Umlatdoh limestone and Umlatdoh limestone is overlain by Narpuh sandstone. Narpuh sandstone is characterized by its dirty white, fine grained to coarse grained with calcareous girt and thin limestone. The Narpuh sandstone is overlain by Prang limestone which is the uppermost Shella formation. It is characterized by hard, compact, highly fossliferous and massive limestone (Bora 2013).

1.3. Karst and Caves of Meghalaya

Meghalaya has a large number of caves in the Jaintia, Khasi Hills and Garo Hills districts and they developed along the entire limestone region (Figure 2). They are amongst the longest cave systems in the world. Meghalaya holds the top ten longest and deepest limestone caves in India. The longest is the (Krem)LiatPrah cave system) in the Jaintia Hills, which is 31,070 m (101,935 ft). The word "Krem" means cave in the local Khasi language. The highest density of caves found to date is in Jaintia Hills, with the Nongkhlieh Ridge near Sutnga being the home of the most spectacular ones (Brooks et al.,.2009). Meghalaya plateau as it is located in the northeast flank of peninsular India. It is one of the rainiest, most tectonically active areas in the world and hosts the richest type of karst phenomena in India. The combination of its regional uplift, associated river incision, head ward erosion and chemical weathering, has lead to the development of diverse landforms. This hasresults in deep valleys with magnificent

waterfall contrasting with mature undulating hills and kart topography over short distances (Prokop2014).

The exploration of the Caves of Meghalaya is currently undertaken for both scientific and recreational pursuits, and there are still many unexplored and partially explored caves in the state. The annual international caving expedition,supported by Meghalaya Adventurers Association (MAA) is known as "Caving in the Abode of the Clouds Project". The expedition team has been exploring the caves of Meghalaya since 1992. During this period1005 caves have been explored or partially explored to yield in excess of 450 kilometres of surveyed cave passage, with much more still waiting to be discovered.

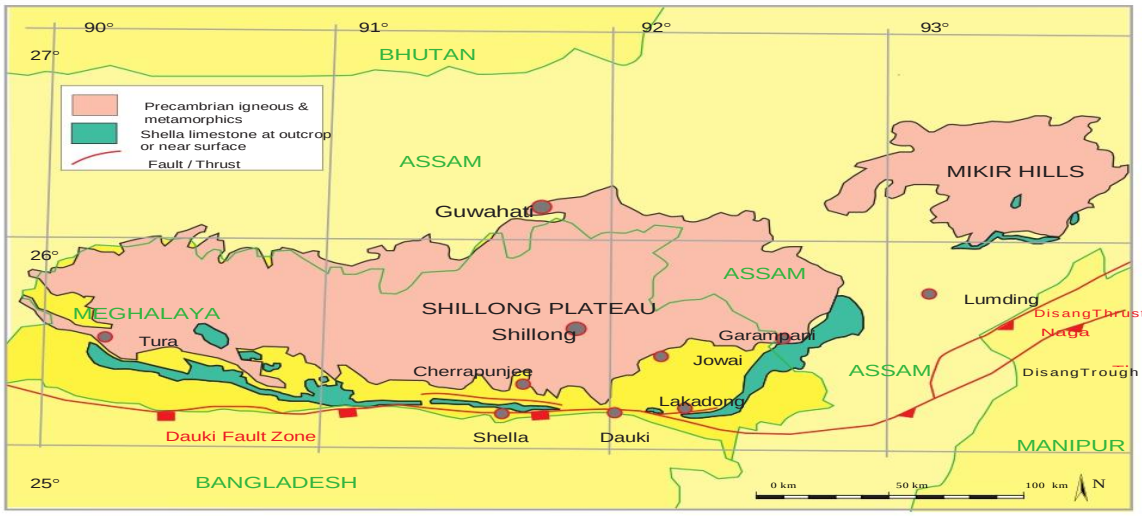

Figure 2: Regional geological map of Meghalaya showing main structures and Shella Limestone Occurrance. Based in part on Geological Survey of India (1981 & 2009)

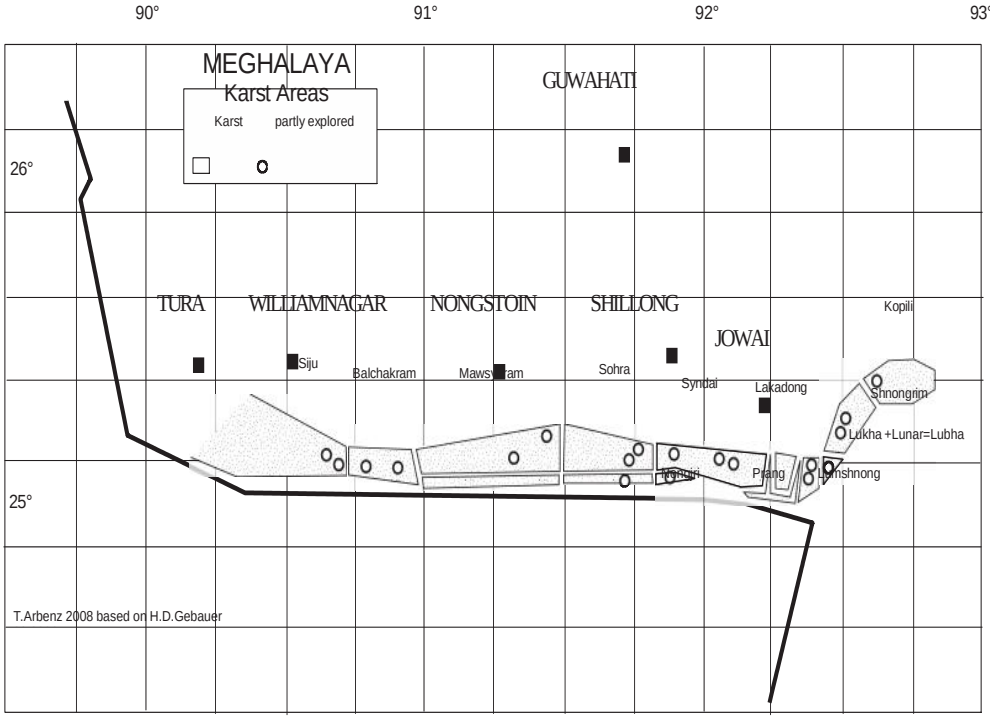

Figure 3: Map of the karst regions in the southern fringes of the Meghalaya plateau

2. REVIEW OF LITERATURE

Beneath the earth surface lies an underground world of caves full of astonishing creatures and a remarkable environment carved into different shapes and sizes. Caves form in different rock types depending on the topography and climate of the area. In karst area, carbonate rock (limestone or dolomite) and water, create most of the longest cave system in the world. Underground water that drains throughout the caves collects carbon-dioxide and becomes acidic and slowly with time dissolves the carbonate rocks and forms a cavern. Stalactites and Stalagmites are formed by the dripping water re-depositing minerals from dissolved rocks. The environment inside the cave depends mainly on the daily seasonal and long term surface climatic changes which inturn provide stable, shelter and moist refuges for animals thatlive undergrounds.

The subterranean ecology i.e. the study of the underground habitats, the flora and fauna can becategorized based on the degree of their dependence on the environment that ispresent there. For some organisms caves act as a place of shelter and a place of hunting for food and they aretermed as Trogloxenes, Those organisms that completea greater part of their life cycle inside the caves are termed as Troglophiles and those that can only survive in caves are termed as Troglobites.Troglobitesorganisms have evolved special adaptative featuresessential for survival in the subterranean environment. Some of these are loss of pigmentation, partial or total loss of eyes, and development of long antennae or legs.The subterranean cave organisms are abundant and arthropods make up the majority of all cave organisms. In India there have been few biospeleologicalsurveys of cave organisms and the few reports are mainly from the North-Eastern part of India in the state of Meghalaya.

Biswas, 2009; In his study on **"**The biodiversity of KremMawkhyrdop of Meghalaya, India, on the verge of extinction"expressed how the irresponsible way of coal mining and limestone quarrying affect the biodiversity of the cave leading to extinction of cave fauna. During his research on Mawkhyrdop cave, few species were found inside the cave and some of his findings within the Mawkhyrdop cave are troglophiles.

Harries,et al., 2008: In his paper “A Review of the biospelelogy of Meghalaya” stated that the quantity and length of caves in Meghalaya exceeds that of any other known karst region of India. He also observed that taxa with pronounced troglomorphic characteristics appear to be relatively common in Jaintia Hills region of eastern Meghalaya and rare elsewhere in the state, but taxa with partial troglomorphy are widespread throughout Meghalaya. In some cases there is evidence of troglophiles which reproduce, feed and complete their life cycle inside the cave. There is a wide range of taxa which occur regularly within caves and should be considered as significant components of the cave ecosystem regardless of troglomorphy.

In 1922, during their visit to Siju cave, Kemp and Chopra spent about three weeks in examining the cave fauna, topography and geology of the cave. They did a detailed study of the species that are present in the Siju cave. In their publication (Kemp and Chopra, 1924)entitled “The Siju Cave, Garo Hills, Assam. Part 1“, a complete list of the species that are found inside the cave at different depts have been described in detail. They reported a total of 102 species. However, of the 102 species that they discovered in Siju cave, most of them are known to occur on the surface environment but the number of species recorded to be a true cavernicolous is extremely low.

3. Objective and Sampling Method

3.1 Objective: Collection and Identification of cave fauna in Mawsiarwait and Ri-Blai caves.

3.2 Sampling

- Collectionof terrestrial and aquatic biota through hand picking, pit fall traps.
- Collection of aquatic fauna by plankton net, bottle trap.
- Sampling of soil fauna by modified Berlese Tullgren apparatus.

3.3 Method of Collecting and Preserving

3.3.1 For collection of terrestrial arthropods inside the cave Pitfall trap, Hand picking and Berlese Tullgren funnel is used.

Pitfall trap:

1. A container made up of plastic bottle or a beaker is used and a pit of required length is made.
2. The length of the bottle should be of the same length with the pit, so that the rims of the bottle should be on the same level with the soil surface.
3. A pit of 15cm to 30cm is dug to immerse the plastic bottle or beaker.
4. A soapy water or ethyl alcohol is used to trap the Arthropods that fall into the trap.
5. Bait is also used and kept inside the Plastic bottle or Beaker to lure the Arthropods into the trap.
6. Pit fall trap are widely used for collecting ground dwelling arthropods such as ant, cricket, spider, etc.

Hand picking:

1. It is a simple method of collecting Arthropods at first sight.
2. Gloves are used to protect the hand while picking up the Arthropods.
3. Arthropods that have been picked are kept in a 100ml plastic bottle containing ethyl alcohol for storing.
4. The specimens collected are then separate accordingly in the laboratory and kept in separate vials containing ethyl alcohol.

Berlese Tullgren funnel:

1. The funnel is a large rectangular box with insulated walls, open at the bottom and supported on 4 legs.
2. Overall dimension including legs, are (4×1 ½ ×3) feet (Lenght×Breadth×Height). Heat is provided by three- four 100W bulb mounted on the interior ceiling of the rectangular box.
3. The funnel is placed into the rectangular box through a hinged door in the front of the box and above the funnel a 100W bulb is wired, and a nylon mesh is placed on the mouth of the funnel to hold the soil.
4. A random amount of soil sample of (5×5×5 cm, Lenght×Breadth×Height) is collected from the study sites and brought to the laboratory and a small amount of soil is pour into the funnel.
5. At the bottom of the funnel, a vials containing 70% of ethyl alcohol is placed to collect and preserve the specimen.
6. The soil is placed in the rectangular box for 24 hour under the three to four 100W bulbs for 48 hours.
7. The specimens are then collected in the vials after 48 hours for identification.
8. The reason for keeping the soil for 48 hours under a light of 100W bulb is that soil dwelling organism tends to move downwards away from the direct light, organism leaving the soil fall into the vials.

3.3.2 For collection of aquatic biota inside the cave Plankton net and Bottle traps are used

Plankton net:

1. Plankton nets is made with a metal frame which act as a mouth of the net and hold the net, at the bottom of the net, a vial is attached for collecting of micro-organism and other aquatic biota that are trap inside the vial.
2. In deep pond and streams Plankton net are sweep randomly or a specific sites is selected and kept the Plankton net for.
3. In shallow stream the plankton net is held facing upstream for a good catch.

4. Micro-organism and aquatic biota that are collected inside the vials and net are then preserved in a bottle container having ethyl alcohol.

Bottle trap:

1. A clear plastic bottle is used and modified into a fyke.
2. Bottle trap is used to trap small aquatic biota.
3. The bottle trap should always be placed upstream in flowing water, in case of standing water a fixed placed is selected to set the trap.
4. Inside the bottle bait is kept to lure the aquatic biota into the trap.

Collection of arthropods and aquatic biota either for study or documentation is an important part for the entomologist or for those who study the cave environment. Arthropods and Aquatic biota are found almost everywhere and can be collected in any season, a good knowledge of how and when to collect and preserve the arthropods is needed by applying good technologies methods and studies. This willprovides the essential data and samples for future reference in research

3.4 Preservation of the Specimens

Wet preservation (Liquid preservation):- Specimens can be preserved in liquid such as ethyl alcohol (70-80%) or formalin (4%). Small glass or plastic vials containing the preservatives are used for storing of specimens. The vials should be handled carefully and tight fitting of the cap and sealing with paraffin wax to reduce evaporation of the preservative is essential. Labels may be inserted into the vials after writing the date of collection, location and host etc. either by water proof pen or pencil.

3.5 Study sites

3.5.1 Cave 1: Mawsiarwait Cave (Krem)

On the month of May, 2015 (dated 21st – 23rd), a first field survey was done on Mawsiarwait Cave. This was a pre field survey before the real documentation was carried out so as to know the inside structure of the caves for safety measures. A final sampling at Mawsiarwait cave was carried out in the month of June.2015 (dated 24th – 25th). During the sampling, data was collected and digital photographs were taken for the study and as evidence.

For the field survey at Mawsiarwait cave, a team of four members was formed as it is the minimum number required for entering the cave and to fulfill all the criteria that cavers must follow during the exploration inside the cave, that is,for safety and to easily carry out the exploration.

3.5.2 Cave 2: Ri-Blai Cave(Krem):

On the month of November, 2015 (dated 26th – 28th) a first field survey was done on Ri-Blai Cave. This was a pre field survey before the real documentation was carried out, so as to know the inside structure of the caves for safety measures. A final sampling at Ri-Blai cave was carried out in the month of December, 2015 (dated 18th – 19th). During the sampling, data was collected and digital photographs were taken for the study and as evidence.

For the field survey ofRi-Blai cave, a team of four members was formed as it is the minimum number required for entering the cave and to fulfill all the criteria that cavers must follow during the exploration inside the cave. That is, for safety and to easily carried out the exploration.

4. GENERAL DESCRIPTION OF INSECT AND ARTHROPODS

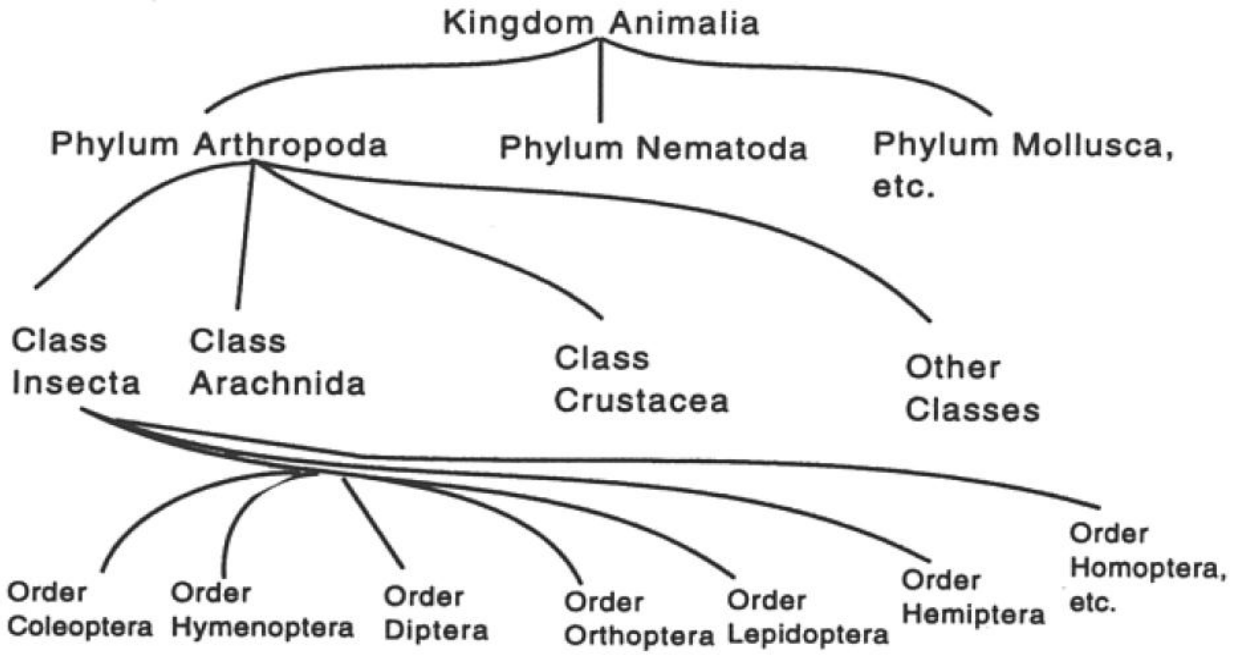

Figure 4: A Phylogeny of selected invertebrate groups with a focus on the arthropods

4.1 Insects

The insects are the dominant group of animals on earth today. They far surpass all other terrestrial animals in number, and they occur practically everywhere. Several hundred thousand different species have been described-three times as many as there are in the rest of the animal kingdom. The insects can be found in almostall types of environment and adapt themselves to the condition of the presence environmental factors that surrounds them; they are of great value to man and society in terms of food, medicine, nutrient cycle, in agricultural sector insect helps in pollination and suppress pest population, scientific research and many other services.

Insects have lived on the earth for about 300 million years, compared to man who have live for 2 million years. During their 300 million years of presencein this earth, insects have a greater diversity compared to any invertebrates in respect of structural modifications, habitat and ecological niche, they have evolved in many aspect such as morphologically, physiologically and become adapted to almost every different types of environment, so that they can reproduced, search for food and protect themselves

against predator. Based on their morphological diversity, they have been classified under 33 orders under the class-Insecta and phylum-Arthropoda.

4.1.1 Origin of Insect

The first sign of life on earth were single celled organism that lived in the oceans around 3500 million years ago. The first land living animals were emerging from the ocean as scavengers perhaps to escape aquatic predators about 420 million year ago. The most successful of all land living animals are the insects. Of all the species on earth 73.5% are invertebrates and most of these are insects and they are the most successful creatures adapting to the early environment on land.

4.1.2 Basic anatomy of an Insect

Insectsarebuilt on a segmental plan and their characteristic feature consist of a hard jointed exoskeleton which is form by the cuticle and is continuous through the body and consists of a series of hard sclerites joined to each other by a flexible membrane which are also cuticular. The function of sclerites is to give precise movement of the neck. The body is segments into three regions – the head, thorax and abdomen in which the various basic parts of the segments may be greatly modified such as the walking legs are on the three thoracic segments. In the head the appendages are modified for antennae and mouth parts as sensory and feeding purposes, and in the abdomen there are no appendages except modified as the genetalia and some pregenital appendages are present in apterygota.Insect have two pair of wings which are the lateral outgrowth of the body wall located dorsoventrally between the nota and pleura. The fully developed wings of an insect appear as thin, rigid flops attached to the meso and metathoracic segments.

4.1.3 Head

The head of an insect is composed of a series of segments with different specialization i.e. for food gathering, sensory perception and neutral integration. The head bears the eye (compound and ocelli, antennae and mouthparts (Figure: 1).

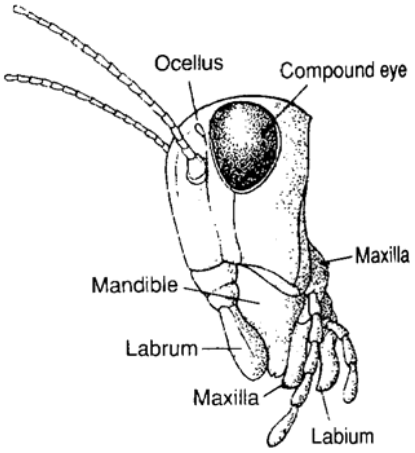

Figure 5: Insect Head

- **Mouthpart:**Mouthparts are the organs concerned with feeding, comprising the unpaired labrum (upper lip) in front, a median hypopharynx (tongue) behind the mouth, a pair of mandibles (upper jaws) and maxillae (lower jaws) laterally, and a labium forming the lower lip. Mouthparts that are enclosed internally are called endognathous. The mouth parts that are externally visible are called ectognathous.
- **Antennae:** Antennae vary greatly among insects both in length and functions. Antennae function almost exclusively in sensory perception i.e motion and orientation, odor, sound, humidity and a variety of chemical cues. The most common types of insects antennae are Setaceous, Clavata, Filiform and Aristate (Figure: 2a-2d).

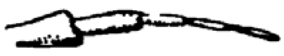

Figure 6a: Odonata

Figure 6b: Coleoptera

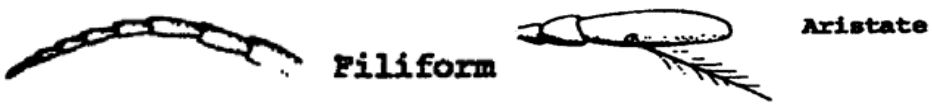

Figure 6c: Lepidoptera Figure 6d: Diptera

4.1.4 Thorax

The insect thorax is divided into three parts: the prothorax, mesothorax and metathorax, each segment consist of sclerites. Each of the thorax parts contained one pair of legs and wings are found only on the mesothorax and metathorax segments. The legs are group into three types the fore-legs located on the prothorax, the mid-legs located on the mesothorax, and the hind-legs on the metathorax. Each of these legs has six major components i.e., coxa, trochanter, femur, tibla, tarsus and pretarsus (Figure: 3a-3b).

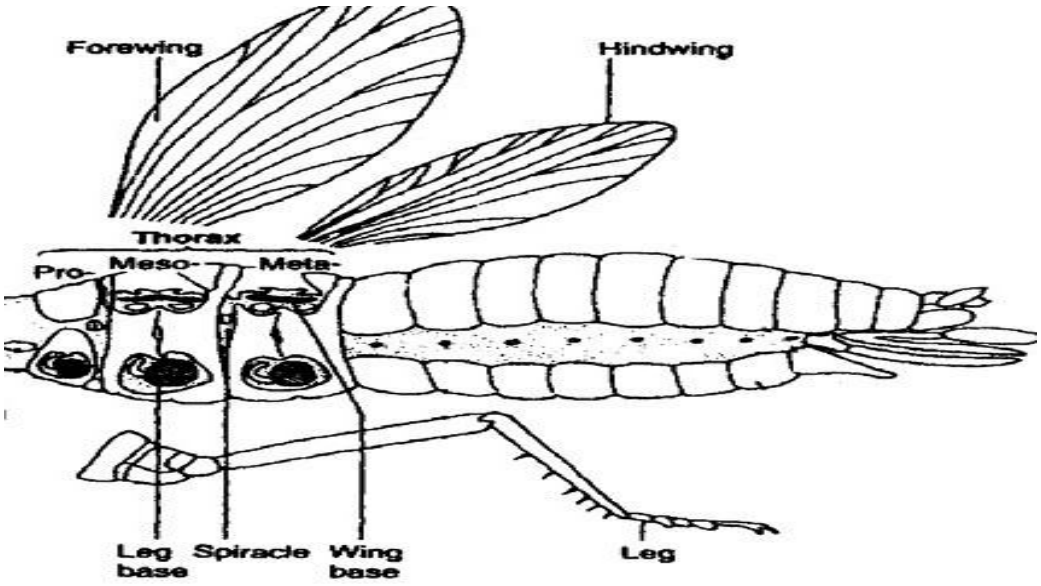

Figure 7a: Insect Thorax

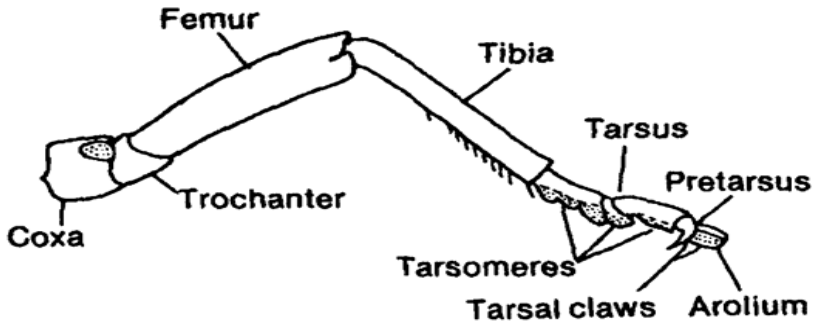

Figure 7b: Insect Legs

4.1.5 Abdomen

The abdomen of an insect can split into two parts, the dorsal and the ventral abdominal segments. The abdomen is the most flexible parts of the body, abdomen usually have 10 or 11 segments. The abdomen holds all the digestive or reproductive organs, but the posterior abdominal segments are modified for mating and ovipositor. The abdominal segments of an adult insect are without appendages except for those who are concerned with digestion and reproduction and a pair of terminal usually sensory cerci (Figure: 4).

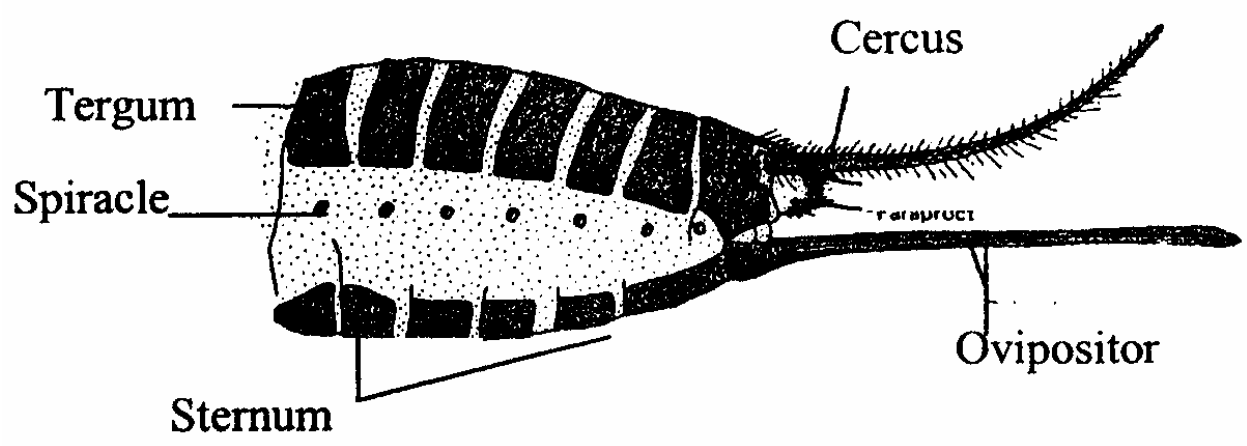

Figure 8: Insect Abdomen

4.2 Chelicerates

Chelicerates is a sub-phylum of the phylum Arthropoda and there are three class under the subphylum Chelicerates, namely; Merostomata, Pycnogonida and Arachnida. The Chelicerates have two distinct body region, the anterior prosoma (ce[halothorax) and posterior opidthosoma (abdomen) that may be divided into mesosoma and metasoma. Chelicerates don't have antennae; they all have four pairs of uniramous waling legs on the first tagma. The sub-phylum includes a variety of animals such as spider, scorpion, horseshoe crab and the unusual sea spider. In almost all Chelicerates, they are predators

4.2.1 Arachnida

Arachinida is a class of phylum Arthropoda. The class Arachnida is one of the major class and it contain 12 orders, among these 12 order Scorpiones is considered to be a primitive and evolved without much change in its morphology and it is termed as a good example of "living fossils". Arachnids are also called Chelicerate Arthropods. Class Arachnida differs completely from other classes that fall under the phylum Arthropods. The body of members of class Arachnida basically composed of 18 somites and divided into a prosoma of six units and an opisthosoma of twelve units. The prosoma ventrally possesses six pairs of appendages, the chelicerae, the pedipalps and four pairs of legs.

4.3 Myriapoda

Myriapoda is a sub-phylum of the phylum Arthropoda. There are four group of centipede like creature known collectively as myriapods but their relationship to each other is not clearlu understood. Nearly 13,000 species of arthropods are classified in the class Myriapods, Myriapods are terrestrial form and only some are marine. Most Myriapods live in humid environment, and can be found in soil, in leaf litter, or under stone and wood. Species under Myriapods can have from a fewer ten to nearly 200 pairs of appendages. Chilopods have only one pair of legs per body segment, while two pair of legs in one body segment is in the case of Diplopoda species.

4.3.1 Diplopoda(millipedes)

Diplopoda are a class within the phylum Arthropod. Millipedes are usually found in damp places. That is, in moss, under stones, under leaves, in rotten wood, in soil in the above ground and in caves with similar conditions. Millipedes are elongated, wormlike animals with 30 or more pairs of legs and the body segments bear two pairs. The body is cylindrical or flattened in shaped and they have a short antennae, the head of most millipedes is convex above bearing a large epistomal area and flat beneath. Most millipedes are scavengers and feed on death and decaying matter of plants, they lay their eggs during summer and in winter they are in protected situation. The eggs are usually white and hatch within afew weeks; newly hatch millipedes have only three pairs of legs.

4.4 Crustacea

Crutacea is another sub-phylum of the phylum arthropods and it consists of eight sub-class and some of the species that are found in the Mawsiarwait and Ri-Blai cave fall under the sub-class Malacostraca and Isopoda. They form a heterogeneous group within the class. Nearly all of them are aquatic and breathe by means of gills. The head and the thoracic portion of the body is sometimes fused into a Cephalothorax. The head bear two pairs of antennae,usually one median eye and two lateral eyes and three pairs of biting mouthparts. The appendages vary in numbers, a pair of segments is found on each segments of the Cephalothorax Some species of the crustacea class are free swimming or live as parasites on fish or larger organisms and they can be found on both marine and freshwater forms.

4.4.1 Malacostraca

Malacostraca is the largest of the six class of crustacean, it include wide diversity such as Decapoda (crab, lobster, crayfish, shrimp),*Euphausids*(krill), etc. They are abundant in all marine and freshwater bodies. They are segmented animals, having a common body plan comprising 20 body segments and divided into head, thorax, and abdomen. Malacostracans are characterized by the presence of an abdominal appendages, three tagmata, afive segmented head an eight segmented thorax and anabdomen with six segments and a telson each body segment bear a pair of jointed

appendages. Most species of malacostraca have distinct sexes (gonochorism) and some exhibit hermaphroditism. The female genital gonopores are located on the sixth thoraicic segment, while the male gonopores are on the eighth segment and in small number of species, on the seventh.

4.4.2 Isopoda

Most of crustaceans are aquatic and the isopods are one of the few groups of which some members are terrestrial. Isopoda are marine animals living under stone and they have evolved through the evolutionary transition from marine to terrestrial habitats. The isopods are small, slightly dorsoventrally flattened gray or brown organisms with numerous legs, called pereopods. Their bodyis divided into the head, the leg bearing thorax and the abdomen. The length of the isopods ranges from approximately 5 to 15 mm. Isopods are distributed globally and they are found in a wide range of habitat ranging from marine to freshwater and terrestrial, but they are best found in rotting woods and log and in damp area. Terrestrial arthropods play a significance role in many tropical and temperate ecosystems by aiding in the decomposition of plant material and dead organisms through mechanical and chemical means. Many species of isopods have the behavior to defend themselves by rolling into a ball and that also helps conserve moisture.

5. Results

5.1 Study site

5.1.1 Site description Mawsiarwait Cave(Krem)

Mawsiarwait cave, Mawkawir, near Mawsahew (West of Sohra). East Khasi Hills Meghalaya	Latitude: 25º15'16.71" Longitude: 91º39'22.11" Elevation: 1089m Atmospheric temperature ºc: 19.5±0.2 Soil temperature ºc: 16.03±0.27 Soil pH: 5.94±0.13 Surface water pH: 6.8±0.22

Figure 9: Entrance (Mawsiarwait cave)

KremMawsiarwait before known as cave Mawshyrpait meaning a Whetstone or sharpening stone, is located in Mawkawir village in the southern part of East Khasi Hills district of Meghalaya, the distance from the capital city Shillong to Mawkawir is 70 km and takes around three hours by car. The cave has multiples entrances and they intersect with the main passage from the,main entrance almost at a right angles to form a short maze. The entrances of the cave are surrounded by a dense jungle, with in the main entrance there is a small man-made-reservoir, which is used by the villagers and

tourists for bathing as it is believed by the villagers that the water coming through this cave contain some medicinal properties that are able to heal some skin diseases and other sicknesses.

The dimensions of the cave vary from 7-12 feet Width to narrow crawls of only 3-6 feet and being a horizontal cave has a rivulet that runs throughout the year. The cave is activelyformed by water and it is inaccessible during monsoon season, large boulders are found in main passage. The cave is formed in calcareous sandstone, therefore stalagmites and stalactites 5 to 30 cm long are found in some parts of the cave.

On the two days of exploration inside the caves we were able to documentterrestrial and aquatic species. Photographs of these species have been taken to support identification.

5.1.2 Fauna of Mawsiarwait Cave(Krem)

Figure 10: *Crytodactyluskhasiensis* (Mawsiarwait Cave)

Figure 11: *Trachyiulusmimus* (Mawsiarwait Cave)

Figure12: *Raphidophoridae specie*(Mawsiarwait Cave)

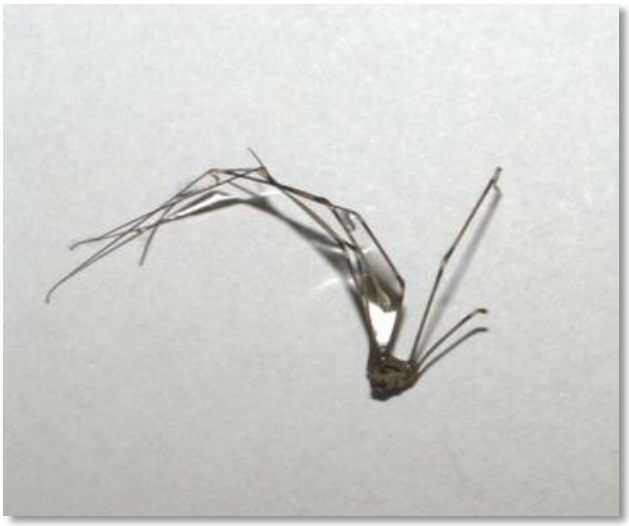

Figure 13: *Phalangiidae* Daddy long legs (Mawsiarwait Cave)

Figure 14: *Callobius*(Mawsiarwait Cave)

Figure:15*Arachnida* (Mawsiarwait Cave)

Figure 16: *Heteropoda species* (Mawsiarwait Cave)

Figure 17: *Potamon*(Mawsiarwait Cave)

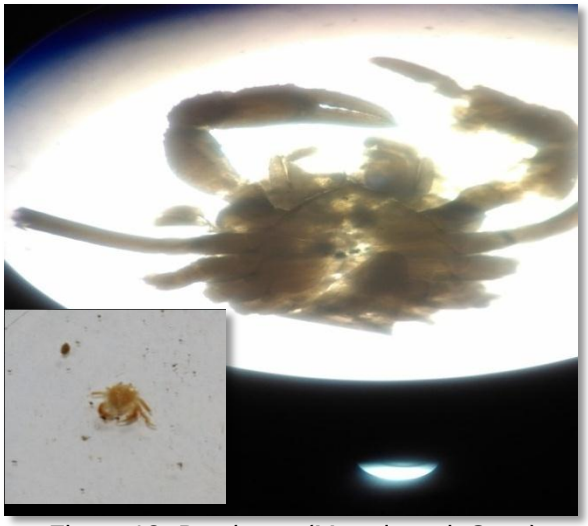

Figure 18: *Brachyura* (Mawsiarwait Cave)

5.1.3 Site description of Ri-Blai Cave(Krem)

Ri-Blai cave, Bairong, near Wahlong (South of Sohra) East Khasi Hills Meghalaya	Latitude: 25º12'13.30" Longitude: 91º43'06.35" Elevation: 416m Atmospheric temperature ºc: 18.9±0.2 Soil temperature ºc: 19.03±0.27 Soil pH: 5.97±0.13 Surface water pH: 6.6±0.22

Figure 19: Entrance (Ri-Blai cave)

KremRi-Blai meaning God protected cave is located in the southern part of East Khasi Hills district of Meghalaya near the village of Wahlong, the distance from the capital city Shillong to Wahlong is 78 km and takes around three an half hours by car. Ri-Blai cave is surrounded by a broad leaves forest and Areca nut tree. The main entrance of the cave is about 30 feet wide and 15 feet high, the route from the main entrance to the first chamber is very steeply down-sloping to vertical and the ground is covered with loose soil and rocks which make it very difficult to get into the chamber.

Being a vertical cave, the dimensions of the cave varies from chamber to chamber along with different heights of the vertical shafts. The first chamber of the cave is about 100-130 feet wide to 50-80 feet high, below the first chamber lies another chamber which is connected by a vertical shaft of 25 meters and a double drop of 8 meters and 10 meters to the second chamber which then continues as a horizontal passage that stretches a few hundred meters some which have been explored and the rest has been left untouched.

During the two days of exploration inside the caves, we were able to document terrestrial and aquatic species. Photographs of these species have been taken to support identification.

5.1.4 Fauna of Ri-Blai Cave(Krem)

Figure 20:*Raphidophoridae* (Ri-Blai Cave)

Figure 21: *Cubaris species* (Ri-Blai Cave)

Figure 22 : *Heteropoda*(Ri-Blai Cave)

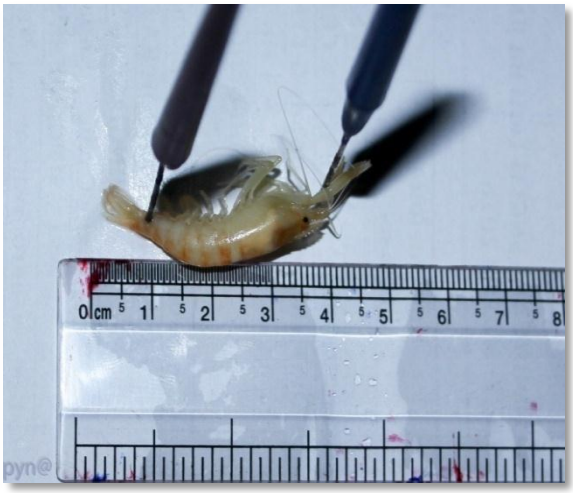

Figure 23: *Macrobranchiumcavernicola* (Ri-Blai Cave)

Figure 24: *Trachyiulusmimus,* Adult (Ri-Blai Cave)

5.2 Description of species found in Mawsiarwait and Ri-Blai Cave

Arachnida (spiders): Spiders of the genus Heteropoda are among the commonly recorded species of the meghalaya cave. Spider of this genus is found in both Mawsiarwait cave and Ri-Blai cave (Figure:8, 9, 10, 11, 16). They are abundant and are commonly found on the passage wall and ceiling near the entrance and deep within the cave where there is absence of light. Two species of spiders of the genus Heteropoda are present Heteropodarobusta (Fage, 1924) which can be found in the western part of the state (Garo and West Khasi Hills) while Heteropodafischeri(Jaeger,2005) appears to be predominant in the eastern part of the state especially inJaintia hills. In Mawsiarwait cave Heteropoda sp. was seen to carry an egg sack on her belly, the sack is in the shape of small disc/biscuit of white colour maybe 3-4cm in diameter. (Fage,(1924); Kemp and Chopra,(1924) have recorded that in Siju cave Hetropodarobusta was abundant and seen to be reproducing nor feeding of prey.Heteropodafischeri, aspecies of huntsman Spider, was first identified from the caves of Jaintia Hills, Meghalaya (Jaeger 2005). Early reports document Heteropodafischeri preying upon brown Rhaphidophorid cave crickets in Jaintia Hills (Harries et al.,2008) and later from other cave within the Jaintia Hills region (Biswas and Harries 2011).

Brachyura (crabs): The fresh water crabs was found to be common in the surface stream outside the cave and deep within the cave, the Potamon sp. (Figure: 17, 18) was found in the Mawsiarwait cave and it is already an adult but the white crab that was found 180 meters inside the Mawsiarwait cave is very small and white colour. A reason for this white crab to be white in colour might be in the juvenile stage or trying to adapt itself to the environment inside the cave which lack the presence of light (Figure:18).

Palaemonidae (Shrimp): Shrimps are often abundant and are present wherever there is water, even in small standing water within the cave as well in active flowing streams. The shrimp Macrobrachiumcavernicola (Figure: 23)was found in a pool in the Ri-Blai cave from point of 400 meters. The shrimp Macrobrachiumhendersoni and Macrobrachiumcvernicola were recordedfromsiju (Kemp, 1924 andLindberg, 1960) reported on the shrimp *Macrobrachiumcavernicola*.

Isopoda: One isopod Cubaris sp. (Figure: 21) was recorded during the field visit to Ri-Blai cave, it was found at a distance of between 350 to 400 meters from the entrance in a slightly wet area. There is less abundance and occurrence of isopods inside the Ri-Blai cave and they have not been observed inMawsiarwait cave. Usually isopods are widespread and abundant in cave as cave fauna, but the absence of isopods in Mawsiarwait cave might be to the reason of perennial flow of water from this cave into the open area. In monsoon season the water level is high and the high flowing velocity of the stream making it hard for the isopods to live, and reproduce inside the cave, since there is lack of food and decaying vegetation or animals inside the cave, which might been washed away by the running water during the monsoon seeason. Four species(*Porcellioassamensis, Cubariscavernosus, Cubarisdobakholi, Burmoniscuskempi*) have been recorded with in Meghalaya caves (Collinge, 1916; Chopra, 1924; Lindberg, 1960).

Diplopoda (millipedes): Millipedes of Trachyiulus species (Figure: 11, 24) have been recorded in both Mawsiarwait and Ri-Blai Cave. Millepedes are widespread and abundant especially in driers area away from the stream. Their feeding habit is mainly on dead bats, snakes, insects and guano and faeces of other death organic matter of animals and plants. Millipedes species of *Trachyiulusmimus* was recorded from Siju in 1922 (Silvestri,1924).

Orthoptera (crickets):Orthoptera are found in almost all the caves with in Meghalaya, Rhaphidophoridae Species (Figure: 12, 20) are found in both Mawsiarwait and Ri-Blai cave. They can be easily found on the walls and ceiling within a few hundred meters from the entrance of the cave and also deep inside the cave in dry passage along with other cave fauna, their occurrence is most significant particularly below the bat roosts. Orthoptera strongly attract to meat bait. Harries, (2008) recorded some Orthoptera from Umthloo cave (2005).

Chrodata (gecko): The genus Cyrtodactylus currently comprised of seven species: *C*. *fasciolatus*(Blyth), *C*. *gubernatoris*(Annandale), *C*. *khasiensis*(Jerdon), *C*.*malcomsmithi*(Constable), *C*. *marcuscombaii*(Darevsky, Helfenberger, Orlov andShah), *C*. *martinstolli*(Darevsky, Helfenberger, Orlov& Shah) and *C*. *nepalensis* (Schleich&Kästle). But in the recent years more species have been added to the genus Cyrtodactylus. Cyrtodactyluskhasiensis (Figure: 10) has been found in Ri-Blai cave within 100 meters inside on the wall of the cave. *CyrtodactylusKhasiensis* is wide spread among the areas of North-Eastern India, Xizang (Tibet), Myanmar and Bangladesh. Its presence inside the cave might be related to abundant of prey or as a shelter and hideout from predator living in the surface environment, and their habitat is mainly in dry area on the walls and the ceiling of the cave.

Table 1: Number of species that is found in Mawsiarwait and Ri-Blai cave

Phylum	Sub-phylum	Class	Number of species found in both the caves	Number of species found in Mawsiarwait Cave	Number of species found in Ri-Blai cave
Arthropods	**Chelicerates**	**Arachnida**	**5**	**4**	**1**
Arthropods	**Myriapoda**	**Diplopoda**	**2**	**1**	**1**
Arthropods	**Crustacea**	**Malacostraca**	**3**	**2**	**1**
		Order-Isopoda	**1**	**-**	**1**
Arthropods		**Insecta**	**2**	**1**	**1**
Chrodata		**Reptilia**	**1**	**1**	**-**

Figure 25: Side passage(Mawsiarwait cave)

Figure 26: Mycetophilidae(Mawsiarwait cave)

Figure 27: Gypsum (Ri-Blai cave)

Figure 28: 1st Vertical Shaft(Ri-Blai cave)

Figure 29: SRT 1st Vertical Shaft (Ri-Blai cave)

Figure 30: Measuring soil Temperature (Ri-Blai cave)

Figure31: Flora (Ri-Blai cave)

Figure 32: SRT 2nd Vertical Shaft (Ri-Blai cave)

Figure 33: Main passage (Mawsiarwait cave)

Figure 34: Fossils (Mawsiarwait cave)

Figure 35: Stalactites (Mawsiarwait cave)

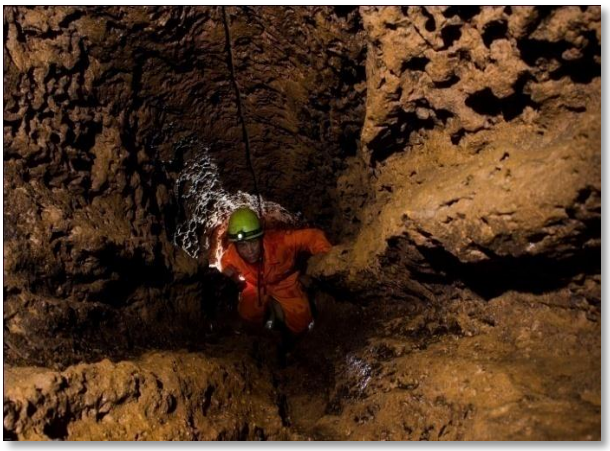

Figure 36: Pipe passage (Mawsiarwait cave)

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6. Discussion

The present study in Mawsiarwait and Ri-Blai cave led to the discovery of 14 species, five species fall under the class Arachnida, two species under the class Diplopoda. Under the sub phylum Crustacea three species of the class Malacostraca have been discovered and only one species under the order Isopoda, two species under the calssInsectaand one reptile.

The Insecta species are found in both the cave (Mawsiarwait and Ri-Blai cave). They are abundant and can be foundinside the cave ceiling wall and floor; they are not a true troglophile but they have evolved with long antennae and legs and they can be class as troglobite.Arachnida are predominant in both the cave, four species have been discovered in Mawsiarwait cave and only one in Ri-Blai cave. Heteropoda that have been found in Mawsiarwait cave is seen carry an egg sack. In similar case a heteropodarobusta is seen carrying an egg sac in caves in the West Khasi Hill and Heteropodafischeri in a cave in thejaintia hill(Harries et al., 2008).Trachyiulus species found in both the caves, they are seen to be abundant in drier area and below the bat roost. They help in decomposition of death organic matter inside the cave. Trachyiulux species have been recorded in Siju cave by Kemp and Chopra.

The white crab in (Figure 18)that present inside the Mawsiarwait cave might or have been transport mainly from rainfall runoff as adults or another possibility might be that the female crab carrying the eggs have been transported from the outside environment into the cave during monsoon season and release the eggs inside the cave and due to the absence of light inside the cave, the egg that are released cannot hatched because the environment is not favoring them and this lead to a high mortality rate leading to the survival of only one or two infants. The white crab found in Mawsiarwait cave is seen to lack pigmentation. Thebody is seen to have a well-developed apron, cheliped, paddle fins, carapace but the eye could not be seen properly from the observation under a microscope,an explanation for the eyes is they

might be folded back into the socket or lack the formation of the eyes. With respect to their abundance and occurrence and their distribution deep inside the cave, it is believed by many speleologists that crab should be consider as troglophiles.Freshwater crab *Maydelliathephusafalcidigitis* (formerly *paratelphusa (Barytelphusa) falcidigitis*) was found to be common in Siju in 1922 (Kemp,1924) and was present deep into the cave (730 m). Shrimp (*Macrobrachiumcavernicola*) can be found in any area where water can be easily available it was recorded in Ri-Blai cave few hundred meters from the cave entrance. It was consider as apartial troglomorphic due to reduce in eye size and reduced pigmentation

Most of the 6800 species of brachyurans are marine but one-fifth of all crabs on earth are strictly freshwater, this makes the freshwater crabs the largest assemblage within the Brachyura and they are the rich species of all decapods crustacean groups (Ng et al., 2008). Freshwater carb as a group showed very high number of endemic species in India with three near threaten and vulnerable (IUCN 2001).Terrestrial orsemi-terrestrial species (*Phricotelphusahockpingi* (CR) and *Johorapunicea* (CR)), aquatic species (*Johoratiomanensis* (NT) and *Heterothelphusafatum* (VU)), cave-dwelling species (*Stygothelphusabidiensis*(VU)), highland species (*Johoragapensis* (VU)), and species onsmall islands (*Johorasingaporensis* (CR) and *Parathelphusa reticulate*(CR)) all are vulnerable to disturbance and pollution (Ng and Yeo, 2007)

The conservation of freshwater crabs relies heavily on preservingpatches of natural forest large enough to maintain good waterquality because many species of these decapods are extremely sensitiveto polluted or silted water and cannot survive exposure. Giventhis, it is of concern that water quality of drainages isdeteriorating even in key natural habitats (Ng, 1988, 1989, 1990a,b, 2008; Brook et al.,., 2003; Tan et al.,2007; Yeo et al., 2008b).

7. Conclusion

Throughout the field visit and survey in the Mawsiarwait and Ri-Blai caves, some species have been recorded identified and preserved. The abundance and frequency of the terrestrial and aquatic biota inside the cave varies from species to species depending on their feeding habit and the environmental condition inside the cave. Caves in Meghalaya, either sandstone cave or limestonecave are the home for rare and endangered fauna but they have been threatened by anthropogenic activities and natural causes. Caves within Meghalaya have been a centre of attraction for national and international biospeleologists for their research. Fauna and Flora present inside the caves may often be found as accidental trogloxenes, but some very rare species are true Troglobites (Kottelat, et al., 2007) and a few species appear to be oftroglomorphic characteristic. Rapid ongoing industrial development and exploitation within Meghalaya is creating a new urgency to conduct research on the biospeleology of the region with a view to assessing conservation status (Harriers et al., 2015).It has been stated that the biological studies of Meghalaya caves have raised more questions than answers. It was suggested that one of the most important question that arises is how are the cave animals likely to be influenced by changes caused by human activities such as limestone extraction and coal mining. The cause of the difference in cave fauna between east and west is not yet clear, since the Meghalayan limestone is not a continuous band but is divided by deep incised valleys. So it is possible that the difference in caves species occur because the communities are effectively isolated in separate islands of limestone. Alternatively, the differences might be partly due to climate. The information on the relationship of cave vertical range to species richness would suggest that deeper caves are of higher biological / conservation importance than shallow caves (Harries et al.,2012).

Environmental problems like deforestation have a great impact on altering the environment and the biodiversity inside the caves, another problem that affecting the

biodiversity inside the caves is Acid Mine Drainage a runoff from coal mines and open coal storage area, that leeches into the soil and flow into the river. Caves are not just the home to a wide variety of fauna and flora but some caves also act as a reservoir for the villagers to fulfill their daily needs, mainly in drinking water supply.Therefore conservation of cave biota is important for it aesthetic value, and the most important is that Meghalaya is the home of the most important karst of the Indian continent and has ahigh potential for studies and research in the future.

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